

Louvain School of Management

Sustainable solutions for “last mile” deliveries in the parcel industry

A qualitative analysis using insights from third-party logistics service providers and public mobility experts

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This thesis represents the last step of my academic journey as a student. Completing this individual research and exploratory process has been one of the most intense and empowering experience I have been able to live during the completion of my Master's degree in Managements Sciences in Louvain School of Management.

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Abstract

This thesis addresses the solutions that can contribute to improving the level of sustainability of parcel deliveries in the “last mile” of the supply chain. Indeed, the last stage of the parcel delivery process presents many inefficiencies and causes severe negative outcomes economically, socially and environmentally, referred to as the “last mile issue”. The urge to tackle this issue is strengthened by the growth of the industry, boosted by the expansion of online commerce.

First, the concept of the “last mile” issue is contextualized and illustrated through a thorough literature review whose aim is to provide a comprehensive view of the challenges of the last mile, the stakeholders involved and the extent of the current and prospective solutions that have been researched from a sustainability perspective, focusing on processes, modes of transportation, public policies and marketing.

Secondly, executives from various companies from the parcel delivery industry and local authorities’ representatives from Belgian cities have been interviewed. They provided this thesis with their own perspective of sustainability concerns related to the last mile and how they are tackling it in their respective organizations. A crossed analysis then reveals the significant disparities that may arise between the literature and the expertise provided by the interviews. Insights gathered through this exploratory approach may provide food for thoughts for further researches in the field of last mile sustainability. Particularly, the findings that have been highlighted mention the differences in views regarding the degree of efficiency of some delivery solutions, the important role of the driver in the routing process, the increased role of digitalization, the interest of alternative modes of transportation and the current extent of collaborations between companies. In addition, many inefficiencies were linked to the different aspirations between the third-party logistics providers and the public mobility deciders, as well as the counter-productive interference of political interests and public power structure for efficient and relevant sustainability policies.

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I. Introduction

1. Motivations for choosing this topic

In 2019, when this thesis has been realized, focus is more than ever on climate change. Youngsters from all over the world are protesting for tougher regulations, for clear commitments towards sustainability. Whether the consequences of such protests and a collective realization that structural changes can have a successful and substantial impact on climate, we do not know yet. At the heart of the issue, greenhouse gases (GHG) emissions are one of the most contributing factors to climate change. Greenhouse gases contribute to retaining heat coming from the sun into the earth's atmosphere.

Over the course of Earth's recent history, uninfluenced by man's footprint, greenhouse gas remained at a steady level of concentration. However, since the start of the industrial revolution around 1750, fossil fuels such as coal, oil and gas have been used as major sources of energy. These fuels are usually located deep underground and undersea where they do not have any impact on the atmosphere. The combustion of those fuels due to mankind activities therefore leads to additional greenhouse gas emissions into the atmosphere, at the head of which we find carbon dioxide (CO₂), which results in an increase of the greenhouse effect that causes a general Global Warming. In 2014, 91% of the CO₂ emissions worldwide were due to the usage of fossil fuels. The consequences of Global Warming are potentially disastrous with many fragile animal and vegetal species suffering from the change of their climatic conditions, threatening the whole ecosystem; with glaciers melting increasingly fast, causing river streams to dry out earlier each year and to raise the sea level; with natural disasters becoming more and more frequent, causing even more damage to wildlife as well as human casualties, also making agriculture less efficient.

Decreasing substantially CO₂ emissions from human activities is therefore essential. Global concern has emerged in the past 30 years, resulting in several international agreements where countries engage in significantly reduce their emissions of GHG, such as the Kyoto Protocol in 1997, or the Paris Agreement (COP21) in 2015. However, despite this growing concern and generalized realization that actions must be taken to decrease GHG

concentration in the atmosphere, emissions are still increasing. This is why, through my thesis, I wanted to contribute to building a better, more sustainable society for the next generations. When considering CO₂ emissions in each industry, the transportation sector stood out as one of the worst pupils in the class. Indeed, the carbon footprint of this sector is overall still increasing. Why is that? What could be done about it?

This is the main reason that pushed my research towards this particular industry where I felt there needed to be progress. In addition, my focus went towards a particular sector: the parcel delivery, or express package delivery sector. These are the companies we come across so often in our streets today that we do not even notice them anymore. UPS, DHL, FedEx, and many more regional and local actors, are names that we read daily on delivery trucks while walking or driving around, especially in densely populated areas. The reason we are seeing them more and more regularly fits in one word: e-commerce. Whenever browsing the internet, we are offered the option to buy online. “Why not, after all?” “Oh, and there’s free shipping directly to my home! And the shipping is guaranteed to be home by tomorrow... There’s a tempting idea!” Nothing wrong with such thinking, however it is not costless, neither from an economic perspective nor from a socio-environmental one. The easiness, variety and affordability of home delivery solutions are bigger than ever before, and it becomes possible to get practically anything delivered on our doorstep within very short time. This explains the impressive boom of e-commerce and the interest of most companies for e-commerce solutions that provide a direct home delivery option. Consequently, carriers and package deliverers are increasing strongly the number of their deliveries, which results in more delivery vehicles on our roads, and eventually more CO₂ in the atmosphere. The sustainable consequences of those deliveries are not limited to environmental concerns, but also have an impact on congestion, especially in densely populated areas like in Belgium; on accident risk; noise in delivered areas; on air pollution with fine particles that are hazardous for the health of nearby residents...

Whether we should simply choose to renounce to e-commerce or not would be a little extreme. Along this research we will focus instead on the current efforts and potential solutions that would help combine home deliveries with the sustainable practices that should become the norm in today’s society. We will focus exclusively on last-mile delivery, the most carbon-consuming stage of the package delivery process. Indeed, this stage, due to its relatively young age compared to other stages of a traditional supply chain, presents

more potential for improvement and optimization in addition to being a very resource-intensive stage of a package's journey. What could be done to help the parcel industry become more sustainable in its last step?

Buckle up for the rest of your reading, because we need to deliver some answers.

2. Research questions

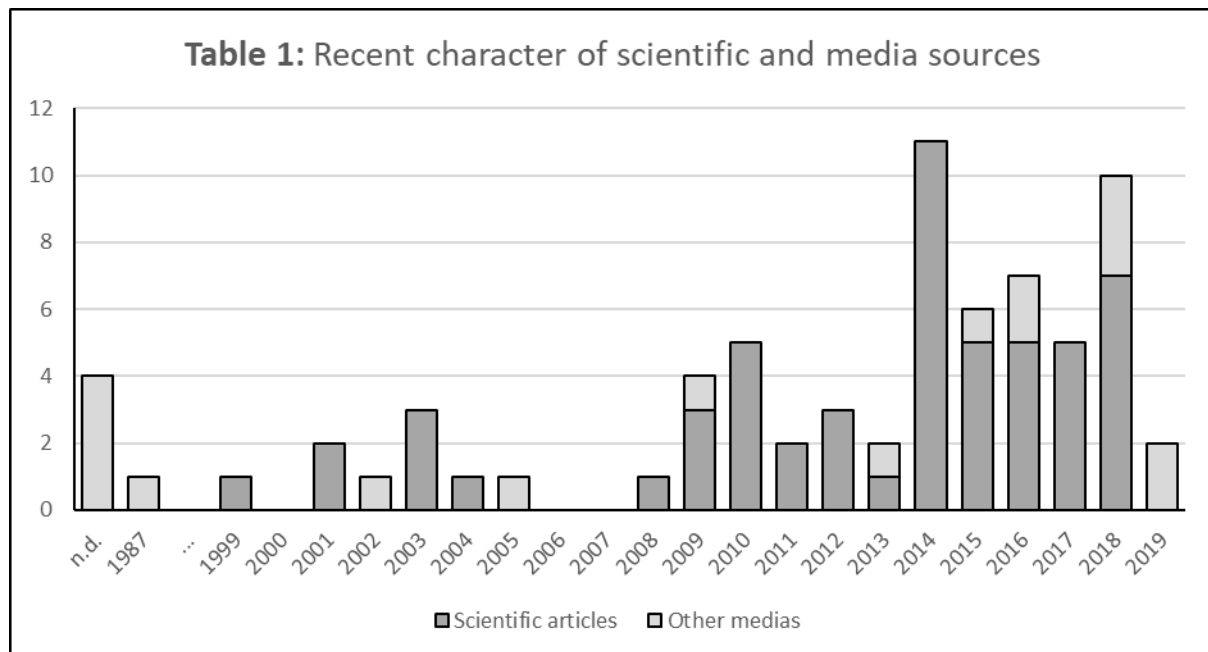
At first, this thesis will attempt to provide an overview of the main solutions available for improving sustainability of package deliveries in the last mile. To do so, the first part of the work will be dedicated to a thorough literature review. The objective of the literature review will be to obtain a comprehensive view of the various solutions highlighted by scientific research and to assess their impact, opportunities and barriers. The various processes and solutions developed by the various stakeholders of the last mile will be organized in a relevant way which will help us during the second part of our work.

The second section of the thesis will focus on the main stakeholders of the last mile and their perspective on sustainability. To do so, interviews will be conducted on various people related to last mile stakeholders: global third-party logistics providers (3PLs), postal operators, other carriers as well as authorities active in transportation regulation and mobility solutions. This exploration will consist in providing current processes and initiatives through interviews with these field experts. The information gathered during the interviews will be analysed and organized so that it will be possible to compare it with our findings from the previous section.

By comparing processes undertaken by actual last mile stakeholders with each other and with the information and theories gathered from the literature, we will be able to look at the eventual differences that may emerge between what the research has been focusing on so far and the reality of the field. This exploration of information gathered from field experts during the qualitative analysis, crossed with theoretical information published by scientific and academic sources, will be analysed. We will try to understand the differences that may arise and to understand why they are, resulting in recommendations to consider for further research in the areas of last mile sustainability in the parcel industry.

3. Limitations

The concern for the challenges of last mile sustainability is relatively recent. Indeed, e-commerce, the main responsible for the explosion of last mile home deliveries, has only been existing for 20 years. Before that, home deliveries, although they existed, were not substantial enough to capture the interest of many researchers. In addition, sustainability concerns were not part of the most discussed subjects in logistics before, resulting in a lack of relevant literature before the start of the 21st Century. On the positive side, however, the last decade has seen a steep increase in the number of research papers that can be linked to last mile sustainability, as shown from the chronology of the literature review in Table 1.



Source: bibliography

Another limitation is related to the intensive competition that currently characterizes the parcel industry. Rival companies try to differentiate themselves by providing unique services, however in this sector one of the main competitive advantage is the price of the delivery. As a result of this intense price competition, corporations active in parcel distribution activities are rarely willing to share their cost characteristics as well as other numerical data. This caused some difficulty in assessing the costs and GHG emissions of the industry and their various delivery methods precisely. In most cases, although comparisons between several delivery methods will be possible, few quantitative data will be available,

sometimes contributing in a lack of precision as for the relative efficiencies of some mechanisms with each other.

Finally, regarding the qualitative analysis, some local authorities' representatives were unable to be reached due to the current political climate in Belgium. Indeed, in the Brussels-Capital region, the recent elections held on May 29, 2019 and the talks conducting to the formation of the new government in July led the personnel of the region and its cities to be too busy working on the political transition to find some time to discuss the mobility projects of the City of Brussels. Besides, the local elections held in Belgium on October 14, 2018, caused some occupations to be relatively recent, as it is the case for the Secretaries of Mobility in Charleroi and Liège. While they can provide guidelines on the general projects in development, some of the matters of interest for this thesis had not been yet discussed in detail in the political agenda.

4. Prerequisite concepts

Before reviewing the literature on the subjects discussed in the research questions, four concepts need to be defined and contextualized. Therefore, we will provide a definition of the concept of “sustainability”, a recurring theme in current literature and press, which can be subject to misinterpretation. Afterwards, we will define the “parcel industry” and summarize its history briefly. We will also list the various types of third-party logistics providers that are active in the industry and their characteristics. Then, we will focus on “home delivery” to understand better its current state, with a focus on a determining characteristic of the home delivery process: e-commerce. Finally, using the literature, we will define what “the last mile issue” is. The background context provided by the following sections is meant to withdraw any form of misinterpretation of these concepts as well as to provide a documented approach for the further content of the thesis.

4.1. Sustainability

Sustainability is one of the most popular concepts across several management research themes over the past years. Growing concerns about the environmental outcomes of human activities have contributed to increasing the importance of the concept.

Sustainability is now at the heart of the corporate concerns; financial profitability no longer is the only goal pursued by managers across the world. It is therefore important to understand what sustainability is about because a side effect of its popularity is that it has led to some ambiguity regarding its actual meaning. The most often used definition of sustainability is: *“development that meets the needs of the present without compromising the ability of future generations to meet their needs.”* (United Nations, 1987, p. 8). A common way to refer to sustainability is to divide it in three categories using the Triple Bottom Line approach: in order to achieve sustainability in its activities, any corporation, any organization, any government has to satisfy three criteria: economic performance (the traditional bottom line), social wealth creation and environmental responsibility. Companies should obviously keep focusing on corporate profit, which ensures that the company will last in the long run. This is why economic performance is an inherent part of the Triple Bottom Line approach to sustainability. In addition to maximizing the profit of the organization, two other objectives must be fulfilled. The second bottom line should focus on people, by measuring the social implications of the company’s activities, in other words care for their impact on human welfare. In the transportation industry, this can typically refer to the congestion issues, health risk from pollution, accident risk and noise, all caused by the impact on traffic. The third bottom line is the environmental responsibility, meaning all the outcomes that have an impact on the environment must be accounted for, such as GHG emissions and waste management, or the concern for biodiversity preservation. In transportation economy, the improvement of environmental sustainability is strongly linked to the reduction of CO₂ emissions. To summarize, the ultimate objective of the triple bottom line is to improve:

- **economic sustainability** by making financial profit;
- **social sustainability** by minimizing the negative outcomes of economic activities on people – or to balance them with some positive ones;
- **environmental sustainability** by decreasing pollution and GHG emissions – or mitigate them with actions that will have a positive impact on the planet.

Throughout this thesis, sustainability will be addressed from the Triple Bottom Line approach perspective, however there will be a stronger focus on environmental responsibility, which is at the heart of the current issues in last mile parcel delivery and has the more potential for sustainable improvement (The Economist, 2009).

4.2. The parcel industry

Parcel delivery – also called package delivery, or express package delivery – consists in the physical transfer of small packages or high value mail from a shipper to a receiver. Shipments often are single packages of small size (less than 70 kg¹). One or several third-party logistics providers (3PL) need to be in charge of the entire shipping process, otherwise it could include a company transferring goods from one place to another in its own supply chain (Dennis, 2011).

The history of the parcel delivery industry has always been correlated with the evolution of information and communication technology (ICT), transportation technology and economic climate. It traces back to 1852, when Wells Fargo became the first company to provide delivery services for packages around the United States, using stagecoaches at first, then trains, and proved to be a success. At the end of the 19th Century, the first postal unions between European and American nations rapidly included parcel shipments into their treaties. In the early 20th Century, the industry became more popular, with the emergence of oil-fuelled vehicles that helped cover large distances cheaper than by horse, which increased competition. The foundation of privately-owned United Parcel Service (UPS) in 1907, who is still one of the market leaders to this day, is followed in 1913 by the introduction of parcel post by the U.S. Post Office Department. Train delivery progressively decreased and eventually became marginal in the 1970s, while air delivery became the norm for express packages, with the emergence of the hub-and-spoke freight system. Another market leader of the industry, FedEx, developed this system in which local airports connect to central ones – the “hubs” – that take care of long-distance flights, substantially improving efficiency. The industry has kept evolving, having extensively recourse to new ICT to improve their supply chain’s efficiency, which helped deliver a better and more varied customer service, also adding next-day and same-day delivery options to their offer, all while lowering costs. In addition, the globalisation of trade since the end of the Cold War in the early 1990s, coupled with the increase in free trade agreements developed international commerce of parcels as well. With the arrival of the Internet, finally, the generalization of the use of e-mail services as a replacement for physical mail hurt public postal services, pushing them to

¹ In practice, the majority of packages are under this limit and rarely weigh over 30 kg.

extend their activities further into the parcel delivery sector, leading to an increase in the number of competitors in the industry (Kafle, 2015).

The industry is characterized by a sustained growth since its beginning. With the complementarity of mail-order shopping – also called catalogue shopping – in the 20th Century and e-commerce since the beginning of the 21st Century, it has allowed customers to shop from home, which impacts will be discussed in more detail in a further section. Technology and globalisation have extended the logistics capabilities of the 3PLs and have unlocked new markets, which contributed to the success of the parcel industry. Since 2014, growth in the industry has been steady around 19 % per year, with the Asia-Pacific region driving growth. Similar growth numbers are expected until 2021 at least (PWC, 2016 ; Statista, 2018).

The market is characterized by an intense competition and is highly concentrated, with three companies, called global integrators, sharing around 90% of the market share: UPS, an American firm who built its success with ground home delivery in the United States; FedEx, American as well, who revolutionized the industry with its air delivery hub-and-spoke system; and DHL, a German subsidiary of Deutsche Post AG – privatized in 1995. Locally, they compete with other parcel delivery services, whose size and international reach is less important. In the United States, the market is split between four companies: UPS, FedEx, DHL and USPS, the United States Postal Services. In Europe, there are other competitors. Indeed, each national postal service, whether state-owned or privatized, has extended its activities to parcel delivery. UK Royal Mail delivers parcel all over Europe through its subsidiary Global Logistics Services (GLS) and facilitates cross-border shipments by partnering with the Chinese ZLS Express. In France, La Poste, although state-owned, has also developed its offer through Geopost for cross-border shipments and DPD, Chronopost and Interlink for parcel delivery across the continent. Other European examples include PostNL, bpost, NordPost... Private logistics services providers emerge as well. They try to differentiate themselves to obtain a competitive advantage in this competitive sector, such as XPO, who specialized in the delivery of large, odd or high value packages; Yodel, that proposes B2C home delivery services in the UK at a lower price than global integrators; or Hermes, that specializes in small time window deliveries in Germany and cross-border custom clearance services. In addition, Amazon, the US-based global leader of e-commerce, is starting to develop its own delivery solutions (grocery deliveries, same-day deliveries,

investment in drone technology...). Finally, the success of peer-to-peer platforms – the “uberization” phenomenon – also starts to expand to delivery services, with companies such as Nimber that ask private drivers to deliver packages from a location to another in exchange for a fee (Braunstein, 2015 ; Ducret, 2014 ; Haber, 2016).

