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City logistics: Challenges and opportunities for technology providers

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ABSTRACT

Current last-mile logistics operations are inefficient. The economic competitiveness of logistics service providers is affected by distinct factors, such as the limited time windows they are given to deliver freight in increasingly complex urban environments. This paper presents the different challenges that the sector faces to make its operations more sustainable, from both economic and environmental perspectives. Then, an exhaustive list of measures and initiatives is presented and for each of them, the impact on the different agents involved in last-mile operations is analyzed. This study is expected to help understand the relations between the different actors and design compensatory mechanisms between the parties that mostly benefit from the measures and the most affected ones. Finally, a particular focus is set on the technological developments that are expected to shape the evolution of last-mile operations in the medium or long term. As in the passenger mobility industry, digitization, the emergence of more innovative and modular vehicles, and automation are trends that will undoubtedly affect the market. To maximize the impact of these new technologies, balanced and fair governance schemes and compensatory mechanisms between agents should be designed. The authors believe that the EIT Urban Mobility framework is perfectly adequate to improve this required collaboration between all agents. As a first step towards an increased sustainability of last-mile operations, win-win and agreed measures should be implemented to set the ground for more innovative and disruptive solutions that will emerge in future years.

1. Introduction

Providing people with a reliable and robust transportation system is fundamental to ensure the efficiency of a given city or metropolitan area. Goods are also moved, and ensuring that this can be done efficiently is a key aspect to support the economic attractiveness of a given region. Nowadays, goods are most of the time manufactured out of a city, they are transported to inner neighborhoods, and the resulting waste is then evacuated from the city center to the outskirts. This situation is the result of the sprawl of industrial activity towards less dense areas. It is interesting to recall that this is a quite recent trend and that, throughout history, cities have almost always been considered as centers of production and residence, with mixed land use.

When considering the whole supply chain of a good from the manufacturer (which can be located in Asia) to the final customer (located in cities, as the world population is becoming increasingly urban), the last mile refers to the trip of a good between the last distribution center run by the carrier and the final customer. It can be part of a business-to-business (B2B) or business-to-consumer (B2C) transaction. This generic term of “last-mile logistics” describes very different realities, ranging from the courier express parcel (CEP) market (e-commerce, mail collection, and delivery) to retail (shop) replenishment, food delivery, delivery of construction materials, or garbage collection. Unfortunately, even if this is a fundamental aspect of the economic life of a city, the movements of goods and the relations between the different stakeholders involved in these operations are still quite unknown at the moment, especially when compared to the passenger mobility market in which the situation is evolving rapidly and innovation is flourishing. It seems that last-mile logistics have attracted less interest from city practitioners. Nevertheless, the situation has evolved over the last few years. With the development of sustainable urban logistics plans (SULPs), considered as complementary to the sustainable urban mobility plans (SUMPs) and promoted by the European Commission, planners are expected to become increasingly aware of city logistics challenges.

The main objective of this paper is to propose an overview of how logistics operators are currently dealing with the last mile and describe the main tendencies that will shape this activity in future years. The remainder of this paper is organized as follows. The first part addresses the state of the market and the different challenges that the sector will have to face to increase its sustainability, either economic or environmental. Then, an exhaustive list of measures, including how each one of them impacts the operations and behavior of the different stakeholders, is proposed. Finally, the third and last section presents the technological developments that will be needed to support these measures.

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2. Urban last-mile logistics challenges

In this section, we intend to build an exhaustive panorama of the last-mile logistics market current situation. We identify the main reasons why last-mile operations show a clear lack of efficiency and analyze how the increasing fragmentation of the market and the rise of e-commerce are barriers to improvement.

2.1. Low efficiency of last-mile logistics operations

Urban last-mile logistics are a significant source of traffic and air pollution. The impact of commercial vehicles in traffic may vary depending on the methodology and the area under study, but they represent more than 20% of the total vehicle kilometers traveled in a city (Dablanc, 2007; Russo & Comi, 2012). Their relative contribution to air pollution is generally estimated to be higher (approximately 25% of the total greenhouse gas emissions) because of the aging fleet of vehicles (Dablanc, 2007; Russo & Comi, 2012). These figures show the great importance and huge economic weight of the logistics sector in cities. However, the economic competitiveness and productivity of these operations are still low. Segura et al. (2020) estimated that the last mile represents up to 40% of the total logistics costs (in the Spanish case).

This very low efficiency of urban last-mile logistics can be explained by the fact that carriers have to move and work in an increasingly complex urban environment that is not adapted to their operations (Lindholm & Blinge, 2014). The low cruising speeds in urban areas, vehicle size limitations, and temporal route constraints cause the resource consumption in the last-mile distribution to be high compared to other legs of the transport chain. Tozzi et al. (2013) reported that the average occupancy rate of the commercial fleet in Parma (Italy) was only 30%, as 74% of deliveries must be performed during peak traffic hours. The access restrictions and time windows imposed by local authorities and receivers significantly worsen the efficiency of the supply chain. Figliozzi (2007) estimated that only 51% of driver shifts are spent overcoming the local distance between consecutive customers in the urban delivery route. The complementary fraction is required for loading and unloading operations (32%), resting times (6%), and moving freight from distribution centers to the final delivery area (11%). Indeed, the logistics sprawl has been accentuated in many metropolitan areas as noisy and heavy activities have been relocated to freight villages outside of city centers. Dablanc & Rakotonarivo (2010) studied the evolution of distribution center locations in the Paris (France) metropolitan area between 1974 and 2008. They concluded that the distance that the driver needs to cover from the distribution center to access the first client of the route has increased by 10 km in 30 years. In the case of fleet electrification, this tendency could be a real challenge because of the limited vehicle range with the current battery technology.