4.3. Home delivery services

Home delivery is the bringing of items to a customer’s home, in contrast with traditional shopping where the customer collects these items from stores (“Home delivery”, Collins, n.d.). For this event to take place, there always exists a preliminary contact between the buyer and the seller. Hence, home delivery does not include home sales where a seller comes to a potential customer’s house with the intention to convince him to buy a good. It also excludes service delivery because it is mandatory that a good is shipped. Some companies build and deliver the goods themselves (2PL), but in the overwhelming majority of cases, the seller of the goods has recourse to a third party logistics service provider (3PL) who will take care of the entire shipment process from good collection at the manufacturer’s warehouse to the home of the final customer (Dennis, 2011).

Home delivery has been existing for more than hundred years, with the emergence of mail order shopping, which consisted in placing an order to a company by mail. Since the end of World War II, however, due to the democratization of the price of cars and the expansion of the road network, it became possible to go to stores more easily and to bring goods home effortlessly. Shopping became more popular, going to the mall became a leisure activity in itself. Home shopping slowed down. It went back up during the 1980s with the growth of catalogue shopping and TV shopping – some TV shopping channels were entirely dedicated to the demonstration, promotion and sale of goods. Phone shopping developed as well. Its success was smaller, mainly due to the absence of visual information. Phone shopping therefore switched its focus on the sale of services rather than home-delivered goods. However, these distance sales presented several issues such as unidirectional information flows and transaction issues, which tarnished its success. Since the beginning of the 21st century, however, the sector has fundamentally changed with the arrival of the Internet, the main contributor to the expansion of home deliveries (Eastlick & Feinberg, 1999 ; Grant et al., 1991).

The uprising of the Internet in the late 20th century had many consequences for households as well as for companies. Unsurprisingly, it also had – and still has – an important impact on the growth of home deliveries. The Internet has caused two important major changes that will affect home deliveries: the ICT revolution and the e-commerce boom (Laghaei, Fabri & Li, 2015). The emergence of big data and high-level ICT improved logistics to the point where complex global supply chain networks can be managed on a large scale in real time. Supply chains and logistics networks have extended and have become more complex, more efficient, quicker and more reliable. 3PLs have become able to improve their use of information: it is now more accurate and up to date, which allows a more efficient transportation flow of the goods along the supply chain, contributing to lowering the cost of transportation. This cost reduction made affordable the delivery of any single package at home. It also increased the range of services offered to the consumer such as instant tracking, returns management, safer transactions... (Lee & Whang, 2001).

Besides the optimization provided by ICT, the major change provided by the vulgarization of the Internet has been the emergence of e-commerce. Since the United States ceased to fund the Internet in 1991 and let private investors handle its future, the Internet has started focusing on the commercialization of goods and services through this new communication network (Weis, 1992). The “Internet economy” was born. It is characterized by the networking of its stakeholders and processes and the electronic communication between them, which resulted in structural changes for value creation, market mechanisms, professional life and consumption patterns. E-business is one of the aspects of the Internet economy, defined by Fichter (2003, pp. 26-27) as: *“business processes, commercial activities, or other economic tasks conducted over the Internet or computer-mediated networks”*. It includes video conferencing, teleworking, etc., and particularly e-commerce (Fichter, 2003 ; Fan, Xu, Dong & Wei, 2017). According to OECD’s definition (Organization for Economic Co-operation and Development, 2002, p. 89), e-commerce is the part of e-business that characterizes as *“[...] the sale or purchase of goods or services, [...] conducted over the Internet, but the payment and the ultimate delivery of the good or service may be conducted on- or off-line”*.

A major reason for e-commerce fast growth over the last twenty years is that it provides additional features compared to traditional commerce. E-commerce presents many advantages for shippers, mainly cost reducing factors:

- No need for physical vendors and outlets anymore: websites act as a direct links between shippers and customers, withdrawing many intermediary actors;
- Infinite virtual shelf space on web pages: e-retailers no longer need a physical store and can ship the orders directly to the customer's home. They only resort to one intermediary, usually a 3PL, that will take care of all the steps of the shipping process. In the extreme case of dematerialized goods (movies, music...), delivery itself can take place on the Internet. Downloading a file is instantaneous, marginally costless and no intermediary at all is needed. (Laghaei et al., 2015).

Customers as well benefit from e-commerce. According to, Mangiaracina, Marchet, Perotti & Tumino (2015), these are the factors that contribute to the enthusiasm about online sales:

- The wide range of products available, due to the instant access from the home computer or from the mobile phone to thousands of stores around the world;
- The very competitive prices, due to lower costs and the global competition;
- The high-quality customer experience;
- The premium service level, such as return policies, tracking options, promotions...;
- The consumer protection mechanisms;
- The secure payments;
- The value proposition, including its convenience. The delivery of goods at home is perceived as one of the most convenient aspects of e-commerce, since round trips to the store, time spent looking for a parking place and queuing time are eliminated (Durand & Gonzalez-Feliu, 2012).

In its early days, the online shopping experience used to be perceived as riskier than traditional shopping, which could drive away the most risk-averse customers. Since then, e-retailers have set up many incentives that influence on two components of the perceived value of an online purchase. First, the utilitarian value of a good is driven up by additional services that increase the utility for the customer, the most important one being home delivery. Secondly, the hedonic value of a good depends on personal customer tastes that can be fulfilled when shopping online, like the taste for adventure when browsing the Internet or the will to share a shopping experience on social media. Online shippers also developed mechanisms that contribute to decreasing the risk level, such as secure payment methods and additional guarantees. This increase in perceived value and decrease of

perceived risks contribute to an overall improved online shopping experience resulting in more customers choosing e-commerce over traditional commerce. These different factor of success of e-commerce contribute to its impressive success. Online retailing has been experiencing a two-digit growth for more than a decade. This growth can directly be linked to the increase in the volume of packages carried by 3PLs to the customers' homes. The current popularity of smartphones has also developed mobile online shopping, called m-commerce, which is expected to be an important contributor to e-commerce growth in the near future (Chiu, Wang, Fang & Huang, 2014 ; Schöder, Ding & Campos, 2016 ; Statista, 2018).

4.4. The "last mile" issue

The "last mile", sometimes referred to as "last kilometre", is the last segment of the supply chain. Gevaers, Van de Voorde & Vanelslender (2009) define B2C last mile logistics as: *"the final leg in a business-to-consumer delivery service whereby the consignment is delivered to the recipient, either at a collection home or at a collection point"*. This definition focuses on B2C deliveries, which is the main concern along this thesis. Nevertheless, researchers disagree on the extent of the last mile reach: Janjevic & Ndiaye (2014) include only B2C deliveries and B2B *"small business in which fast moving consumer goods can be obtained, i.e. express shops and restaurants"*, while Morganti & Dablanç (2014a) argue that B2B final deliveries should all be included in the last mile definition. When considering parcel delivery, Bates et al. (2018) describe last mile as *"the final journey made by a parcel between the local depot and the end recipient in the urban logistics network"*. The concept is figurative: it does not represent exactly one mile or kilometre. It originates from telecommunication networks and is characterized by the fragmentation of the network at this stage. In logistics, this is the case a well with hub-and-spoke networks that are similar to trees, with branches getting thinner at every stage of the supply chain. The last branches, thinner and in larger number, correspond to the last mile and lead to inefficiencies and other consequences regrouped under the concept of "last mile issue" (Cardenas et al., 2017).

The concept of "last mile issue" regroups all the potential problems that are specific to the last stage of parcel delivery and that have been observed in most of the main developed cities, although some of its externalities can be observed in rural areas as well (Pronello, Camusso & Rappazzo, 2017). As stated by Moroz & Polkowski (2016), *"[...] delivery*

of a parcel to a recipient's address results in high costs of customer service [...] and greater environmental pollution [...]." Indeed, carriers need to cover large distances to reach the homes of all the final customers, which increases all transport costs and drives up the total amount of emission of CO₂ and fine particles, traffic congestion and noise in the served areas. The last mile issue has a direct negative impact on all three components of the Triple Bottom Line (Moroz & Polkowski, 2016). However, when considering the reduction of personal shopping trips due to the recourse to home deliveries, the overall footprint of last mile can be positive. From a financial perspective, last mile represents a substantial cost: an estimated 28% of the total transport cost of a parcel can be linked to the last mile, because the fragmentation prevents most of scale effects to apply at this stage (Goodman, 2005). Regarding external costs caused by last mile, there is no consensus however on a numbered estimation, as they can be more difficult to assess and are often neglected in corporate financial balance sheets. Nevertheless, the main social costs can be spotted: they are linked to vehicle noise in residential areas, illegal parking practices and congestion issues – last mile vehicles' contribution to traffic increases average travel time and results in more pollution, causing health issues. As for environmental costs, they mainly consist in the CO₂ and fine particles released by oil-fuelled last mile delivery vehicles. In logistics, last mile transportation is believed to be the stage which has the biggest impact on sustainability (Mangariacina et al. (2015).

II. State of the art

Upon reviewing the literature, three major subjects arise when it comes to matters of sustainability in last mile home deliveries. First, some studies assess the sustainability impact of home deliveries compared to traditional shopping. They also highlight the barriers linked to the concept of home deliveries. This is an interesting starting point to discuss to assess the overall efficiency of home deliveries in the last mile from a sustainability perspective. Secondly, we will review in detail the mechanisms explored by the scientific literature that aim at improving sustainability in the last mile. Four major classes of current and future solutions can be observed:

- **Delivery process improvements:** current and new methods – developed mostly by 3PLs, but not only – in terms of attended deliveries, unattended deliveries and consolidation processes to improve the degree of efficiency of deliveries;
- **Fleet improvements:** all the means of transport used to deliver the goods at the customers' homes;
- **Regulation improvements:** all the tools that city councils and governments are using or can use in order to improve sustainability in the last mile, from a local, regional and national perspective;
- **Consumer perspective:** this section will discuss the power of the final recipients of the parcel in the process of becoming more sustainable.

Finally, it is not possible to address last mile sustainability solutions without addressing the important role played by ICT, which is why there will be a category dedicated to their development. Indeed, several researchers highlight the impact of ICT development on all the delivery processes, means, and policies linked to last mile, which will form the last part of the literature review.

1. Sustainability impact of home deliveries

1.1. Online shopping vs. traditional shopping

Online shopping has increased considerably in the past 20 years, to the point where it is now possible to find a larger product offer online than by physically going to a store in a nearby area. Traditional shopping, however, remains the main channel used by consumers for their purchases. As online and traditional shopping are both very present in the consumer's everyday life, it is interesting to wonder which one is the most suited for sustainable growth. Indeed, as stated earlier, online delivery is nearly always paired with home delivery, where the delivery of goods at home by a 3PL is needed. On the other side, conventional shopping requires the consumer to travel himself to the location of the good to purchase it. Edwards, McKinnon & Cullinane (2010) assessed the sustainability impact of both consumer behaviours – online and traditional shopping behaviours – in terms of grams of CO₂ emitted per package. It reveals a significant lower CO₂ emission per package when a customer is using last mile home delivery than when he is completing purchases using his vehicle. In the extreme case where the customer would complete a trip to purchase one single item, he would emit on average 4,274 grams of CO₂, while the delivery of the item through a 3PL diesel van would emit only 181 grams of CO₂². This advantage comes from the multi-purpose trip of the delivery van, that allows the distance covered by the vehicle to be divided by the number of parcels delivered, as opposed to the single-purpose trip of the private consumer. Even when considering the use of public transport, home delivery has a significant lower environmental impact. An efficient way to decrease the impact of personal shopping trips would be to group several purchases together in one trip, which is called “chaining”, which is often the case to some extent. Still, when considering non-food parcel delivery, 24 purchases would need to be completed by a customer in a car – 7 purchases when using a public bus – to compete with a delivery van. This underlines the important advantage of online shopping over traditional shopping. However, many elements can have

² This model requires many assumptions which make it unrealistic, nonetheless it is a decent starting point for traditional vs. online shopping comparison. In the following sections of their research, Edwards et al. include more elements that help represent better the reality of the field. They will be discussed further into the thesis.

affect negatively this utopic 24-to-1 ratio, as we will review in the next section. Besides, Weltevreden & Rotem-Mindali (2009) estimated that the increase in freight travels caused by B2C e-commerce was not as important as the opposite drop in personal travels related to e-commerce.

1.2. Barriers

Before reviewing the solutions for improving sustainability suggested by the literature, we will describe the main issues that occur on a regular basis during the last mile delivery process. 3PLs and other last mile stakeholders encounter several barriers to sustainability, whether it is financially by driving the delivery cost up, socially by impacting the community around which last mile activities occur, or environmentally by increasing the level of CO₂ emissions or other substances prone to increasing pollution, e.g. fine particles. Once we are more familiar with these barriers, we will be able to understand better how to solve them.

1.2.1. Fragmentation

This barrier to sustainability may be the most difficult to overcome of all due to its nature, strongly linked to the last mile concept. Indeed, it is part of the essence of last mile delivery to be fragmented and appears necessary to deliver parcel at home. Fragmentation is the split of the supply chain tree into numerous smaller branches at its last stage, from the departure of delivery vehicles from the last depot to the recipients' homes. Since the destinations of the vans are scattered around large areas with many stops needed, the only way to deliver each parcel is to rely on an important fleet of small vehicles to take care of the last mile. This increase in the number of vehicles in the last stage of the supply chain results in a higher cost per package, with drivers' wages, fuel consumption and vehicle fleet amortization as main cost contributors. It represents a higher cost per package because each delivery vehicle will carry substantially fewer packages in the last mile than the heavy trucks, aircrafts, trains and ships that took care of the previous steps of the transportation process.

1.2.2. Unpredictability of final destinations and volumes

In addition to the high number of final recipients that causes fragmentation, there is much unpredictability in last mile, as the final destinations are scattered through an area and are unknown to the drivers until the morning of the day the delivery is taking time. It is impossible to predict exactly which consumers will be ordering a “next-day delivery” parcel online, and how many will. Therefore, it requires a part of improvisation that supply chain managers need to deal with, such as changing the delivery routes each day. It will induce more costs than if routes, delivery schedules and drop-off points were fixed, predefined.

The delivery volume is unknown as well, but the fleet size and the volume capacity of each delivery vehicle is fixed for a single distribution centre. This may lead to a gap between the fleet overall capacity and the demand. This excess of capacity, coupled with the scarcity of delivery points in residential areas, especially in suburban and rural areas, cause a phenomenon that is called “empty running”. It occurs when a vehicle’s capacity is underused. The fewer parcels are delivered by a single vehicle, the more the distance covered per parcel increases, along with the cost of delivery, traffic intensity and greenhouse gases emissions.

1.2.3. Failed deliveries

A recurring problem for all carriers is the risk of failed deliveries, that occur when customers are not present at the time of the delivery. Delivery failures can happen for several reasons: the absence of the customer, mostly due to the fact that delivery time windows often conflict with work hours; or the refusal in case of error, damage or other motive. If there is no alternative to deliver the parcels, they will be considered as failed deliveries, which causes inefficiency. Fewer packages will bear the economic and environmental costs of the delivery vehicle’s round. Edwards et al. (2010b) estimate that the failure rate of deliveries can vary from 2% to 30% depending on the nature of the delivery services provided – some parcel may be delivered when no one is home, such as the ones that are small enough to fit into the mailbox; whereas others require a signature that prevent any unattended delivery – and cause CO₂ emissions to increase from 181g to 226g per package. Moreover, failed deliveries often result in re-deliveries in the following days (or

may be returned to the shipper³), resulting in even more distance covered per package. The cost of re-delivery is high because it means that a single parcel must bear twice or more times the cost of last mile, which in some cases can cause the parcel delivery to be unprofitable. One of the most recurring subjects in the literature is to provide solutions for decreasing the failure rate of deliveries, which stresses out how seriously this problem is taken.

1.2.4. Urban area congestion

Most deliveries occur within urban and suburban areas, characterized by developed infrastructures and high densities of population, offices and shops, all sources of vehicle movements. Therefore, the increase in the number of delivery vehicles contributes to the overall city traffic congestion. In most developed cities, traffic is an important issue. This impact on congestion has negative economic and environmental outcomes, as the lower speed of delivery will cause additional costs and CO₂ emissions; as well as a social impact for nearby residents that can be disturbed by the air pollution, increased accident risk and additional noise caused by congestion. In addition, a recurring problem enhanced by last mile in urban areas is illegal parking. Parking space may be hard to find in dense areas, and carriers have to stop frequently to complete their deliveries. To stay on schedule, they tempt to privilege illegal and kerbside parking solutions rather than legal ones, which can once again increase congestion, be unsafe and contribute to citizens' unhappiness.

2. Home delivery solutions for the last mile

2.1. Home delivery process improvement

This section will regroup the solutions developed in various research articles that focus on operational methods and processes. The main purpose of the explored methods is to reduce inefficiencies in the last mile either by decreasing the rate of failed deliveries, by pooling deliveries or by increasing the loading rate of vehicles. The outcomes of these

³ In the case of unclaimed low value packages, when the return of the shipment is at the expense of the shipper, it is increasingly common to have the parcels destroyed rather than shipped back.

efficiency gains are expected to decrease the distance covered per parcel. This should result in less overall traffic for a given volume of parcels, as well as a decreased cost through lower fuel, labour and vehicle use. The decreased use of fuel is also expected to lower greenhouse gases and fine particle emissions, which is positive for the environment as well as for citizens' health.

2.1.1. Attended deliveries

Usually, home deliveries should be attended to, for safety or perishability reasons. Typically, high value products (e.g. laptops, smartphones...) and food deliveries (from e-grocery shopping) have a higher risk of being stolen or perishing, respectively. However, it becomes increasingly common for customers to be absent when the carrier knocks at the door to deliver a parcel, mainly because deliveries occur during working hours. McKinnon & Tallam (2003) also point out the increase in the number of double-income and single-person households as well as the longer leisure time spent outside of home, increasing the probability of no one being home, both inside and outside working hours. Alternatives must be found to avoid delivery failure, which would cause a re-delivery on the next day, resulting in extra time spent on the road with repercussions on costs, traffic and CO₂ emissions.

Attended deliveries usually require a Proof of Delivery (POD) by asking an adult person at the delivery address to sign to confirm delivery reception. POD transfers the responsibility of the good from the carrier to the end customer. Different levels of clearance can be required by customers for POD, from the more flexible "indirect signature required" option, where a neighbour or building manager's signature is authorized; to the "adult signature required", where a piece of identification must be shown to the carrier upon delivery. Those services come with additional fees as they are time consuming – more time is spent by the driver on the doorstep of the consumer – and have an impact on the probability of success of the delivery (FedEx, 2019).

Delivering parcels when people are less likely to be absent is one way to avoid delivery failures. This led to the uprising of off-peak deliveries. 3PLs try to take advantage of the times of the day when the customer is more likely to be at home: early morning deliveries (from 6:00 AM to 9:00 AM) and late-night deliveries (from 5:00 PM to 11:00 PM) would help reduce the failure rate efficiently (Van Duin, de Goffau, Wiegman, Tavassy &

Saes, 2016). This would also represent an extra labour cost because drivers would be working outside traditional schedules. This can be reflected into the price of the delivery as an extra service fee. It also has the second advantage of lowering the likelihood of being stuck in traffic (Gevaers et al., 2009). Saturday delivery is another form of off-peak delivery, it is also becoming increasingly common and can be available by default or in exchange for a fee depending on carriers. According to Pan, Giannikas, Han, Grover-Silva & Qiao (2016), the time windows of the week that present the highest chance of customer attendance are on Saturdays from 9:00 AM to 11:00 AM and from 2:00 PM to 4:00 PM⁴. To this day, no deliveries have taken place on Sundays (Pan et al., 2016).

Another way to increase the rate of success of home deliveries is customer contact. A case study from Gevaers et al. (2009) highlighted the potential benefit of using customer contact on a delivery company in Berlin. Sending an SMS to the customer to inform of the time of delivery helps the customer know more precisely when he has to attend delivery, which is expected to lower the “not-at-home” problem. In e-grocery home deliveries, some carriers call the customers on their phones to confirm attendance (Pan et al., 2016). Van Duin et al. (2016) suggest combining evening deliveries with customer contact to optimize their impact, especially in residential areas with high failure rate of deliveries. However, Kolinska, Jelén & Cudzilo (2015) estimate that the improvements brought by phone notification prior to delivery are not significant, the savings realized being lower than the costs related to the implementation of the notification process. In addition, this additional service is not perceived as an important customer service level improvement. The evolution of technology improved the cost efficiency of such mechanisms, especially for tracking information about parcels in real-time, however these improvements failed to prove efficient enough to impact significantly attendance rates. Other mechanisms include e-mail notification that notify the time of delivery and suggest alternatives to the customer if he replies that he will be unable to attend the delivery at the scheduled time. Finally, they conclude that *“there were many more variants of cooperating with customers and eliminating the problem of repeated deliveries than there were courier companies in the market”* (Kolinska, Jelén & Cudzilo in Golinska-Dawson & Kolinski, 2017, p.92). This variety might be a sign that the most optimized way of using customer-contact to improve home delivery attendance rate is yet to be discovered.

⁴ The research from Pan et al. (2016) did not consider early morning and late evening deliveries.

To address the absence issue, another alternative consists in delivering the good to a next-door neighbour in the case no one answers at the door of the original receiver, who will receive it from the hands of his neighbour when he comes home. According to a market research survey from Van Essen (2013), enabling neighbour delivery in case of customer absence can reduce failure rate from 25% to 10%. A similar method has been used by carriers for decades, but it used to be in an unofficial way. Prior to the boom of e-commerce and subsequent home deliveries, informal networks of local agents were already used by mail order retailers, usually housewives, that would receive the goods from the carrier for a whole neighbourhood and deliver them to their neighbours once they came back from work. This trend has slowly been decreasing for 20 years. 3PLs have understood the importance of neighbours in the last mile and are used to knocking at the neighbour's door in case of absence. However, such delivery increases the risk of theft by the neighbour if he claimed he did not receive any parcel, although this phenomenon has proven to be very isolated and easily detectable if it is repeated (McKinnon and Tallam, 2003). Competitive pressure to build a reliable service has pushed 3PLs to incorporate neighbour delivery services (Bpost, 2019 ; FedEx, 2019 ; United Parcel Service, 2019). This alternative delivery does not imply any additional fuel consumption, neither from the carrier nor from the customer, as the travel to a neighbour's home is expected to be on foot (McKinnon and Tallam, 2003).

Finally, carriers can show creativity in the way they are trying to optimize their delivery patterns to maximize customer attendance probability. Pan et al. (2016) predict consumer presence in real time using big data and analysing electric energy use patterns of consumers. This innovative approach takes advantage of ICT improvements, including the use of Big Data, to predict whether a consumer will be home in real time, with a software updating the route of the delivery vehicle accordingly. If the electric consumption of the household of a customer is lower than usual, it increases the chance of the customer not being at home at the given time, therefore the software will point the driver to a different address and deliver the good only when the electric consumption of the receiver's home shows more activity. This approach is best suited for groceries deliveries as attendance is required and any time gain can be critical when delivering perishable goods.

2.1.2. Unattended deliveries

Deliveries that require no POD can be delivered unattended, which means that the delivery can take place successfully even when no one is physically present to receive the parcel. The chance of failure of an unattended delivery is therefore significantly lower than for an attended delivery. The literature mentions failure rates from 12% (Visser, Nemoto & Browne, 2014) to as low as 2% when efficient delivery alternatives have been set up (Edwards et al., 2010b). Punakivi, Yrjöla & Holmström (2001, p.428) consider that: *“Unattended reception allows for greater operating efficiency without sacrificing the service level, but requires investments in reception solutions at the consumer end”*. Indeed, the challenge of unattended delivery is to find the best place for the parcel to be left between the moment it is delivered by the carrier and the moment the customer picks it up. By default, carriers will try to fit the parcel in the mailbox (Visser et al., 2014). If the parcel is too big, an alternative way is needed to avoid knocking at the customer's door, which would cause the delivery to have a chance of failing, just as attended deliveries. A large range of delivery methods has been developed to improve the chance of success and the quality of unattended deliveries, as the following paragraphs will detail. In addition, delivery mechanisms that improve the chance of success of attended deliveries can theoretically be transposed to unattended deliveries as well.

The most widely spread unattended delivery method is secret place delivery, also called doorstepping, or unsecured delivery. It regroups the cases when the parcels are left in unlocked areas, including outside. It is a simple way to avoid delivery failure and its negative consequences and does not require any additional cost. However, this is the delivery method that presents the highest risk of theft and/or damage from weather or any other unfortunate interaction (McKinnon & Tallam, 2003). In addition, it is absolutely not suited for groceries delivery as it would cause the food to perish. This mainly happens in rural and suburban areas, where the properties are usually larger and the density of population lower, which decreases the chance of a passer-by seeing the parcel from the street. Typical secret delivery places include unlocked garages, garden sheds, back terraces or simply doorsteps of the house, hence the surname of the practice (McKinnon & Tallam, 2003). A common practice used to be the use of dustbins as containers for the parcels, but it had to be dropped due to the important number of mishaps, highlighting another issue of unsecured deliveries (Edwards et al., 2010b). Despite these heavy downsides, carriers tried to include

secret place delivery processes into their operations to take advantage of its main benefit: it can reduce the failure rate at no cost (Morganti, Seidel, Blanquart & Dablanc, 2014b).

More developed – and costly – alternatives exist under the form of controlled access systems. This type of unattended delivery is meant to be safer than secret place delivery, while still achieving a very low failure rate. It consists in using ICT technology or a secret code known only from the driver to access a secure area on the recipient's property (Iwan, 2015). This requires a connected front door or garage door. Upon delivery, the carrier can send a message to the customer or ring to a connected bell even if he is not home. Using his mobile phone, the customer will remotely and instantly unlock its door to the driver, who will leave the parcel inside the house rather than on the doorstep where there are multiple risks of theft and damage. However, so far, the success of this innovative delivery mechanism is yet unknown. This type of unattended delivery can extend to the unattended delivery of groceries at home as well, because the driver can be granted access to the refrigerator of the customer, as Walmart eCommerce's CEO Marc Lore announced recently (Bpost, 2019 ; Bailly, 2018; Lore, 2019).

A reception box can be defined as a piece of furniture, sometimes refrigerated and grid-connected if it is meant to store food products, which serves the purpose of storing unattended home deliveries. It is located on the customer's property in a fixed place, typically in a garage or a garden shack. It is a powerful way of improving the chance of success of an unattended delivery, as the reception box will hold most types of parcels while waiting for the customer's return, safe from theft, weather damage and perishability risks. It can be compared to the aforementioned controlled access systems in the sense where it is a device which is locked by a code or a key that only the carrier and the customer possess. However, to customers, it does not represent the same feeling of "home invasion" as granting the access of their homes to strangers. Besides, while controlled access systems are usually an individual choice of the customer, the set-up of a reception box is the consequence of an agreement with a specific carrier that sells the product to facilitate its deliveries. However, as a reception box is in the majority of the cases a refrigerated container equipped with a power supply, the investment can be substantial for a household. On the other side, the delivery company cannot bear by itself the cost of all the devices installed inside their customers' homes, as the financial advantage gained from the increased delivery efficiency would be lower than the investment in the reception boxes.

Therefore, given the important investment needed to install a reception box on a property, reception boxes are better suited for people who place frequent orders that need to be kept in a safe or refrigerated area. In addition, a delivery box is an alternative to reception box which is mobile and needs to be attached to a lock on the recipient's land, reducing the investment cost needed from the customer and allowing couriers to use them on multiple occasions. They can also be insulated to contain food deliveries. However, the collection process of the delivery box makes this variation highly inefficient (Punakivi, Yrjölä & Holmström, 2001; Siikavirta et al., 2003).

2.1.3. Alternatives delivery locations

When carriers try to optimize the last mile of the parcel deliveries, efficiency is the key. Whenever it is possible to reduce the total mileage of a delivery round, this has a positive impact on cost, by reducing vehicle usage, labour cost – shorter distance covered are correlated to the time needed to complete the delivery round – and fuel cost. The latter also contributes to improving the environmental impact of the rounds. In addition, the lower the distance and the time spent on the road, the lower the impact on traffic congestion. It is possible to act positively on all three pillars of the Triple Bottom Line of sustainability simply by lowering the distance needed to complete a delivery round. How could it possibly be feasible to decrease the distance? To do so, given a certain number of packages, the only way to decrease the total distance covered per package is to reduce the number of stops that the driver needs to make on his round. Regrouping the drop of several packages in a single destination is called consolidation. It is a very important concept when it comes to last mile deliveries as it is the opposite of fragmentation, one of the main barriers to last mile sustainability and efficiency. The following paragraphs will detail the processes developed as alternatives to home deliveries explored by the scientific literature. The deliveries will not take place at the customer's home but at other locations, which will increase consolidation and the chance of success of the deliveries, increasing substantially the efficiency of deliveries. In opposition to the other delivery solutions already listed earlier, they will therefore not be home deliveries *per se* – although they serve the same purpose and are considered as home deliveries in the literature.

From an environmental approach, one might argue that the environmental gains from the decreased distance would be cancelled out by the customers' trips to and from the alternative location, therefore resulting in a poor performance in terms of CO₂ mitigation. This is only partially true: since the automated parcel lockers and other collection points are strategically located, most customers do not have to take a trip which only purpose would be the collection of their parcel. Indeed, the delivery can take place to a locker located close to their routine travels: next to their workplace, on their way home from work or nearby frequent grocery and shopping areas. This substantially mitigates the travel distance of the package in its last mile, even when considering customers' travels. In urban areas, it is also increasingly common for customers to pick up their package on bike or on foot. This results in general in a very low carbon footprint per package from the customer's perspective as well as from the carrier's perspective: according to a case study from Carotenuto et al. (2018), the CO₂ impact is 21% lower for carriers when delivering to lockers and pick-up points than when doing home deliveries. The more parcels are being dropped at the same place, the higher the environmental gains (Carotenuto et al., 2018 ; Morganti et al., 2014b).

The use of automated parcel lockers is the alternative to home deliveries which is most often cited by literature, along with collection points. Automated parcel lockers are compartments located in strategic areas of a city or a neighbourhood, that are locked with a code. This code is usually sent to the customer by e-mail. Once the carrier has placed the parcel in the locker, the customer can retrieve it whenever he wishes. The locker acts as a temporary storage location in the final stage of the delivery process (Cardenas et al., 2017), which presents many advantages. For customers, first, lockers are generally located in public areas, close to parking spaces, meaning that parcels can be retrieved conveniently 24/7 by the customers, providing a service with more flexibility than traditional delivery processes. As for carriers, the consolidation factor is substantial, since the driver does not have to go to the recipients' homes and can deliver all the parcels destined to a same neighbourhood in the same location⁵, saving a lot of time and energy. The flexibility of the service is however not enough to efficiently push the customer to use lockers compared to the convenience of receiving the parcel at home. Therefore, given the substantially lower cost of this method of delivery for carriers (Gevaers et al., 2014), choosing this delivery service is offered at a lower

⁵ Theoretically, this is possible, however in practice it would require all recipients from that neighbourhood to have indicated locker delivery as their preferred delivery option.

price than having the package delivered at home. On average, choosing locker delivery over home delivery results in a 40% drop in the overall transportation cost for customers in Belgium. This type of delivery also never fails because the driver will always be able to deliver the parcel within the locker. In the rare case when the customer does not pick it up from the locker within the given time frame, a failure can still occur but the phenomenon is extremely rare. Besides, the potential utility of lockers goes beyond 3PLs deliveries and could be used by nearby shops as well. Some refrigerated locker systems are also suitable for food and groceries deliveries (Iwan, 2015 ; Gevaers et al., 2009 ; Pronello et al., 2017). Nevertheless, locker delivery has some downsides as well, the main one being the lack of willingness from consumers to make the last step of the trip themselves, which can be perceived as cancelling out the benefit of online shopping (Iwan, 2015). Another issue is the size limitation of the storage units of the automated locker banks, not suitable for the delivery of large parcels. Besides, an initial investment is necessary for the building of the automated parcel locker stations. To ensure their success, it is therefore important to choose their locations strategically (Muerza, Larrodé, Moreno-Jimenez & Jiménez, 2018).

Another service provided by most carriers is the delivery to collection points, also called service points. They are partner shops which usually have another primary activity than handling parcels. Typically, libraries, supermarkets, flower shops, night shops, gas stations – and local post offices in the case of postal logistics service providers – can diversify their activities into collection points. This is the most widespread alternative to home deliveries. Carriers can drop the parcels at a collection point if the customer has chosen this delivery option. This delivery service is offered at the same price as locker delivery, which is understandable as it provides the same consolidation and cost and fuel reduction advantages than automated parcel lockers. However, opposite to them, collection points involve human handling, offering an added service to the customer but causing additional cost for 3PLs. And unlike parcel lockers, this type of pick-up points is not available 24/7 (Edwards et al., 2010a ; Kolinska et al. in Golinska-Dawson & Kolinski, 2017 ; Morganti et al., 2014b ; Weltevreden, 2008). Collection points are also the most used delivery alternatives in case of delivery failure. Drivers leave a note into the recipients' mailbox indicating at which collection point they will be able to retrieve their packages, provided that no previous instruction had been given regarding the delivery (such as second presentation, etc.). Van Duin et al. (2016) consider the main advantages of the collection points to be their proximity, that allows customers to retrieve their failed deliveries from a closer location than

a depot; the increased customer satisfaction; the security level of the alternative; and the positive environmental impacts from the consolidation and certainty of successful delivery (Van Duin et al., 2016 ; Visser et al., 2014).

Workplace delivery has also increased in the recent years. Since the main reason for delivery failure is the absence of the customer because he is at work, 3PLs have made it possible for customers to be delivered at their workplace instead of using the home address. To do so, the customer can simply provide an alternative address that suits him better during delivery hours, reducing the failure rate of such deliveries and potentially achieving consolidation by delivering several parcels in a same place (Visser et al., 2014).

Finally, the use of local depots and has been researched by Durand & Gonzalez-Feliu (2012). In this case, the consumer can come pick up his order from a depot or a supermarket which is located close enough from his home that it can be considered to some extent as a collection point. In the case of a supermarket, for e-groceries, the order is prepared beforehand by picking up the goods in-store. More and more physical retail shops also develop their web shops, which is called multi-channelling. Some of these shops therefore propose a “click-and-collect”, or “clicks-and-mortar” model where the customer can come and pick up his online purchase in the nearest physical shop. This alternative prevents the recourse to last mile delivery. The advantages of this method from the customer’s perspective are linked to the upsides of e-commerce such as customization, availability of the product and lower price. Depending on the proximity of the pick-up location, this can be considered as an alternative, like collection points ; however if the customer needs to cover a distance which is similar to the one he would have covered if he had not shopped online, then depot and shop picking’s efficiency is questionable (Durand & Gonzalez-Feliu, 2012 ; Lee & Whang, 2001 ; Visser et al., 2014).

2.1.4. Routing optimization

To improve the efficiency of deliveries, there are other solutions than developing processes to decrease the ratio of failed deliveries. The literature shows that carriers are very interested in optimizing the models used for the routing of their vehicles, as with the exception of lockers and collection points implementation, is the most discussed topic in last mile sustainability. Depending on the variety of solutions provided by a 3PL company, the

objectives researched by this company, the best way to plan the delivery routes may vary. We will review some researches who aim at achieving a higher degree of efficiency in the last mile. The developed models are expected to decrease as much as possible the time spent on the road by drivers, resulting in a lower road occupancy, lower congestion and lower CO₂ emissions. The original goal of routing optimization remains economic, as stated by Aized & Srai (2014, p. 1055): *"[last mile] problems call for an efficient routing planning in order to generate reasonable profit margins necessary to run the system smoothly"*.

Routing optimization consists in using the technological advantages of recent ICT developments to improve the delivery routes used regarding a variety of variables. Many models have been developed, with different focuses. However, routing is difficult in the last mile parcel delivery because of the unpredictability of the order volume for the next day. Due to the impossibility to plan in advance the optimal route for carriers, 3PLs have invested in the development of responsive mathematical models that are able to select the best route almost instantly just before leaving the depot in the morning (static models) or even to change the route during the round using real time data (dynamic models).

Most models focus on improving the efficiency of delivery by decreasing time and distance needed to complete the delivery round: they are known as Vehicle Routing Problems (VRP). They are mainly used by 3PLs, as they are a factor for cost reduction, through increased efficiency (that includes CO₂ emissions reduction as a secondary outcome); although some public stakeholders may have an interest in such models for social and environmental motives, as stated by Cardenas et al. (2017). There are different categories of VRP, each with a focus on a different variable for delivery optimization. Time Window Vehicle Routing Problem (TWVRP) models consider primarily the time windows at which the carrier will complete the delivery at each customer's home: Boyer, Prud'homme & Chung (2009) showed the efficiency gains that are possible when using density of deliveries and time windows of delivery as variables. Reduced time windows of delivery increase the average distance per package but help reduce the number of failed deliveries and increase customers' satisfaction, as they usually do not want to clear their schedule for long time frames when expecting a delivery. It is uncertain however whether the expected decrease in failed deliveries is sufficient to cancel out the increased CO₂ emissions from narrow time windows of deliveries. Time Dependent Vehicle Routing Problems (TDVRP) use real time traffic data provided by GPS networks to optimize their route depending on instantaneous

congestion situation, e.g. Ehmke & Mattfeld (2011) and Maden et al. (2010), whose tests resulted in CO₂ emission reductions. Besides, Banyai (2018) highlights the benefits of using real time data in combination with multi-stakeholder cooperation, loading rate optimization and time windows of delivery.

However, few models go as far as to assess the cost of the last mile per parcel: Gevaers, et al. (2014) developed a cost model with respect to several variables such as city delivery vs. rural delivery, that showed the substantial financial advantage of delivering in densely populated areas for 3PLs. The cost of delivery per package in the last mile is estimated to be 64.5 % less than the cost of a rural delivery, which represents a substantial difference in the overall transportation cost, of which last mile accounts for 28 %. This significant gain in cost is mainly due to the gain in time and distance that result in a smaller labour cost, fuel cost and vehicle amortization. The authors underline that their future work will focus on developing a similar model for external costs, including carbon footprint of last mile, because the reduction in fuel consumption has a direct impact on CO₂ emissions. More generally, it is assumed that every time a process manages to decrease distance covered per parcel, there will be direct positive consequences for the financial and environmental sustainability of the delivery operations. Decreasing the distance covered per package in the last mile is therefore one of the main goals of all operational delivery solutions, as most alternative delivery processes in the previous sections are aiming at (Boyer et al., 2009 ; Ehmke & Mattfeld ,2011 ; Gevaers et al., 2014).

2.1.5. Urban Consolidation Centre

Another frequently studied process is the recourse to an Urban Consolidation Centre (UCC). A UCC is located within an urban area, on the contrary of most distribution hubs that are typically located in industrial areas outside cities ; and its goal is to achieve a higher level of consolidation of deliveries. Indeed, the proximity between the UCC and the final destinations makes it possible to avoid fragmentation until the last moment. In addition, significant benefits may arise from the use of a UCC: it can be used in combination with sustainable delivery vehicles, like cargocycles and e-vans, who cannot cover as much distance as diesel vans between the depot and the area they deliver to. It will result in a lower road occupancy, and a more sustainable one, requiring – besides the bikes and other

e-vehicles – only one truck delivery in the morning and one in the evening, which is more convenient than numerous vans roaming the city centre. The potential sustainability benefits are important because it would make the delivery of the parcels almost totally sustainable once they reach the UCC, with a low impact on traffic, safety and GHG emissions. This is why local authorities tend to push such projects more and more, even funding some of them. Nevertheless, in spite of public funding, the economic profitability of a UCC remains difficult to reach. Researchers agree that the threshold volume for a UCC to be profitable is higher than for a regular distribution centre, resulting in the failure of several projects (Allen, Browne, Woodburn & Leonardi, 2012 ; Browne, Allen & Leonardi, 2011 ; Janjevic et al., 2016). In some cases, the hub can be mobile for more flexibility and a lower cost, as mentioned by Verlinde, Macharis, Milan & Kin when they studied the impact of a Mobile Depot – a container acting as a depot and that can be towed by a truck – in the Centre of Brussels.

2.2. Modes of transportation improvements

Gevaers et al. (2009) identify vehicle fleet and technology as one of the core characteristics when it comes to innovation in the last mile. While most delivery methods explored earlier aim at improving the efficiency of deliveries, it is also important to focus on the means of delivery. Rethinking the fleet of vehicles used in the last mile can sometimes impact the efficiency of the deliveries themselves, but mainly their fuel-efficiency. The impact on cost is uncertain, as investment needed for the ecological transition may result in higher costs, cancelling out a part of the efficiency gains and cuts in fuel expenses. Some of these alternatives can also have a positive impact on congestion reduction, contributing to an overall improved sustainability. In addition, the evolution of ICT has introduced another mean of delivery: dematerialized goods delivery is possible without having recourse to any physical channel.

2.2.1. Alternative fuels and green fleet development

The standard delivery vehicle is the diesel van. Diesel is the cheapest source of energy for such vehicles but is not sustainable. Growing concerns – from consumers and

manufacturers – for the environmental impact of GHG emissions from fossil fuel have caused carriers to search for alternative energies for their motor vehicles. Besides, the European Union is pushing for the use of vehicles with lower carbon impact and support plans to prohibit the sale of diesel vehicles by 2030 in some countries. In the literature, many researches have highlighted the potential positive environmental outcomes of using other types of fuel. The other types of fuel that can be used are biofuel, which releases carbon into the atmosphere coming from renewable non-fossil sources, hybrid, electric and hydrogen engines. A shift from fossil fuel to alternative energy has started amongst carriers, with electric vehicles considered as a *“viable strategy for reducing the oil dependency and environmental impacts of road transportation”* (Weiss, Dekker, Moro, Scholz & Patel, 2015 in Oliveira et al., 2017). The variety of alternatives to standard fossil fuel are numerous, with electric vehicles widely considered to be the current best alternative – although the sustainability of batteries has been questioned. However, no global information is available on the current extent of this shift. Most public objectives worldwide are running behind schedule (Gilbert & Perl, 2010 ; Mangiaracina et al., 2015 ; Nielsen, 2018 ; Pronello et al., 2017 ; Schöder, Ding & Campos, 2016 ; Visser et al., 2014). Different strategies for improving fuel efficiency and reduce carbon impact are also stressed out by Visser et al. (2014), such as the development of newer engines that are more fuel-efficient, the use of smarter and lighter vehicles, and cleaner exhaust gases such as the use for newest particulate filters. As for the impact on such measures on efficiency, it is suggested that environmentally friendly alternatives to traditional diesel van delivery would hurt the service level by increasing the time needed for delivery, or by expanding the time windows of delivery (Gevaers et al., 2009 ; Oliveira et al., 2017).

On the opposite hand, Schöder, Ding & Campos (2016) highlight the difficulty to operate a shift from a type of vehicle to another due to the “lock-in effect”. Indeed, the current high market price of electric vehicles is a substantial barrier because the investment needed is important. Carriers are tempted to keep their current fleet and systems and are “locked” in their current systems because they usually do not have the financial leveraging power necessary to operate a significant shift.

2.2.2. Cargo bikes

Bicycle is the alternative mode of transportation most often cited in the literature when it comes to last mile sustainability, according to Oliveira et al. (2017), research articles focus rather on particularly on electric bikes (64 %) than on human-propelled bicycles (36 %). Such bikes specially equipped for the transport of goods are called cargocycles. A special compartment is fixed either on front or at the back of the bike to store goods. The concept of electric bikes can be extended to small electric motorbikes. Both cargocycles and motorbikes can exist in a tricycle version, that offers bigger storage but is slightly larger. They complete delivery rounds like vans do and recharge their batteries overnight. This mode of transportation, in addition, is extremely sustainable: it represents a low energy consumption, which can originate from renewable sources ; it also emits zero pollution (no GHG or fine particles); causes no noise and does not generate any additional congestion on the road network as it is part of soft mobility. In addition, their delivery rounds are less subject to be delayed by traffic hazards, making it a reliable mean of delivery. It is also unaffected by parking issues: unlike vans it can park anywhere, overcoming the problem of the “last 100 metres”, where delivery van drivers need to find a legal parking spot within a short distance of the place of delivery, which is made especially difficult in densely populated areas like cities. According to Gevaers et al. (2014), under certain density assumptions, the cost of bike delivery would be 42% lower than a standard city delivery, making it one of the most efficient alternatives for last mile delivery, economically, socially and environmentally (Bates et al., 2018 ; Gevaers et al., 2014 ; Oliveira et al., 2017).

However, its range is limited to very dense areas, where its efficiency peaks and it can compete with the van. Moreover, the size and number of parcels that can be handled at the same time are limited. To overcome the small loading capacity and range of bikes, the use of Urban Consolidation Centres has been considered as an efficient combination, as it would allow a bike to refill in a location close to its delivery area. (Janjevic, et al., 2016 ; Verlinde et al., 2014).

2.2.3. Autonomous vehicles

A new mean of delivery is starting to emerge due to the progress of technology. Although they currently remain in test phases, autonomous deliveries are becoming increasingly discussed in the media, especially under their most revolutionary form: the drones. Autonomous deliveries rely on the latest technological advancements in the car and drone industries, that start to develop electric self-driving vehicles. A car or a drone without a driver would deliver the parcels to the recipients' homes without needing any human assistance in the last mile. The use of such technology could help reduce the labour cost for carriers, one of the most important cost factors. It could also withdraw any form of human error, responsible for traffic hazards, inefficient vehicle use, non-optimal routing... The car manufacturer Renault, for instance, has announced it was working on the development of such an autonomous ground vehicle for last mile delivery purposes (Mangiaracina et al., 2015 ; Renault, 2018).

In addition, in the case of drone deliveries, the benefits from delivering from the sky are potentially gigantic, as drones would not depend on traffic conditions and would reach their destination faster than any other mean of transportation, unrestricted by any form of terrain. In addition, it would take a shorter, straight route which would reduce energy consumption per package. Amazon, the leader of online commerce, has announced it was planning to develop its own last-mile network using this technology, along with other logistic operators, like UPS. However, the lack of regulation regarding both self-driving road vehicles and delivery drones are currently preventing such projects to take place. Some safety and security issues are still concerning authorities. Nonetheless, it is expected to become a reality in the years to come, due to the increased pressure of the last mile stakeholders, and is expected to revolutionize the whole industry (DHL, 2018 ; Duvall, Green, Langstaff & Miele, 2019 ; Pan et al., 2016 ; UPS, 2019).

2.2.4. Dematerialized goods delivery

Dematerialized goods are all products that do not exist physically. Due to the progress of technology, some of these goods no longer need a physical support before being delivered to the client. Such goods include mail, music, movies, books, video games, documents, software, photos, and more recently blueprints for 3D printers. These goods

used to need to be printed onto CDs, DVDs or paper before they could be shipped to the customer but are now more and more shipped via Internet download. The delivery of the good therefore becomes almost instantaneous, with a marginal cost close to zero for the manufacturer, who does not need the intermediary of a 3PL company anymore. This causes digital goods to be generally cheaper than physical ones (Lee & Whang, 2001, Visser et al., 2014).

This new mean of delivery is the most sustainable one, as it does not require any physical transition through a supply chain, cancelling all emissions from the first to the last mile. While the environmental impact of dematerialized goods in their delivery process is clearly less than physical ones, the overall impact needs to consider other factors, such as the variation in energy and resource consumption linked to these downloads and the need for devices at home that are necessary to use the product, such as music stations, computers, printers and 3D printers. The quick evolution of the latter is expected to increase the range of products available for download in the future. The popularity of digitalized products is such that it can lead to the fall of some outdated physical substitutes. Indeed, downloading music and movies instead of buying them on physical supports is being more and more common, up to the point where the CD and DVD industries, for instance, are expected to disappear in the upcoming years, with customers shifting to dematerialized platforms such as Netflix, iTunes or Amazon Prime. Particularly, the popularity of the e-mail has caused most postal services worldwide to change their business models and extend the range of their activities, usually to parcel delivery, due to the important fall in the amount of paper mail. However, the need for physical delivery is still very present, as most goods cannot be downloaded from the Internet and require a physical delivery (Barnatt, 2013 ; Laghaei et al., 2015 ; Mokhtarian, 2004).

2.3. Urban policies for last mile deliveries

The growth of e-commerce has strongly increased the number of delivery vans on the road. In addition, the intense competition between last mile carriers has pushed them to widen their service range so that they can increase the quality of deliveries and avoid failed deliveries, resulting in an even higher number of vehicles on the roads. Most congestion and pollution issues linked to last mile deliveries are occurring in urban areas, where the road

occupancy rate is the highest. Van traffic is estimated to represent around 14% of all motor vehicles. Hence, more and more cities have developed policies that impact directly or indirectly last mile deliveries. In parallel, regional and national authorities also tend to increase the number of regulations regarding the freight transport industry, with a relatively smaller focus on last mile. Usually, urban policies do not distinct B2C home deliveries from B2B deliveries to local shops. In this section, we will review the different regulations set up by local, regional and national authorities that have been discussed in the literature. We will also highlight the various impacts of these regulations, as public stakeholders may not research the same objectives as carriers or customers: 3PLs may not benefit from these policies, because cities are trying to reconcile all stakeholders' interests: citizens, shopkeepers, commuters, parcel recipients... (Bates et al., 2018, Muñuruzi & Van Duin, 2014).

2.3.1. Illegal parking prevention

In urban areas, parking space can be difficult to find, with passenger cars and freight vans competing for the occasional spots. The further away a driver is parked, the more he will need to walk with potentially heavy packages in his arms from the delivery vehicle to the recipient's address, wasting energy and time. In cities, drivers can spend as much as half of their delivery round time walking. To avoid losing time looking for a decent parking spot, which might be located far from their destination, they tend to prefer illegal parking locations. Studies in various European cities have shown that between 57% and 86% of goods vehicles are parked illegally. Since a single delivery only takes a few minutes, drivers consider that the probability of being fined is not high and can be tempted to take the risk. Illegal parking includes kerbside parking, double parking, or the use of restricted parking zones. However, although they usually do not take a long time, illegal parking will bother the nearby residents and shopkeepers and cause congestion and safety issues. To face this problem, cities increase enforcement and carriers are fined. UPS, for example, had to pay over \$17 million for illegal parking tickets in New York City in the year 2016 alone. Neither authorities nor carriers are satisfied of this situation, sometimes called the "last 100 metres issue" (Bates et al., 2018).

To prevent illegal parking and solve the “last 100 metres issue”, some cities have developed their loading and unloading policies regarding vehicles transporting goods. In some cities, the number of loading zones has been increased, where only delivery vehicles are allowed to park. Other cities go one step further, by creating “virtual loading bays”, which are smart parking spots, that carriers can either book in advance if they know at what time they will need them – or simply use them if they are free at the moment they are passing by. Carriers are billed for this service, which is cheaper than paying fines and that can improve the delivery service by avoiding time wasted looking for parking spots. In addition, using GPS technology, some solutions can point to the free unloading bays in real time. Enforcement is necessary here as well, with reports showing that unloading bays are used for illegal parking by other vehicles (Mairie de Paris, 2006, in Danielis, Rotaris & Marcucci,, 2010). Other solutions include “shared dropzones”, which are large unloading areas in a city centre, where shopkeepers can come and pick up their deliveries, taking care of the last 500 metres themselves. This last alternative, however, does not focus on last mile B2C home deliveries (Bates et al., 2018 ; Danielis et al., 2010).

2.3.2. City access restrictions

Cities who want to reduce congestion in their city-centre can also restrict the access to a specific area of their territory to delivery vehicles. Literature describe city access restriction as one of the most impactful tools available for municipalities. It consists in a city establishing which vehicles may or may not enter a predefined zone during a given time frame. Within the restriction time window, no vehicle is allowed within the zone. Freight vehicles must therefore wait until it is open to carry on their deliveries. Usually, these time windows prevent vehicles from accessing the city between 06:00 AM and 11:00 AM, so that the morning peak hours conditions are not worsened by the presence of delivery vehicles. The biggest incentive for the choice of access regulation over other policies is that it does not require any significant investment in infrastructure or technology and therefore represent one of the cheapest tools that can be implemented. However, authorities need to consider many variables, because there can be backfire in such policies. Indeed, the literature points out that it often leads to carriers using more vehicles to access the city and complete their deliveries within the limited time frame of access. Some carriers may choose deliberately to ignore the regulations if they find it too difficult to overcome efficiently. The

original social sustainability goals – traffic congestion reduction, stakeholder reconciliation, noise reduction, pedestrian safety or improving the shopping/touristic climate – may in this case end up hurting the operational cost for logistics companies and environmental sustainability as well, since the afternoon peak-hour conditions could be aggravated. Researches recommend a thorough planning process to establish the time access windows that will suit best the three aspects of the Triple Bottom Line of sustainability. The choice of the time window policy can vary strongly depending on each city's objectives: if the goal is to decrease noise nuisance from freight vehicles by banning late night and early morning deliveries, time windows will be different than if the main objective is to avoid congestion, e.g. A common mistake is to neglect the cost impact on carriers, who may opt for alternatives solutions that would offset the objectives wanted by authorities. In light of this, Van Rooijen et al. (2007), in Muñuruzi & Van Duin (2014) investigated the efficiency of various measures to optimize the efficiency of urban access time windows and found that the best results were obtained when increasing the length of the access time windows, with positive impacts on costs and on CO₂ consumption ; when access time windows are too tight, the cost and the pollution increase substantially. They also point out that the regional and central power levels could play a coordination role so that nearby cities do not have the exact same time windows, which would help carriers achieve more complementary deliveries (Danielis et al., 2010 ; Muñuruzi & Van Duin, 2014 ; Quak, 2008 ; Ville, Gonzalez-Feliu & Dablanc, 2013).

In addition to time windows, other restrictive alternatives exist for delivery vehicles. Some city areas can simply be forbidden to certain types of vehicles. Typically, such policies aim at banning trucks from the city centres, for social and environmental sustainability reasons listed in the previous section. Once again, the policy should specify the vehicle ban with respect to the objective it is trying to achieve. If the primary goal is to reduce air pollution and improve sustainability, a well-suited regulation criterion would be the fuel type or the emission factor of the vehicle. If the city is focusing on social aspects first, dimension and weight factors can be better criteria. McKinnon (1999), in Danielis et al. (2010), points out the potential downside of such measures that could hurt consolidation of deliveries: it would result in improving the number of small delivery vehicles on the road, with a negative impact on congestion and environmental implications. To overcome this issue, restricting the access based on the load factor of delivery vehicles would be more appropriate, however it is difficult to measure, hence the suppression of weight restriction is

recommended. Finally, in some cities, a fee needs to be paid to access the city centre, based either on weight or on emission factor (Danielis et al., 2010 ; Pronello et al., 2017).

2.3.3. Other city traffic planning tools

Although the most popular tools used by local authorities are linked to restricted areas, time windows and (un)loading bays management, the literature also points out two additional mechanisms that cities may use to improve the sustainable impact of final deliveries. First, Visser et al. (2014) highlight the environmental benefits of reducing the speed limit in urban areas, with a positive impact both on safety and on CO₂ emissions from increased fuel efficiency. This last consequence is enhanced by the use of fuel-efficient vehicles. Another idea is the use of dedicated lanes for freight transport, for free or in exchange for a fee. This would help increase the efficiency of deliveries in dense urban areas. A variation of this principle would be to allow freight vehicles to use lanes currently dedicated to public transport only. The use of time windows for the use of those lanes is also an option (such as in the early morning hours), depending on the extent of the issue. This costless improvement could help improve the efficiency of deliveries, however the impact on overall urban congestion is uncertain (Pronello et al., 2017 ; Visser et al., 2014).

2.3.4. Public funding mechanisms

Gonzalez-Feliu, Taniguchi & Faivre d'Acier (2014) have researched the different mechanisms used by public authorities to fund projects in the area of urban logistics. Indeed, an important number of projects that could help improve sustainable freight transport in urban areas have been cancelled due to their lack of profitability or due to insufficient funding. Different strategies exist to fund projects that answer to the objectives of sustainability researched by a city. The choice for the funding type will depend on the city's strategy, financial capability and perception of the specific project. A project that brings a collective utility from the city's perspective can be financed entirely by public funding, whereas projects that would only benefit to a specific category of stakeholders may need the help of private investments, which would result in a paying service that would amortize the project's cost, which is called "user's refunding", through a rent, for infrastructures, or a parking fee in the case of loading bays, e.g.

The first financing mechanism highlighted in the literature is public funding. In this case, the project is a public initiative, its cost will be integrated in the city's budget and no form of collaboration with private stakeholders is necessary. It is exclusively reserved to projects of public utility. Delivery bays or dedicated lanes can be considered of public utility.

When the project is a private, however, initiative, private funding is by default required. Nevertheless, three forms of public intervention can take place to help developing the project. The first one is delegation, where public authorities⁶ will cover the investment needed for the project and then offer to a private company the right to use the infrastructure for free or in exchange for a small rent. The private company will run the result of the project and pay for operational cost itself. In some cases, public intervention via delegation can go as far as to cover a part of the operational expenses as well. The interest for the city is that the development of such a project is in line with its sustainability's objectives but that it does not need to control its operations since it will be run by a private party, as opposed to publicly funded projects who remain the responsibility of the public authority. Infrastructures remain public property. However, delegation projects will generate no return on investment for the public powers, other than the expected utility of the project. Delegation are extensively used for the development of Urban Consolidation Centres in France and Italy.

The next form of public intervention is the granting of subsidies. Subsidies are a financial help that is applied to projects which meet some criteria. Subsidies often come from higher level of authority than cities, such as regional power or the European Union, and can be granted to private investors and to local authorities as well. Subsidies typically cover some specific areas: R&D projects, structural and infrastructural investments, support of public authorities investing in green vehicle fleet, technological subsidies (e.g. financing the training to the use of a new technology),... Like delegation, subsidies do not need to be paid back to the institution that granted them, however some conditions – related to efficiency, profitability, social objectives – may need to be met, otherwise refund may be asked, or upcoming subsidies suspended. In addition, subsidies rarely cover the cost of the whole project, some private investment is needed as well.

⁶ Multiple levels of authorities can join to collect sufficient funding, such as several neighbour municipal powers, regional authorities, etc.

Finally, the third form of public intervention, the public loan, is less popular. Public loans, on the opposite of delegations and subsidies, need to be refunded back, similar to a loan to a bank. The main advantage of public loans over bank loans is the attractive interest rates that make the projects more affordable to private investors. Private projects are rarely financed entirely by using public loans: the private-public partnerships, in which both public and private investors contribute to a part of the funding, are common. The private company hopes that the benefits from the realized project will help pay back the loan from the public party (Gonzalez-Feliu et al., 2014).

2.4. Consumer perspective and marketing stakes

The uprising of the internet has revolutionized marketing. Since the “Internet 2.0”, the use of social media, online reviews, blogs, etc. is becoming the norm. Communication about products is therefore better balanced, with both retailers and customers being able to advert, comment and share information publicly, instead of retailers only. The power has shifted from the manufacturers to the consumers, who can give feedback and express their expectations more easily. They can communicate what they are expecting on social networks, which manufacturers cannot ignore. This is especially the case in e-commerce, which relies on online marketing tools more intensively than traditional commerce. Does this increased consumer power have an impact on the level of sustainability of home deliveries? Gevaers et al. (2009) observed an increased interest from both consumers and companies for environmental concerns, including transportation issues. Customers are expecting manufacturers and logistic companies to be more environmentally friendly. However, they generally do not want to sacrifice the level of comfort of the service. They are not ready to pay more for the same level of service, or to wait longer for their delivery to come home. Some customers also consider that going to an alternative delivery location such as a collection point or a locker is a drop in the level of service and are therefore reluctant to choose this delivery option. Depending on their environmental consciousness, customers need to choose whether they are willing to make a trade-off between the advantages of high level delivery services (fast shipment, home delivery, narrow time window of delivery) that result in a higher carbon impact or the more sustainable delivery methods that cause the parcel to be delivered slower and with a service level that can be perceived as lower (Buldeo, Verlinde & Macharis, 2018 ; Gevaers et al., 2009).

The role of 3PLs and online retailers is important in this matter. If they want to improve the level of sustainability of their respective industries, they have to promote the sustainable services that they have set up. A common way of making sustainability delivery methods more attractive is to deliver at a lower price when choosing standard delivery over express delivery – which will enable more consolidation in the upstream supply chain and in the last mile – and when choosing to be delivered to a nearby automated locker or a collection point. The two main incentives for 3PLs for offering lower prices for these delivery options are their lower transport cost and the improved consolidation, with consequences on the environmental footprint of the final deliveries. In addition, added services with a high negative impact are more expensive, such as asking for re-delivery in the next day in case of failed delivery – although this may be motivated by economic reasons rather than ecological ones (Van Duin et al., 2016).

Besides, to counter the increased consumer decisional power in the final deliveries, especially regarding the time window of delivery (this is particularly the case for e-grocery home delivery), the introduction of variable delivery prices depending on the time, dates and time windows asked for delivery could help improve the way deliveries are made. For instance, prices could be increased if the customer requires a delivery during peak-hours, while a delivery in a more convenient time window should be rewarded with a more attractive price. This could also help improve the consolidation of deliveries. Lee et al. (2001) push this reflexion even further: by proposing deliveries at a significantly more attractive price for a specific weekday for all customers from a same neighbourhood, the degree of consolidation of the shipments would be increased significantly. Using price incentives, different methods can be applied by carriers to improve the efficiency of their deliveries, mainly through consolidation, improving sustainability independently from the degree of environmental consciousness of the end customers (Lee et al., 2001 ; Mkansi, Eresia-Eke, Emmanuel-Ebikake, 2018).

III. Empirics

1. Methodology

In the following part of the thesis, we will conduct a qualitative analysis based on interviews carried on with various stakeholders of the last mile in a way that will help us establish cross comparisons with the hypotheses that emerged from our literature review. The interviews can be divided into two groups: the first group regroups interviews with experts from third party logistics companies: The second group will consist in interviews with experts from the public sector with an expertise in mobility and sustainability matters. The details about the interviews are listed in Table 1 below.

The interviews took place under the form of formal meetings, during which the interviewees debated around various last mile matters and sustainability matters related to their areas of expertise, in a semi-directive way. To do so, the interviewer constructed two interview guides, one destined to 3PL experts and one to public authorities' experts. The two interview guides can be consulted in **Annex 1 (pp)**. To broaden the fields covered and the range of observations, interviewees were encouraged to talk freely. As a consequence, the interviewer does not follow strictly the guidelines and questions provided by the interview guides, which is mainly a tool used to refocus the debate around its core subjects, should the interview take a turn which would not be related enough to last mile sustainability issues. This freedom helped gather hindsight that directive interviews would not have unravelled.

All interviews were all recorded for transcription purposes. After the interview took place, they were converted into text format strictly. The transcription of the interviews can be found in **Annex 2 (pp)**. Upon reviewing the transcripts of the interviews, the observations provided by the experts are being analysed to improve our comprehension of the extent of sustainable delivery solutions for the last mile, their enablers and barriers. The hypotheses arising from the literature will be compared to the relevant observations highlighted by the interviews.

2. Profiles of the interviewees

Table 1. Interviewees' profiles and numbering

#	Name	Occupation	Company / Public institution
Third party logistics service providers			
1a	Alessandro BARBETTI	Country Operations Manager BeNeLux	United Parcel Service
1b	Guiyoca CARDOZE	Industrial Engineering Manager	
1c	Niel EYCKMANS	Operations Manager	
2	Paul DAVIES	Innovation Manager	bpost Future Lab
3	Anne PUTZ	Head of Communication & Marketing	Global Logistics Services
4	Geert VAN AERSCHOT	Ground Operations Manager	DHL Group
Public authorities			
5	Xavier DESGAIN	Secretary of Mobility, Energy, Public buildings, Social economy and Ecological transition	City of Charleroi
6	Michel DUC	Mobility Advisor for the Secretary of Mobility, Ecological transition and Digitalization	City of Liège
7	Herlinde SMET	Innovation Manager for " <i>Civitas Portis</i> " (EU project)	City of Antwerp

The 3PL interviewed cover a substantial part of the market share in Belgium and regroup various companies that have different profiles so that we can have a comprehensive idea of how the different types of companies are operating in the last mile:

- Company #1 is UPS, one of the three global integrators and the world market leader of the parcel industry, where three experts were interviewed simultaneously. UPS is very active in North America but is increasingly expanding its activities on all continents, especially in Europe.
- Company #2 is bpost, the Belgian postal service operator, where we met with Paul Davies, Innovation Manager for bpost Future Lab, an innovation group within bpost whose task is to develop innovative solutions useful for the future of bpost, with a focus on sustainability matters.

- Company #3 is GLS, a 3PL delivering throughout all Europe, with the particularity of being a subsidiary of the British postal operator Royal Mail.
- Company #4 is DHL, another global integrator and one of the market leaders in Europe, where we interviewed Geert Van Aerschot, Director of Ground Operations for Belgium.

The literature highlighted the important role of local authorities and their policies regarding urban logistics. Therefore, experts working in the field of mobility in 3 of the 5 biggest Belgian cities, with different profiles were interviewed to have a better idea of the motivations pursued by cities when it comes to urban sustainability and the measures regarding the last mile that may arise from it.

- City #1 is Charleroi, where we met the Secretary of Mobility, Energy, Public buildings, Social economy and Ecological transition, Xavier Desgain. Charleroi is the most populated city in Wallonia but is characterized a low revenue per inhabitant.
- City #2 is Liège, where we met with Michel Duc, who is a Mobility advisor for the Secretary of Mobility. Liège is the most important economic centre in Wallonia and home to the third biggest inland port of Europe.
- City #3 is Antwerp, who is the second biggest agglomeration in Belgium. It is also home to one of Europe biggest maritime ports. Antwerp is part of an EU project called "*Civitas Portis*" which focuses on improving the mobility of coastal industrial cities throughout Europe. We met with Herlinde Smet, who is employed by the city as an Innovation Manager in the scope of this project.

IV. Analysis

1. Sustainability impact of home deliveries

All interviewees agree on the significant sustainable impact of home deliveries. The difference in their various perspective will be observable in the way they are developing solutions to decrease the social and environmental impact of them. Particularly, Expert #6 points out the substantial 15 % part of whole traffic represented by last mile delivery vehicles (B2B and B2C aggregated) in his city, which he considers to be a ratio close to the one of most important European cities. 3PLs' and public authorities' experts are conscious of the social and environmental implications of this increased number of delivery vehicles on the road. The negative consequences of the presence of such vehicles on the road that have been pointed out are:

- **Air pollution:** the emission of GHG (CO₂) and fine particles (NO₂) are a threat to the environment as well as the health of the nearby residents (Interviews 1, 2, 3, 4, 5, 6 & 7).
- **Traffic congestion:** the increased road occupancy in urban traffic hurts the local economy – it makes shopping more difficult – and the efficiency of vehicles stuck in it. It also is disliked by the residents, who perceive the urban lifestyle as less enjoyable (Interviews 1, 2, 3, 4, 5, 6 & 7).
- **Safety:** the presence of delivery vehicles on the road is considered as dangerous for other users' safety, mainly by increasing the accident risk when double parking or by forcing pedestrians and cyclists on the road when parking on the kerbside and bike lanes; but also as a consequence of increased road occupancy (Interviews 5, 6, 7). Distraction behind the wheel and night deliveries are also pointed out as a factor of risk (Interview 1).

1.1. Online shopping vs. traditional shopping

Carriers do not consider the relative impact of traditional shopping vs. home deliveries since they only are active in the latter. They have no interest in researching the most sustainable ways of completing a physical shopping activity.

However, city representatives have considered solutions that are aimed at decreasing the carbon and traffic impact of shopping travels. Hence, in Charleroi, Expert #5 points out that taxi-bicycles – with room for shopping bags – will be implemented between Rive Gauche, the city's most important shopping mall, and the nearby parking lots and rail station. In Liège, Expert #6 highlights the existence of lockers where customers can leave their shopping bags until they have completed their shopping activities, with a project of installing a service carrying the shopping bags sustainably to lockers located outside of the city, preventing the need for customers to enter the city centre with their car to retrieve their belongings. Both alternatives would decrease the sustainable and traffic impact of shopping travels by taking care of the urban part of the “last mile” personal travel, making it more competitive against home deliveries (Interviews 5, 6).

Whereas these two projects may indicate that some authorities are willing to tackle the last mile on a broader scale than the one related to online shopping, this should not have a significant impact on the overall sustainable advantage of home deliveries over personal shopping trips highlighted by Edwards et al. (2010).

2. Home delivery solutions for the last mile

All interviewees from 3PL companies pursue the same objective when it comes to sustainability in the last mile: it will be related to the efficiency of the deliveries. The main focus of the companies will be to increase efficiency in the last mile, as it will both improve the profitability of the operations and their sustainability, which is part of their goals as well. However, even though sustainability is considered highly by all 3PLs interviewed, the primary motivation behind the improvement of the processes is economic. Still, profitability and sustainability are positively correlated to the efficiency of deliveries, doubling the interest for companies to invest into processes, vehicles and collaboration projects that will help increase this efficiency. As we discovered from the literature, there are many

inefficiencies linked to the last step of the supply chain. The processes that are being developed by last mile carriers will aim at reducing these inefficiencies by:

- **Reducing the rate of failed deliveries** by providing a large variety of alternatives to the recipients of the parcels so that they minimize the chance of failing to complete a delivery. Failed deliveries represent additional mileage and cost for all carriers, which they want to avoid. As pointed out by Expert #2, *“if a package is delivered properly, then you make money on it, but if not, you may lose money on it.”* (Interview 2). The significant added cost of failure to deliver on the first attempt can result in a net loss for the carrier. That is why it is extremely important for carriers to control the level of failed deliveries.
- **Optimizing the last mile delivery process** by using tools to reduce inefficiencies that are linked to the logistics, independently of the chance of success or failure of the delivery. While many improvements, related to the organization of the upstream supply chain of a company, are outside of the scope of our research; some optimization processes focus on the last mile, mostly linked to how the routing process is established so that it optimizes the time needed to complete all the deliveries at the lowest possible cost. Optimization also includes an improved resource efficiency in the last mile, whether it is by improving vehicle and energy efficiency, reducing labour cost...
- **Consolidating the deliveries** by implementing delivery processes that will improve the loading rate of the vehicles, decreasing the resource consumption per package. Consolidation mechanisms put in place by 3PL companies include solutions that optimize the loading rate of the vehicles, solutions to decrease the number of stops needed and various forms of collaboration; all of which aim at avoiding the additional costs caused by the fragmentation of deliveries in the last mile.

The following sections will compare the assumptions that arose from the literature review with the observations gathered from the interviews and highlight in particular the differences between the research and the reality of the field, which may open room for more reflexion as to how last mile sustainability should be dealt with.

2.1. Home delivery process improvement

This section includes mainly intelligence gathered from the 3PL experts as they are the ones that are the one actively completing the final deliveries, opposite to local authorities' representatives, who aim at minimizing the negative impact of the deliveries in their city. Nevertheless, to some extent, local authorities have an impact on how the deliveries should be carried on.

2.1.1. Attended deliveries

Carriers do not have the same approach as to how a delivery should be completed. While all 3PL companies that have been interviewed are completing both attended and unattended deliveries, they consider them differently. In Company #2, who is a postal service operator, a lower part of parcels needs attended delivery, since a default shipping will result in an unattended delivery: asking for a POD costs more to the shipper. In the other companies, by default, all deliveries will require a POD. Hence, attended delivery solutions will be explored more deeply by Companies #1, #3 and #4. There is also a difference in the clientele served. At Company #2, the majority of final deliveries are to private homes (B2C deliveries), while for Companies #1 and #4, who are global integrators, most parcels are delivered to businesses (B2B deliveries). Company #4 estimates that the share of its final deliveries is split between 60 % B2B and 40% B2C. Some carriers highlight the fact that the risk of failed delivery is mainly linked to B2C deliveries, since it is difficult to predict the recipient's presence, as opposed to B2B deliveries whose opening hours are known (Interviews 1, 3, 4). Carriers however have various visions on how to increase the chance of success of attended deliveries.

First of all, off-peak deliveries – early in the morning, late in the evening or on Saturdays, for B2C – are a method of delivery that increases the rate of success of attended deliveries recommended by the literature. However, 3PL experts tend not share this view. The only advantage of this specific delivery service is that it increases the chance of the recipient being at home. However, sending additional vehicles to carry on evening delivery rounds represents a non-neglectable economic and environmental cost. From Expert #1a's perspective, *"it does not make sense to have another vehicle coming later to the same area to deliver at night"*. It would hurt the efficiency more than it would increase it. In addition,

there is no guarantee that the customer will be at home because of the off-peak hour at which the delivery takes place. From a practical point of view as well, delivering at night complicates the task of drivers, who can have trouble reading street names and house numbers in the dark. In addition, Expert #4 adds that, while his company can deliver up to 8:30 PM in urban areas, it is not frequent to rely on evening deliveries as they are generally inconveniencing the recipients, which hurts the image of the company. Sharing this perspective, Company #3 has recourse to evening deliveries at the recipient's request only while Company #1 never uses it. Expert #1c estimates that from their company's perspective, customers that are only available during off-peak hours can rely on better delivery alternatives, such as the use of collection points, whose opening hours are purposefully longer than time windows of delivery. To sum up, there is a certain cost – the one of the additional deliveries – but an uncertain benefit – the hope of reducing the rate of failed deliveries. Hence, the objective of achieving a higher efficiency for the deliveries will be researched in other ways. Finally, all carriers have recourse to Saturday deliveries (Interviews 1, 3 & 4).

As for customer contact, the literature mentioned that it helped increase the chance that the customer would be present at the time of the delivery. However, Kolinska et al. (2015) pointed out that the added service that was provided by customer contact was not significant and that it was expensive to implement. Expert #1a's agrees that a simple SMS notification is nothing unique, and that the sophistication of the customer contact service had to be improved. Hence, companies #1 & #4 include customer contact as part of a broader customer service, which they call "MyChoice" and "On Demand Delivery", respectively. Company #3 and #4 offer a similar service but with limitations. These services are a combination of customer contact with many alternative options for delivery. Carriers #1 and #4 systematically send an e-mail or an SMS to the recipient⁷ one day before the final delivery, linking to an online platform that allows the recipient to choose his preferred delivery option in the event he would not be able to attend the delivery. Alternative delivery solutions offered by 3PL companies include redirection of the delivery to another address, delay of the delivery until a further date, delivery to a locker, a secret place, a collection point of his choice. Giving additional instructions is possible as well, to make sure that the expectations of the recipients are met. This improved customer contact, although it may

⁷ Only for residential deliveries (B2C). B2B deliveries do not receive upfront notification.

represent an additional operational cost⁸, proves to be well-received. The variety of alternative services offered to the consumer is very high. Indeed, both companies consider that this variety is the key component of their customer service and contributes significantly to their competitive advantage. In addition to the important marketing perspective, contacting the customer has also proved to decrease significantly the failure rate of deliveries. There is a clear disruption between the image of the customer contact service published in the literature and the sophistication of the service reached by the carriers that have been interviewed, especially Companies #1 & #4.

Neighbour delivery presents two main advantages for carriers in case of customer absence: it allows the delivery to be completed without additional cost due to its proximity (McKinnon & Tallam, 2003) and it allows the driver to receive a POD. The latter is especially important to Companies #1, #3 & #4, whose standard delivery policy is not to release a parcel without signature. In light of this, carriers are relying on neighbour delivery extensively to prevent deliveries from failing. Companies #3 and #4 stress out that neighbour delivery is actually the first alternative delivery procedure that needs to be applied in case of recipient's absence. Drivers are trusted to know the people of the area sufficiently that they know to whom they should address in a neighbourhood. As for company #2, to minimize the level of risk associated with neighbour delivery, they propose to the recipients to register a favoured neighbour⁹ on their website so that the driver will attempt the alternative delivery to this neighbour exclusively. If no neighbour is available, the parcel will be delivered to a collection point or back to the depot, depending on the carrier's policy.

2.1.2. Unattended deliveries

Unattended deliveries are not the preferred delivery alternative in case of customer absence. Carriers fear that the insecurity of such deliveries will lead to more complaints and hurt the company's image. They only are used as a last resort when the recipient is absent, that that no neighbour is available. In addition, the parcel must be authorized to be left

⁸ The additional cost of this service for carriers is mitigated by an extra cost – for the shipper – in case of delivery to an alternative address and by data collection upon registration of personal information on the platform.

⁹ within an area of 50 metres of the recipient's home.

without receiving a POD. Expert #1b explained that even though the parcel can be delivered to a secret place (only when no POD is needed), it is mandatory for the driver to knock at the door. Only in case of absence is the driver allowed to deliver to the mailbox – if it fits and that the name of the recipient is written on the mailbox – or to a secret place, following customers' preferences on the website or by SMS. Furthermore, in Companies #3 & #4, where all shipments require a signature by default, a "release authorization form" needs recipient's approval online to proceed to deliver to the secret place, usually the garage or the mailbox. If the customer has not specified anything, the parcel will need to be brought to a collection point (Interviews 1, 3 & 4). On the contrary, due to its different system, where default packages do not need a POD, Company #2 relies more extensively on secret place delivery than its competitors. Therefore, similarly to the favoured neighbour registration, recipients can upload a picture of a secret place located within their land so that it is only known from them and the driver that will deliver the parcel. Upon delivery, he will place the parcel there, which increases the degree of safety as well as the customer trust in the service. A picture can be taken with the device afterwards to constitute a proof of delivery (Interview 2 ; Bpost, 2019). This highlights a certain will of 3PL companies to avoid uncertainty in their delivery alternatives; preferring to release parcels in exchange for a POD, which transfers the responsibility of the parcel ; or to find an alternative way of transferring the responsibility of the parcel when it is left in an unsecure area, whether it is through a release authorization form or the use of a picture as POD.

In addition, Expert #2 highlights the work realized by his innovation group with respect to the use of controlled access systems. A test run has been realized in partnership with an e-retailer: using connected doorbells, consumers get notified by smartphone that a courier is attempting to deliver a parcel. They can then open the door remotely from their smartphone ; the courier will then leave the parcel in the hallway of the house, without stepping in. This withdraws the risk of theft of the shipment but implies that residents trust the couriers with the access to their homes. A large majority of consumers that took part in the first test phase involving controlled access systems were satisfied by it. This innovative process is expected to expand in the future, when connected doorbells will be more common (Interview 2 ; RTBF, 2018).

Finally, no interviewees considered the use of delivery or reception boxes to be suitable delivery solutions, although Expert #2 has carried on unsuccessful research to

attempt to incorporate reception boxes in the range of delivery solutions proposed by his company (Interview 2).

2.1.3. Alternatives delivery locations

Carriers are interested in the possibility of delivering to an alternative location than recipients' homes. Indeed, when delivering to alternative places, the fragmentation of deliveries is lower because more parcels can be delivered at a single place. Like the previous delivery solutions, it also helps fight failed deliveries as delivery to collection points and parcel lockers never fail. *It is much more sustainable than delivering the parcels at home*, adds Expert #2. Carriers prefer delivery at alternative locations for more efficiency. However, this is not simple as home delivery is an important part of the service that is being offered. *Customers are used to home deliveries*, says Expert #1c. Nevertheless, to achieve more consolidation and avoid the problems related to the absence of the consumer at home, all interviewed carriers are relying more and more on alternatives to home delivery (Interviews 1, 2, 3 & 4). To increase the convenience of these solutions, 3PLs are all planning to expand their network, which would decrease the average distance between the recipient's home (or way home from work) and the retrieval point. In addition, according to Experts #2 & #3, the behaviour of the consumers can change significantly from one country to another: in Nordic countries, the majority of deliveries are made to lockers or collection points; while in Western Europe, driven by Germany, people tend to expect their parcels to be delivered at home.

Collection points are being used extensively by all 3PL companies that we interviewed. Referred to as "access points", "pick-up points", "parcel shops" or "service points" by the different 3PL experts, their utility is twofold: first, consumers can choose to be delivered to collection points, at a lower price than at home. Secondly, collection points are *"the standard alternative delivery procedure for residential deliveries"* (Expert #1b). Companies #1, #3 & #4 provide a service that is centred around an express delivery, so the drivers from these firms will bring the parcel to the nearest collection point as soon as they can during their delivery round. Company #2 will bring back the parcel to the depot, awaiting to be sent to a collection point the next morning at the latest. Although they are the default alternative solution when home delivery, neighbour delivery and unattended delivery

attempts have failed, drivers may still need to bring the shipments back to the depot, in case the customer required an alternative delivery options in case of failure, causing re-delivery on the next day, or to another address, or to a locker...

Interviewees point out that collection points consist in independent small shops and grocery stores recruited individually. They have another primary activity but become partner with a 3PL to generate additional revenue by providing another service. The interest for a collection point partner is twofold: first, it generates more revenue because shopkeepers are compensated financially by carriers for every package that they will handle (Interviews 1 & 4). Secondly, it can be beneficial for the core activity of the shop because customers who come and pick-up their parcel can take advantage of their presence in the shop to purchase goods at the same time. In exchange for these advantages, collection points are expected to provide a high level of service to the end consumer but also to the carrier: they store the parcels and they are equipped with scanners, software or smartphone applications so that they can process the goods automatically. Moreover, some criteria need to be met to become eligible for becoming a collection point ; the most important one being long opening hours, especially late at night and/or on weekends, because recipients that ask their parcels to be delivered at collection points usually are unavailable during standard delivery hours. Other conditions can apply such as the accessibility, the parking spots available, the location's safety... (Interviews 1 & 4). Company #2, as a postal service operator, relies both on small shops and on local post offices as collection points (Interview 2). The advantage for carriers is the aforementioned consolidation of deliveries to a same location while maintaining the service level (safety, accessibility...), as well as avoiding to return to the home address a second time.

The other popular alternative used by carriers is the use of parcel lockers. Parcel lockers can be owned by the 3PL (Companies #2 and #4) or rely on shared parcel locker networks such as BringMe, Facility Lockers or Parcels Home (Companies #1, #2, #3 and #4). Their use as a delivery alternative in case of failure is becoming increasingly common as the number of parcel locker banks intensifies. Hence, Company #2 and #4 are planning to expand their networks significantly because the smaller the distance between the lockers and the recipient's home, the more likely he is to resort to them. According to Expert #2, *"the [ultimate] goal would be that you would only have to walk a few hundred metres or stop on your way home"*, which would require the locker network to expand tenfold. The three main

advantages of locker delivery are the decrease in the number of vehicles needed – which improves resource efficiency, the efficiency gains from having people come and collect their parcels sustainably, and the absence of misdelivery risk (Interview 2).

Another alternative that has been researched by literature is work delivery, who aims at reducing the percentage of failed deliveries by bringing people their B2C parcels to their workplace instead of their homes. Companies #1 & #4 offer such a service, which they are calling “In-Room” or “On Desk” deliveries, respectively. This extra service guarantees that the courier will bring the parcel until the office desk of the recipient and not at the reception. Besides, a recent improvement to workplace delivery has been tested recently by Company #2’s innovation laboratory: the delivery to the trunk of the customer’s vehicle on the parking of the workplace. This requires the customer to give access to the trunk of his car to the carrier beforehand, which is possible for the latest car models, which are connected, similarly to control access systems at home. This alternative has been developed because companies were becoming increasingly upset of the daily whereabouts of carriers inside offices as well as stockpiles of packages at their reception desks (Interviews 1, 2, 4 ; Bpost, 2019). The gains linked with workplace delivery are mainly tied with efficiency gains, but consolidation can occur as well, as a workplace is more likely to be delivered more parcels than a home. Trunk delivery, in addition, allows couriers to reduce the average time taken to complete a delivery at a workplace, which translates into a higher efficiency as well.

2.1.4. Routing optimization

Many models have been put forward by the literature to increase the efficiency of the deliveries, providing the delivery vans with optimal routes. The models try to minimize the distance or the time of the cumulated itineraries of delivery vehicles for a certain area, considering various variables made available by the improvement of ICT, such as real time traffic congestion data, optimal time windows of deliveries, etc. The different carriers had a mitigated approach about the use of such models. In general, carriers are resorting to a software to estimate how many vehicles are needed to serve an area and design the sub-areas within. Depending on the variations in volume, the number of vehicles and the number of routes needed to serve an area are subject to change (Interviews 1, 2 & 4). Then, still according to the software, parcels designed to a same area are sorted following a pre-

set order, so that they are put in the order in which they are expected to be delivered following the route calculated by the software for each vehicle. At Company #2, which doubles as a postal service operator, the drivers have to follow a strict route for their deliveries because they are generally delivering the mail at the same time as the parcels. The number of stops is more important and respect the pre-set order in which the letters have been sorted is a necessary condition for an efficient delivery (Interview 2). Other companies, on the other hand, do not rely on any precise routing process during the delivery rounds. Drivers are not told a specific route to follow. Expert #3 adds that in the case of her company, which is subcontracting its final deliveries, it is illegal to impose a strict itinerary to its partners, preventing them from using routing optimization systems close to the ones used in the research. For Companies #1, #3 and #4, the order of the parcels in the delivery vehicle is the only indicator of how the route should be completed¹⁰. Drivers are expected to know the area they are delivering and are therefore trusted that they will try and complete their route in the most efficient way. *"We leave up to the courier to make their own routes"*, says Expert #4. Company #4 equips all delivery vans with a GPS device, while Company #1, for safety reasons related to distraction, forbids the usage of GPS – the drivers are still carrying an electronic device¹¹ that can double as a GPS in last resort. However, none of them imposes an itinerary to the drivers.

The reasons advanced by experts are mainly twofold: that can be the result of a legal constraint, as it is the case for Company #3, that can also be the result of the process model preferred by the companies: in Companies #1 and #4, however, it is due to the last mile strategy. To achieve more consolidation, final deliveries and pick-ups are made by the same vehicles. This avoids the vans to come back empty to the depot at the end of their delivery round, while shippers are calling to have their parcels picked up, once ready for delivery. Drivers, through their delivery device, are connected to a dispatch centre, which communicates in real-time when a customer (usually a company) in the area needs a pick-up service. The driver responsible for that area needs to pick up the parcels and bring them to

¹⁰ This order is usually printed before departure and/or registered into the electronic device used by drivers (cf. footnote #2 below).

¹¹ All 3PLs active in the last mile are using an electronic device, connected to the wireless network, that updates in real time the status of the deliveries and that registers the order and the addresses of all the shipments for the driver to consult. This device is also used also to receive the signatures of the recipients.

the depot where they will enter the supply chain. This is called the “first mile”. This combination of first and last mile allows carriers to reach more efficiency by consolidating their rounds. However, this comes at a cost: indeed, the flexibility that is required for this type of service prevents any optimal itinerary to be pre-set in the morning. Company #2, which operates following strict delivery routes, uses separate vehicles to take care of the “first mile”, combining letters and parcels as well. Consequently, Company #2 routes are more incline to be optimized according to the models developed by the literature – although these models do not consider mail delivery.

Nevertheless, Company #1 realizes that significant efficiency gains would be possible by optimizing their routes using technology. However, this would imply to use a model that would be able to react in real time to the delivery round changes due to the pick-ups. Expert #1a points out that Company #1 has developed a complex but efficient routing system, named ORION (On-Road Integrated Optimization and Navigation), which has been in use in the United States for a few years but is still under development in Europe¹². Indeed, adjustments are necessary before the system can be transferred to other countries because of differences in zip codes design, in road safety rules, in city structures... ORION software plans the driver’s day dynamically, including the dispatch – the additional pick-ups that change the route during the day – and the sequence – the order in which the parcels must be delivered. In addition, everything is transferred in real time to a GPS device in the delivery van. The implementation of this system is only possible because the latest technology has enabled the use of retrieval an analysis of an important quantity of data in real time. Previously, it would not have been possible to develop a system that would be significantly better than the routes decided by the drivers with their field knowledge. However, Expert #1b considers that this software would reach its peak efficiency only once the automated sorting systems will have been updated accordingly (Interview 1). Although many conditions still need to be fulfilled before ORION-like systems replace the current system, routing schemes that have been reported in the interviews, who rely strongly on human judgement, are expected to be replaced by complex routing optimization schemes using real-time data on pick-ups and traffic conditions – and many more dynamic variables. Finally, it represents a consequent cost, so this technology may not be in the reach of other logistics companies,

¹² Pilot projects using ORION system have been launched in 2017 in Germany and in the UK (UPS Corporate Sustainability Progress Report, 2017).

who have less financial leveraging power than global integrators such as Company #1. Nevertheless, the expected decrease in mileage from this optimization should result in a reduced carbon footprint in the last mile.

2.1.5. Urban Consolidation Centre

UCCs are generally considered by research as potentially efficient delivery support to the last mile, by improving consolidation of the last mile. Indeed, fragmentation happens only when last mile deliveries leave the depot, which is located close to the delivery areas in the case of UCCs, cancelling the costs related to the distance between the depot and the area of the final deliveries. During the interviews, all 3PL experts mentioned the use of UCCs to some extent. Usually, they are not the most developed process of the 3PLs, but the projects that include them generally have a high potential for profitability and sustainability. The combination of the exploitation of UCC with the use of alternative delivery vehicles is also systematically mentioned, in the vast majority of them using electric cargo bikes to take care of the final deliveries. They are also often linked with collaboration projects with authorities or even with other 3PL companies. The important costs related to the implementation and exploitation of a UCC are also evoked repeatedly: a substantial threshold volume is necessary for profitability (Interviews 1, 2, 3, 4). Particularly, Expert #1b states that the set-up cost of UCC is the main reason why such projects are not very developed, another reason being that an agreement with local authorities is necessary. Expert #2 adds that a common reason for the failure of UCC projects is the difference in visions between the cities and the delivery companies. Expert #3 and #4 consider that the main reason that pushes their companies to invest into UCCs is the need to comply with the changes in regulations, such as the growing number of car-free zones. In addition, Company #4 uses “pop-ups”, small temporary depots that act as UCCs for short periods during the periods with peak volumes (November and December). Finally, City #5 has developed a UCC for different carriers to share, using EU subsidies. However, the lack of critical volume and restrictive regulation makes it inefficient so far. To summarize, UCCs are helpful for consolidation of final deliveries and their sustainability, but they need to fulfil many requirements to achieve profitability. They are a mean to an end, hence the benefits of the final deliveries arising from UCCs will be detailed in the cargo bike analysis.

2.1.6. Partnerships between third party logistics service providers

Sharing deliveries across 3PL companies in the last mile could help withdraw the redundancy of the deliveries through inter-company consolidation. Many inefficiencies and inconveniences from last mile deliveries are related to the growing number of vehicles on the road. This growth is enhanced by the intense competition: in Belgium, in a densely populated area, it has become common that five delivery vehicles from five different 3PL companies enter the same street on the same day, only to drop a few parcels. There is redundancy because, competition put aside, it would have been much more efficient to have the parcels for a same street delivered by one vehicle: it would help achieve consolidation and reduce congestion at the same time. *In fine*, it could reduce the unpopularity of vans, which is related to their increased and invasive presence. This solution has not been considered extensively by the literature. Reasons for that may be related to the important barriers that prevent such alternatives from happening. Indeed, according to Experts #2, #3 and #4, competition law prevents many forms of collaboration to take place. The collusion that may arise from some forms of information and process sharing could result in a “cartel” which would hurt the consumer’s purchasing power. In addition, intense competition in the last mile is not encouraging 3PLs to push for more collaboration. In this industry, the differentiation is made primarily by the quality of the delivery service (fastness, reliability, variety of solutions...). If deliveries were shared, these differences would no longer exist. Finally, the processes used upstream and in the last mile are different and would be costly to adapt to a shared delivery system (2, 3, 4). Hence, this solution is not put forward by research.

However, partnerships are still possible between different last mile operators, on different levels:

- **Subcontracting:** most 3PLs are using subcontractors to some extent in the last mile: Company #1 use 100 % franchised subcontractors, Company #3 and #4 use independent subcontractors, most of the time with branding and uniform. Subcontractors have to be exclusive to the company they are delivering from. In under no circumstance can a parcel from Company #3 be delivered by a van from a subcontractor of Company #4. This outsourcing of a part of the fleet and drivers allows more flexibility for 3PLs, who can match more easily the volume and the number of vans by calling for additional

couriers during the peak season and not bear the cost of unused vehicles during the summer. In addition, Company #4 is a customer of Company #2, who takes care of its unsigned, non-urgent B2C deliveries for Belgium. Since the level of service required for these products is less critical to the company's image, Company #4 does not mind handing them over to Company #2. Besides, in exceptional situations, usually related to very rural and remote areas, Company #1 recognizes that it can happen that various 3PLs hand over their parcels to a common subcontractor, usually a local one with an experience on the field, who will take care of the final deliveries together and achieve more efficiency (Interviews 1, 2, 3, 4).

- **Site sharing:** an important disadvantage linked with UCC is its cost. Indeed, renting or buying a facility near a city centre represents a huge expense. Therefore, some collaboration projects exist where 3PLs competitors share a same location and split the costs, like in Berlin (5 companies) and Nürnberg (2 companies). Each company still owns its own separate micro-hub to not mix the processes and the data, which is illegal and unsuitable for logistics processes (Interview 3).
- **Exclusive city access:** it is possible that cities create limitations that force 3PLs to cooperate. The case of Vicenza, Italy, has been evoked by Expert #2, where only one delivery company is allowed to enter to the city centre to take care of final deliveries. Therefore, all 3PLs would need to collaborate with this company. 3PLs will not collaborate together with each other because of competition law and because they are not willing to be undifferentiated from their competitors in the last mile. However, cities have the power to impose a monopoly on freight and parcel delivery within a specific area. Usually, the delivery company is a local independent carrier or is owned by the city. This causes more costs for carriers because that requires an interchange point and additional handling. To some extent, this is similar to the monopoly on mail that still belongs to national postal operators¹³. 3PLs have little interest in

¹³ Mail delivery is not a monopoly *stricto sensu* as it is technically possible to have a mail delivered by another 3PL – for a much higher price. Indeed, the economic sustainability of mail delivery arises from public subsidies in exchange for providing a universal service (bpost needs to deliver the mail 5 times a week to each house in Belgium and offer “next day” delivery solutions for any national destination to qualify for these subsidies).

such a solution, this is why the only way for this to occur is with legal constraints ; but the sustainable impact of this urban delivery solution is important. A more realistic and cheaper way to increase consolidation and reduce redundancy is to impose a monopoly on locker delivery (Interview 2). Pioneer cities for shared deliveries have not experimented much success so far, but the growing interest for cities to decrease the number of vans in their city is expected to cause this type of alternative delivery solution to increase in the future.

2.2. Transportation mode improvements

2.2.1. Greener vehicle fleet solutions

Many alternative ways of transportation have been researched by 3PLs to improve the carbon efficiency of final deliveries. Another important criterion that are repeatedly cited is the volume capacity of the vehicles. In general, all 3PL companies are agreeing that they need to operate an important modal shift regarding their fleet of delivery vehicles in the near future. The extent of the shift and its horizon implies that important investments are necessary to reach the objectives imposed by authorities on various levels and by the increasing demand for sustainability solutions coming from the market. For instance, Company #1 long term objective is to withdraw all fuel powered vehicles from their supply chain by 2050 ; Company #4 wants to reduce the use of CO₂ in the last mile by 70 % by 2025¹⁴ Company #2 is planning to replace half of his 6,000 diesel van fleet operating in Belgium by 2030, with Expert #2 stating that the shift should be more important to comply with customers' expectations. The shift is currently ongoing, however all 3PL companies that have been interviewed are using diesel van delivery as a main mode of transportation in the

¹⁴ The reference year being 2007. In addition, Company #4 wants to reduce CO₂ consumption across its supply chain from 50 % by 2025.

last mile to this day¹⁵. This section will provide a review of the sustainable vehicle solutions discussed during the interviews.

- **Compressed natural gas (CNG) vehicles:** 3PL companies have been relying on CNG-powered vehicles extensively in the past years. CNG is a fossil fuel who is less CO₂ intensive than oil. It is also cheaper. Therefore, when sustainability became a global concern and that other alternative solutions were not developed, the shift to CNG was considered a sustainable solution. Company #1 and #4 are relying extensively on this alternative fuel, with Company #4 using CNG-powered vehicles for up to 30 % of its fleet. However, the interest for this slightly less polluting alternative has declined and car manufacturers no longer produce such vehicles (1, 4).
- **Electric vans:** The van is one of the most practical mode of transportation to operate last mile deliveries from most experts' perspective. Therefore, with CNG and diesel solutions to be progressively dropped, shifting to e-vans is one of the solutions that has been put forward by 3PLs. Company #4 is currently testing two e-vans in Belgium, that are considered as interesting alternatives, especially for urban deliveries. In addition, they have taken over a project called StreetScooter that manufactures small 4-wheeled electric vehicles. Indeed, there is a growing number of cities that are banning diesel vehicles. However, e-vans present three major drawbacks:
 - The important investment cost of electric vehicles and charging stations, with Expert #1b pointing that to reach the sustainability objectives it would require "*an important investment on a relatively short notice*" (1, 3);
 - The generally lower capacity of electric delivery vans, whereas the volumes are growing higher (4);
 - The lower reach. Vehicles may need to drive hundreds of miles a day, making the longer delivery rounds unsuitable for electric delivery, such as rural areas (3).

¹⁵ Diesel vehicles are usually from the latest generations, complying with EURO 5 and EURO 6 norms, which are less polluting than previous engines.

- **Electric scooters:** Electric scooters present the same environmental and health benefits than e-vans: they do not reject any CO₂ or NO₂. In addition, they are less subject to congestion issues, making them more suitable for urban deliveries. The investment cost related to scooters is also lower. However, they can carry a much smaller volume than vans. They are especially useful for delivering in old European city centres, where streets are narrow and congestion is important, such as Milan (3).
- **Cargo bikes:** cf. Paragraph 2.2.2. below.
- **Roller-skates:** Expert #3 mentions the occasional use of couriers making the deliveries on roller-skates although. While little information was available, this shows the effort put into searching for sustainable alternative delivery solutions from last mile companies.
- **Boats:** Expert #2 has mentioned that the potential use of autonomous boats by its company had been researched by his innovation team, due to its energy efficiency. A potential use in long-haul is being studied, however, no reasonable last mile application has been found. The only examples of last mile deliveries on boat are in Venice, with the Italian Post, UPS and DHL although they remain anecdotal. Once again, this shows that creativity is required to overcome the last mile issue and that all innovation types must be studied.

2.2.2. Cargo bike deliveries

Electric cargo bikes are considered to be the last mile delivery vehicle with the highest potential in the future. The logistics industry as a whole is very interested in this 100 % sustainable mean of delivery¹⁶. Cargo bikes advantages are threefold:

- **Economic perspective:** cargo bikes complete more stops per hour than delivery vans in city areas, meaning that they are the most efficient mode of

¹⁶ Electrical vehicles' environmental footprint is equal to the footprint needed to produce this electricity. An electric delivery vehicle will actually be 100 % sustainable if the electricity which it is using comes from sustainable sources exclusively. 3PL industries tend to install solar panels on top of their depots to ensure that this is the case (4).

delivery in city centres because they are not slowed down by traffic like vans. They also are suitable for deliveries in pedestrian zones, car-free areas, Low Emission Zones... Finally, they are less likely to be late in the case of deliveries within time windows (4);

- **Sustainability perspective:** like other e-vehicles, they do not release any GHG and fine particles in the area they are delivering into. In addition, they do not contribute to traffic congestion in cities, since they are using the bike lanes. They do not contribute to parking issues either. Finally, they are less dangerous for the safety of other road users and pedestrians than other modes of delivery (1, 2, 7);
- **Marketing perspective:** one big downside of delivery vans is their unpopularity. The general belief around delivery vans is that they are roaming around cities almost empty, causing useless traffic. In addition, they tend to park anywhere, making shopkeepers and pedestrians unhappy. Cargo bikes, on the opposite, are extremely popular: they have a nice design, are fully branded and inspire no danger to the population. This is especially good for the brand image of the 3PL companies that are using them.

According to Expert #4, the feedbacks related to the use of cargo bikes are largely positive, with marketing being a huge incentive to keep expanding cargo bike delivery projects in the future. It is also a big opportunity to combine productivity with sustainability, as cargo bikes accomplish on average 10-15 % more stops per hour than vans in the areas where they have been developed. Expert #3 considers that the first reason that pushed its company to develop cargo bike solutions was the need to comply with new regulations, which restrict the access of diesel vehicles to city centres ; with marketing benefits as a second enabler. However, cargo bike deliveries are not profitable yet but are expected to be in the near future.

Cargo bike delivery can happen in two ways: if the depot is located far from the city centre, the bike cannot ride the distance back and forth every day. Therefore, it is necessary to have a location within the city that can store the cargo bikes at night (Company #1 and #4 rely on independent partners) and where a delivery van will drop the parcels each morning. Company #1 and #2 combine several “meeting points” between cargo bikes and vans so that they can re-fill once they have delivered their packages (1, 2, 4). A more sustainable option is the use of cargo bikes in combination with UCCs. Since the depot is located in the centre

of the city or close to it, bikes can be loaded in the depot and then ride to their delivery area directly. There is a strong complementarity. Some in-between solutions also exist, such as the use of pop-ups or mobile depots (cf. sections on Urban Consolidation Centre).

2.2.3. Autonomous vehicles

The use of autonomous vehicles and drones is currently under research. It is not expected to become a reality yet by 3PL companies, although it may be a solution for improving the sustainable degree of rural deliveries, as no last mile delivery solutions explored so far have been able to tackle them fully. Indeed, DHL states that the drone model that is currently under development aim at targeting areas that are difficult to reach using conventional delivery methods (DHL, 2018). As drones may be less suited for urban deliveries, there is a potential complementarity between these two popular modes of parcel delivery.

2.2.4. Dematerialized goods delivery

Neither of the interviewees from the 3PL companies and from the cities were qualified to provide information on dematerialized delivery: since carriers act as intermediaries for physical transportation, the benefit of the dematerialized good delivery through the Internet is the withdrawal of this physical intermediary and its negative externalities. No additional observation will therefore complete the state of research on this subject.

2.3. Urban policies for last mile deliveries

Mobility has become an important subject for municipalities, with an unanimous willingness to reduce the part of individual cars and delivery vans into the share of total traffic. According to the interviews, reasons behind this objective include:

- **Economic risk:** some economic activities are threatened by the strong traffic congestion and the parking scarcity, which can hurt the shopping experience

for customers, but also slow down people and freight travels, creating inefficiencies for all road users (5, 6).

- **Health concerns** from the fine particles emissions (NO₂) that impact air quality negatively (6, 7);
- **Environmental concerns** from the GHG emissions (CO₂) (5, 6, 7);
- **Lack of conviviality of public urban spaces** is an issue which Liège and Charleroi are trying to tackle. Reducing the presence of loud, polluting, hazardous vehicles in these areas would improve the quality of urban life (5, 6);
- **Touristic motivations** (6);

Hence, cities have set up various policies to tackle these issues. Some are impacting all road users, some focus on improving people transportation, and other ones are directly aimed at reducing the impact of delivery vehicles in cities, rarely differentiating bulk deliveries to stores (B2B) and parcel deliveries from 3PLs (B2B/B2C). There is also a trend to privilege the installation of incentives over restrictive measures, which is more popular and does not imply the investment into expensive monitoring and enforcement systems. Interviews with mobility experts from three of the biggest Belgian cities – Charleroi, Liège and Antwerp – will help us understand better what their mobility policies are and how they can impact the sustainability level of last mile deliveries. In addition, the interviews with 3PLs will provide additional insight about the relationships between the companies active in the last mile and the public authorities ; and the perception of some policies by the 3PL experts, which consider them to be very important. This is illustrated by the regular monitoring of the evolution of city regulations and collaboration opportunities by 3PLs. In Company #1, a department is dedicated to this purpose (Interviews 1, 4).

2.3.1. Illegal parking prevention

Illegal parking on bus lanes and bike lanes is frequent, especially from delivery vehicles, according to Expert #5. However, building more unloading bays is not the priority of local authorities. In Charleroi, streets tend to have few unused areas, therefore road planning projects privilege the development of other types of infrastructures, such as bike lanes (5). The scarcity of parking areas in all three cities is increasing illegal parking.

Therefore, in Liège and Antwerp, enforcing systems have been reinforced by acquiring vehicles equipped with ANPR cameras that scan license plates and check instantly the parking status of the vehicles. Furthermore, in Liège, parking policies consider the interests of shopkeepers with the creation of “Park & Shop” parking spots that allow 30 minutes free parking. They are designed especially for deliveries and express customer shopping trips and are also controlled automatically (Interviews 6, 7).

2.3.2. City access restrictions

The only Belgian city that has imposed a city access restriction on freight vehicles is Ghent, where the city centre’s accessibility window for deliveries is between 9:00 AM and 11:00 AM. However, as expected in the literature, this causes Company #1 to resort to a higher number of vehicles to deal with the deliveries during the time window when delivery is allowed, causing congestion during this time window and reducing the degree of efficiency of deliveries (Interview 1). Time windows of delivery help reduce the inconvenient presence of delivery vehicles in busy areas. In Antwerp, schedules are established for authorized time windows of delivery in pedestrian areas, which vary from one zone to another one. There are also source of friction, arising from the complication of the task for couriers as well as for shopkeepers due to the shorter time windows available for deliveries (Interview 7).

The city of Charleroi is expanding its “shared zones”, which are areas where pedestrians and bicycles have priority over cars, who are limited to 20 km/h (Interview 5). In Antwerp, in a similar way, there is an expansion in the number of car-free areas (Interview 7). The expected outcome of this expansion, according to Expert #5, should cause the presence of delivery vehicles in convivial zones to increase the unpopularity of the delivery companies ; it is hoped that this growing unpopularity of vans will push customers to require alternative solutions more and more, to the point when 3PLs will opt for sustainable, popular delivery solutions. If this proves inefficient, restrictive policies will be added (Interview 5).

In addition, Liège and Antwerp have set up a Low Emission Zone (LEZ). To enter the LEZ, vehicles need to fulfil some conditions in terms of fuel type and resource intensity to be authorized into the area, sometimes in exchange for a fee. The most polluting vehicles are denied access to the LEZ. Antwerp will restrict further the access conditions to the LEZ by

2020. A necessary condition for its success is that monitoring and control mechanisms are set up: hence, in Charleroi, the investment in ANPR cameras – that can scan license plates – is considered too important to install a LEZ zone that is expected to be implemented on the regional level in the following years (Interviews 6, 7). In general, European cities are increasingly requiring to avoid entering into them with diesel vehicles. 3PL companies are interested in the way cities are evolving with LEZ and car-free areas, because alternative solutions will be needed and anticipation is crucial to implement effective solutions on time, especially if investments need to be made (Interviews 1, 2).

The observations gathered from the interview show the increased interest of public authorities for city access restriction tools. There is also a larger panel of solutions in practice. Besides, the use of time windows is considered as an inadequate policy from the 3PL perspective: it is not beneficial to ban delivery vehicles as people expect their home deliveries, according to Expert #1c.

2.3.3. Other city traffic planning tools

The literature mentioned two additional tools that aim at reaching the municipalities' sustainability goals: lowering the speed limit to decrease GHG emissions and allowing delivery vehicles to use dedicated lane for faster transport. No city seems to be willing to invest into infrastructure for delivery vehicles, nor allow them to use bus or taxi lanes, since the general trend is to try to avoid them coming into city centres. As for speed limitations, in practice, Liège will reduce the speed limit from 50 km/h to 30 km/h in large zones from the city centre. In Charleroi, as stated above, there is an expansion "shared zones" where the speed limit is 20 km/h. However, the main purpose of these measure is related to the willingness to improve the quality of urban life for citizens, with more conviviality and safety (5, 6).

Other city planning tools have been discussed with the experts. Some of them include the development of a UCC in collaboration with public power, like the shared UCC in Charleroi or Company #4's UCC in Antwerp, as detailed in a previous section (1, 3, 4, 5).

2.3.4. Public funding mechanisms

In interviews, 3PLs consider that the scale of the investment is the main barrier that slows down the shift to a more sustainable fleet. Particularly, Expert #3 points out that the financial support from public power is rare when it comes to last mile sustainability (3). Financial support can come from various levels of power, such as local, regional and European: in Charleroi, the UCC has been partially funded by the European Regional Development Fund, e.g. However, the regional and federal and governments being currently undergoing changes in Belgium, it was not possible to gather additional insight from them (7).

On the local side, the only observed form of financial support from authorities is in Antwerp, which relies on participative schemes: subsidies are handed out every year to projects that are selected on a platform where anyone with a sustainable mobility project can apply for funding. Each year since 2016, between 7 and 10 projects are granted a subsidy according to their potential sustainable impact (the bigger the project, the bigger the support, up to 50 % of the cost of the project), which will be conditioned to the objectives pre-set by the project. Should the project fail, would the subsidy previously granted need to be paid back to the city. Cargo bike deliveries developed by Company #4 were part of the selected projects on the platform (1, 4, 7). Other cities were not in favour of subsidizing private sustainability projects themselves or to provide any other form of financial incentive to encourage sustainable initiatives due to budgetary reasons. Expert #5 highlighted that Charleroi had a lower revenue/inhabitant than the other four biggest Belgian cities, therefore struggling with its finances, causing the city to pursue its sustainability goals through other mechanisms than the grant of subsidies: the hope of the city is that the sustainability alternatives will be pushed by market power and the increasing demand from customers and citizens to recourse to more sustainable last mile deliveries. In Liège, Expert #6 also points out budgetary reasons as one of the factors playing against the city's lack of financial support for sustainable mobility projects, stating that the administration is facing the same issue: the lack of personnel dedicated to the mobility issues hurts the capability of the city to draw efficient and fast measures (6).

2.3.5. Additional observations

This section will review some observations that were deemed relevant because of their influence on last mile sustainability. In particular, it focuses on the feedback provided by 3PL experts on the way they perceive collaboration with public authorities. The major observations that will be detailed in the following paragraphs will first address the lack of and vision from public deciders ; secondly the inconvenient aspects of political considerations ; then the degree of coordination of public authorities between each other ; and finally the perceived impacts of some additional regulations by 3PL companies.

An important trend that was highlighted by all 3PL experts that were interviewed considered that inefficiencies related to last mile in the urban area can be linked to some extent with a certain lack of qualification of public authorities when it comes to last mile sustainability, and their lack of common ground with 3PL companies. Indeed, Expert #1a provides examples of inefficient policies: for instance, addressing congestion and addressing pollution do not require the same policies: electric vans will not solve the congestion issue; hence the introduction of a Low Emission Zone will not actively fight congestion or parking issues. Cities that want to decrease the number of delivery vans in their city should rather try to work in collaboration with 3PLs to develop bike delivery solutions, e.g. Cities also tend to close the city centre for delivery vehicles during a time window: it will not address congestion as 3PL companies will come with more vans during the authorized hours. Politicians tend to take a decision based upon what they think will happen but do not always see the bigger picture, so, in practice, it happens that unfit regulations are implemented. Logistics companies, no matter how fast they can elaborate solutions, will always be dependent on what the aim of the local authority is, which is why they wish the policies would be more in line with the goals that are pursued (Interviews 1, 2). Nevertheless, in the recent years Expert #1a observes that the knowledge of politicians has been improving.

However, this lack of qualification can be doubled with a lack of will. The strategic plans of cities remain more influenced by politics than sustainability concerns. The problem of urban mobility is complex, involving many stakeholders with sometimes opposite views. Hence, it is difficult for politicians because they want to make people happy by decreasing congestion typically, however decreasing congestion can also reduce the quality of the delivery services, so typically for shopkeepers it could be beneficial – easier for customers to

shop – but it could also be negative – no control on the time of the deliveries. Making people happy, which serves electoral purposes, is complex and not always in the best interest of sustainability. This is illustrated this statement from Expert #6: *“The necessary modal shift should not hurt economic activities”*, which implies that the sustainability goals may be secondary to economic stakes. Experts #3 adds that the final decision to choose whether projects will be supported and encouraged by a city is up to the political concerns. Some are actively helping whereas others are just imposing restrictions without willing to be engaging in collaboration projects at all. As a result, some collaboration projects can be slowed down or aborted due to a lack of willingness of public authorities to provide the necessary authorizations, or the changes in majority that have caused some negotiations to start over from zero (Interviews 1, 3). In Charleroi and Liège, there is currently no collaboration between 3PL companies and municipal authorities, which is mainly linked to budget constraints. A small share of budget allocated to mobility projects, to some extent, can also be considered as a way of prioritizing other objectives over sustainable mobility ones (Interviews 5, 6).

Besides, interviewees from 3PLs and from cities all noticed a lack of coordination between different public bodies. First of all, different cities have different regulations without any coordination between each other: an extreme example provided by Expert #3 relates to a case when there was no coordination at the local stage, which caused subsidies to be granted while the building permit of the UCC was denied. In this specific case, the coordination within the city is already a barrier. More generally, there is a lack of common view between different cities, no common strategic plan supervised by a higher level of authority. In Expert #4's opinion, it would be the key for an integrated development involving cities and 3PLs: one clear strategic plan across cities ; for instance, coordinated time windows of deliveries so that delivery vehicles can operate in one city in the morning and another one in the afternoon. But there is no common direction in which the cities are trying to evolve, and since it is highly related to political matters it will take time before it can change (Interviews 1, 2, 3, 4). A first step to overcome this issue has been taken, according to city experts. Cities have indeed realized that strategic mobility plans go beyond their municipality's borders. Hence, some strategic plans are mutual to neighbouring municipalities, like in Charleroi and Liège who consult with the mayors from their agglomeration ; and economic poles, such as In Liège and Antwerp, where the ports are consulted when designing a strategy and projects realized in partnership. On a regional level,

mobility regions have been created to serve this purpose (in Flanders only). There are common strategies within mobility regions/agglomerations but not across them. There is progress because coordination has been increased to a wider area than the city itself, but this is not sufficient from the 3PL perspective (Interviews 1, 5, 6, 7).

On a different subject, additional observations have emerged from the interviews, related to the impact of regulatory requirements. They are twofold: the main positive sustainability advantage resulting from law constraints is that it pushes companies to find alternative delivery solutions. According to Expert #3, the need to comply with the law is the main incentive to search more sustainable delivery solutions ; marketing and productivity outcomes are secondary. However, some laws are preventing some delivery solutions to take place, such as competition law, which forbids collusion, including data sharing, preventing some forms of partnerships between 3PLs that could be the basis for consolidation. Other restrictive laws prevent Company #3 to ask their subcontracting couriers to follow a predefined route, making all forms of routing optimization useless (Interviews 2, 3, 4).

2.4. Consumer perspective and marketing stakes

Literature highlights an increased sustainable consciousness of consumers, that poorly translates into their delivery preferences when the price of the service increases. Experts consider it to be accurate. It is also mentioned that some of the customers are not willing to sacrifice the comfort of the home delivery for the more sustainable locker or pick-up point delivery. Expert #1c insists that *“customers are used to home deliveries”*, which means that any change regarding the current status of the delivery system is likely to be perceived negatively. Most shippers want their parcels delivered as quickly as possible, which decreases the consolidation opportunities and is therefore less sustainable. Still, Experts #2 and #3 are optimistic that the popularity of locker and pick-up point deliveries will increase in the near future, showcasing the example of Nordic countries where the delivery of parcels to alternative locations has become widely adopted by the consumers.

In the past years, experts have noted a steady growth of demand for sustainable delivery solutions from their customers, who are shippers, themselves influenced by the

growing environmental consciousness of end consumers. So, the desire of the consumers drive change. Consequently, it has become possible to ask 3PL companies to deliver a parcel without any carbon impact. An actual “zero carbon delivery” service is offered by Company #1, provided that the shipping is not intercontinental: the parcel will not be transported in vehicles that cause GHG emissions. This offer, however, increases the duration of the shipping from several days and costs € 2 more than a standard express delivery. Except this rare example, an actual zero-carbon delivery is not yet part of the offering of 3PLs as fuel remains the main energy source in supply chain from the first to the last mile. Nevertheless, they are working towards it. In the meantime, carriers have come up with a solution to provide to their customers: an artificially constructed zero-carbon delivery. When requesting a delivery online, a customer can select a “Carbon Neutral Service”, “Think Green” service and “GoGreen” service for Companies #1, #3 and #4 respectively. These services, which names clearly indicate the marketing goals that they are serving, propose to the customers to offset the carbon impact of the parcel they are about to ship with an opposite action that will mitigate the emission of CO₂ from the transport of the parcel. Opposite actions include planting trees and helping populations from developing countries to live with more autonomy and sustainability, with undergoing projects in Czech Republic, Lesotho, Bolivia and Indonesia, e.g. (1, 3, 4). Whereas the offsetting of the carbon is auspicious in itself, the sustainability of the delivery of the parcel is not any different and the motivation behind such a service is largely dominated by marketing reasons.

Expert #3 addresses the general image of 3PL companies from the consumer’s perspective. Delivery vans are widely considered as undesirable in city centres. Public regulations try to withdraw them ; citizens and shopkeepers do not like them: although they are necessary, they are occupying parking spots or parking illegally, causing congestion and safety issues. The general unpopularity of delivery vans is also strengthened by a bad perception of drivers, who do not always speak the local language (sic). On the contrary, cargo bikes do not threaten the safety of other users of the road and the pedestrian areas. They also do fit better into the urban scenery. They purposefully have a nice branding, a design that looks friendly and increases conviviality around them. The popularity level of electric vans is in-between the one of cargo bikes and the one of diesel vans. From a marketing perspective, an electric cargo bike represents a lot more than a solution to improve sustainability: it reconciles the last mile couriers with the other stakeholders of the

last mile (Interview 3, 4). The favourable marketing impact of the more sustainable mode of transportation is one of the main reasons that pushes carriers to invest into them.

Finally, mobility issues are considered as one the most important domain of interest of citizens, according to Expert #6. Within this domain, safety is the major concern, adds Expert #5. This encourages cities to take steps towards a renewed approach to mobility, that takes sustainability into account, but that needs to consider citizens and companies desires, therefore dealing with safety and economic constraints on the way.

V. Conclusion

This thesis provided an overview of the main delivery solutions available to improve the sustainability of parcel deliveries in the last mile. A thorough literature research first highlighted the main areas explored by research so far for such sustainability improvements. Afterwards, nine experts working in fields related to last mile sustainability were interviewed. These experts either had a field experience in the domain of last mile parcel deliveries because they were working for a third-party logistics service provider (3PL), or because they were employed by an important Belgian city to work on mobility issues. The observations provided by the experts constitute a previously unseen comprehensive qualitative analysis of how the last mile sustainability matters are being dealt with by these two categories of stakeholders, with a focus on Belgian practices. This analysis has been compared with the research from the earlier part of this thesis: differences in opinions and unexpected observations have been highlighted to emphasize the areas where a further inquiry may present some interest. Consequently, the ultimate goal of this thesis is to provide opportunities for further reflexion in future research and other project related to the sustainability of the “last mile” parcel industry.

This paper helped understand the motivations behind the sustainability shift that is being operated in the last mile. First, it highlights the reasons that push public authorities to adopt mobility regulation that aim to decrease the presence of delivery vehicles – or fossil fuel vehicles as a whole – in urban areas, as they create congestion and many other downsides. These motives regroup:

- **economic sustainability goals:** increasing the convenience of shopping by decreasing road and parking occupancy ; developing the attractiveness of the area for touristic purposes ;
- **social sustainability goals:** increasing safety for all road users and pedestrians ; decreasing health risk arising from fine particles emitted by fuel engines; improving the quality of the urban life ;
- **environmental sustainability goals:** decreasing the GHG emissions from fuel engines.

3PL companies have been developing sustainable delivery solutions, pushed by three main reasons:

- The need to comply with the public regulations ;
- The marketing benefits associated with the implementation of more sustainable activities ;
- The efficiency gains associated with these activities, that decrease the sustainability cost per parcel delivered and that raise the overall profitability of the delivery process.

The delivery solutions that increase the sustainability of last mile deliveries have been reviewed, highlighting different processes, mode of transportation and regulations that can reduce the social and environmental impact of home deliveries through increased efficiency, a change of delivery mode or public authorities' intervention. Some insights resulted from our analysis. Carriers privilege solutions that combine sustainability with profitability, through increased efficiency:

- Evening deliveries, considered as an efficient solution to decrease failure rate and increase efficiency, is not privileged by the interviewed 3PL companies, since they represent additional delivery rounds, are linked to uncertainty and may cause safety and image issues. Saturday deliveries are regarded as an efficient alternative solution.
- Contacting the customer prior to the delivery, which efficiency was questioned by previous research, presents a high potential to decrease the failure of deliveries if it is used in combination with online tools that allow the recipient to choose his preferred delivery option until the last moment.
- Delivery to the neighbour remain an efficient way to reduce failure rate without creating any additional cost, like secret place delivery, which is slightly less popular for carriers due to their uncertainty ; causing carriers to develop tools to transfer the responsibility of the parcel before releasing it.
- Controlled access systems rely on the use of recent technologies and is expected to expand in the future, with recipients seemingly favourable to this new process. Reception boxes and delivery boxes combine safety and efficiency ; but no profitable exploitation has been associated with them so far.

- Collection points and locker delivery offer more efficiency by decreasing the length of delivery trips, virtually suppressing failure rate and achieve more consolidation and have proven to be reliable ; they are usually used as an alternative in case of home delivery failure and they are accessible during off-peak hours prove to be an alternative to evening deliveries. Although some customers may find it inconvenient, they are looked upon as a major chance of sustainability improvement.
- Workplace delivery increases the chance of success of a B2C delivery but has been linked with unpopularity in the eyes of employers, leading to the extension of controlled access systems to the trunks of connected cars to deliver successfully at work more conveniently.
- The use of advanced routing systems to show the driver the most efficient route to follow is put forward by research but is not used extensively: 3PL companies are relying on their couriers to optimize the deliveries, solely providing them a suggestion by ordering the parcels into the delivery vehicles. The implementation of in-vehicle advanced routing systems is slowed down by legal compliance, high cost and unpredictability of delivery rounds, due to additional dispatches occurring during the day. Still, technology advancement should help develop advanced real-time routing software in the future.
- The use of Urban Consolidation Centres can improve consolidation substantially, but their implementation cost makes them unprofitable unless they reach a high volume. UCC projects that benefit from public support have the highest chances of success.

The shift to other modes of transportation and other energy sources is primarily motivated by the need to comply with the law. 3PLs, however, are only willing to invest into alternatives that have an economic potential as well. The first shift that was operated by 3PLs was to resort to gas vehicles, which are less polluting but still emit GHG emissions. Due to the environmental urgency, societal, regulatory and customer pressures require the shift to 100 % green delivery solutions : electric vehicles are expected to become the most used alternative in the future, but represent a high investment cost on short notice, often have less capacity than their diesel counterparts and have a lower reach. Electric cargo bikes are suitable for urban deliveries as they do not cause any pollution, congestion, or safety issues. In addition, they are less expensive and widely popular, on the opposite of current delivery vehicles, which has an important marketing impact. In dense urban areas, cargo bikes have

proven to be more efficient than vans. However, they require either a UCC to be operating from or to be supplied by delivery vans as they cannot travel a long distance. Electric scooters are being increasingly used as well. The analysis could not however, assess the extent of opportunities for autonomous vehicles as it was out of the interviewees area of expertise.

Urban policies for last mile have highlighted the divergence of opinions between public and private stakeholders as to how last mile sustainability should be achieved.

- Illegal parking is being actively tackled with the introduction of smart parking spots, connected vehicles and cameras to improve the efficiency of their enforcement.
- City access restrictions include the use of time windows for delivery access, regarded by 3PLs and research as a source of inefficiency rather than an effective solution to the congestion and urban pollution issues ; Low Emission Zones are becoming increasingly used to lower pollution and encourage the use of alternative transport.
- Speed limitations decrease GHG emissions and are increasingly applied by cities, however they are primarily designed to increase safety.
- Funding mechanisms can occur in various forms, however in practice subsidies are the most common, for relatively low amounts compared to the investment needed for the modal shift. Subsidies are conditional to the completion of pre-established goals. Cities are reluctant to provide financial incentive for budgetary reasons and prioritize other solutions and restrictive measures.

The analysis stressed disparities involving the two types of stakeholders that were interviewed – 3PL and local authorities:

- Public stakeholders tend not to have the competence or the vision necessary to take the most efficient policies, but they have been improving in the past years, as sustainability and mobility issues grow more important. Their actions are also biased by political and electoral motives that push them to take popular measures that do not reflect their sustainability objectives and also hurt collaboration projects.
- Public stakeholders also lack coordination between themselves. While cities involve other cities and economic actors from their surrounding area of influence, they do not collaborate with other cities for coordinated transregional policies that could help create synergies.

- Collaboration between 3PLs is slowed down by competition law, that prevents data sharing ; the difference in processes used ; and the intense competition in the industry, because sharing deliveries withdraws the possibility for carriers to differentiate themselves. Subcontracting partnerships require exclusivity, except in rare occasions where consolidation is necessary to avoid losses.

The increase in consumer environmental consciousness has pushed the industry to consider more sustainable delivery solutions, however he is rarely willing to contribute financially to it nor to renounce to service quality and fastness. Marketing considerations have also caused 3PLs to offer “carbon neutral delivery” that compensate the GHG emissions with pro-environmental actions.

Another noticeable trend stressed by the analysis is the omnipresence of Information and Communication Technology and the general digitalization at all levels, helping the sustainability transition by increasing the amount of information available to 3PLs and public bodies, enabling better supply chain systems, instant tools for more variety and efficiency in delivery solutions resulting in a better level of service, better enforcement, monitoring and anticipation of the urban policies by the cities. It also contributed to the increase in the power of the consumer.

In conclusion, this paper brought additional insights to the current state of scientific research through information gathered on the field. It provides ground for further research regarding delivery solutions processes, particularly regarding evening deliveries, customer contact and routing systems, possibly including the potential advantages of digitalization. The evolution of the modal shift to electric vehicles should be monitored, as it is expected to experience structural change in the near future. Finally, in light of the observations gathered during this thesis, we recommend that future research projects also focus on the relationships between the last mile private stakeholders and the public authorities responsible for the implementation of sustainability policies; on the degree of collaboration between the various public entities and on the potential sustainability opportunities of collaboration between multiple carriers in the last mile, such as the sharing of deliveries.

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