Foltyński (2019) and Dablanc & Beziat (2015) ascribed these problems to the low standardization of handling operations and packages (average palletization rate of 5.44%), strong volatility of the market throughout the year (56% of the deliveries during Christmas period), and the lack of loading/unloading (L/U) parking slots (25% of parking is either on double lane or illegal on the curb, bike tracks).

In the particular case of the B2C e-commerce, one of the main challenges is to lower the number of first attempt delivery failures that occur when the carrier comes to the customer's house and nobody is there to receive the parcel. This failure rate, estimated to be approximately 20% in European cities (Eurobarometer, 2013; Van Duin et al., 2016) forces the driver to repeat the delivery without charging any extra fee to the customer.

2.2. Many agents with different objectives and a difficult cooperation

The low efficiency of logistics service providers commented before is also related to the perception that logistics is "an adjusting variable" for many agents involved in the supply chain Dablanc (2007). The freight distribution market involves many stakeholders that pursue very different and, most of the time, antagonistic objectives. Therefore, it seems unrealistic to put in practice innovative solutions addressing the current urban distribution challenges if we do not consider the economic impact of solutions on the profitability of each stakeholder. Carriers have to deal with three different interlocutors: the shipper and receiver, which have economic power, and the public administration, which can impose regulatory decisions with different objectives. The carrier agent, that is, the agent that moves freight, must fulfill the decisions of purchase–sale agreements between shippers and receivers. The relationship between shippers and receivers is essentially economic. They want their goods to be carried from the shipper logistics facility to the receiver's location with specific distribution times, time windows, and shipment sizes. These logistic attributes that result from economic shipper–receiver decisions may vary in every shipment, which limits the carrier's power of action (Holguín-Veras et al., 2014). In addition, the general trend promoted by local governments to decrease the space dedicated to private vehicles (including delivery trucks and vans), and "give the streets back to people" (Bertolini, 2020) will have huge and unpredictable consequences over the carrier's economic competitiveness. In a 15-minute city, how could local shops be efficiently replenished if all the streets are pedestrian and delivery trucks not allowed?

The main driver that pushes public administration to regulate the sector is the reduction of induced externalities. In smaller cities, the main preoccupation is the improvement in safety and reduction of noise levels. In a bigger and denser metropolis, safety and noise are two important considerations, but concerns about air quality have to be added to the list (Lindholm & Blinge, 2014). In contrast, the top three priorities of freight operators reported by Perera & Thompson (2021) are cost minimization, travel time minimization (obviously linked to cost minimization), and reliability. In the survey conducted in the latter study, only 5% of the interviewed freight operators considered the reduction of externalities as the main driver of their actions. Designing policies and organizational solutions that can both reduce externalities and ensure economic profitability for freight operators (beyond some subsidies that may exist during pilot initiatives) is a current research topic. Without this economic viability, carriers' business models are not likely to change (Taniguchi, 2014).

Moreover, public authorities have not fully addressed the issues raised by last-mile logistics. Lindholm & Blinge (2014) conducted a study in Swedish municipalities in which it was reported that only three cities had a person especially dedicated to freight transportation. Despite the importance of freight movement, 88% of the city planners surveyed spent less than 10% of their time on freight-related issues. For most city representatives, last-mile low efficiency is "a matter that the business itself needs to address," and "freight is mainly handled through restriction" (Lindholm & Binge, 2014). In the regulatory framework, all agents expect measures to be led by the other side. City governments assign leadership in this matter to logistics service providers, while the latter are waiting for municipalities to facilitate (and even subsidize) new services before starting a business (Dablanc, 2007).

One of the main reasons that can explain this deteriorated relationship between private carriers and public authorities is the lack of open data, especially when compared with passenger transport. Lindholm & Blinge (2014) highlighted that only 30% of the city representatives in charge of freight-related issues had statistics regarding freight transport in their own municipality. Gathering such data could help to better understand the challenges raised by last-mile operations and provide startups and researchers with reliable and extensive data to create new solutions. In this sense, there is a broad consensus within the research community that more vertical cooperation between logistics operators, shippers, receivers, and public administration is necessary.

Finally, the market has entered a phase of deep reconfiguration. Historical post operators (in which the sustainability component can be more easily integrated because they are public companies most of the time), are struggling to be economically sustainable. In France, in 2020, two billion letters less than in 2019 were distributed (Chocron, 2021). Since 2017, the universal postal service offered by La Poste has been in deficit, and this deficit could reach 1 billion euros by 2025 (Chocron, 2021), which questions its existence. These historical operators clearly need to change their business models; e-commerce could be an opportunity (increased business volumes) as well as a threat to them because their supply chains have to be reconsidered. The last-mile universe is increasingly fragmented, especially in the case of CEP operations. Because of low entrance barriers (one just needs to buy a van to start delivering some parcels), competition is increasing, and subcontracting business relationships are gaining momentum. In this context of fragmentation, the horizontal collaboration between carriers, bringing everyone together around a table to improve the sustainability of the operations, will be a huge challenge in future years.

2.3. The rise of e-commerce

Retail e-commerce sales worldwide are expected to grow from $2.3 trillion in 2017 to $4.5 trillion by the end of 2021 (eMarketer, 2019), approximately 16% of total retail sales. These estimations were made before the Covid-19 pandemic, during which the use of e-commerce skyrocketed. Marketplaces, that is, third parties that aggregate and commercialize products by internet from many providers, are capturing an increasing number of customers because they offer better prices, free or discounted shipping, and a broader variety of products (UPS, 2018). The increasing volume generated by online shopping exacerbates the issues highlighted in the previous sections. More will be demanded from a system that is not capable of efficiently dealing with the current demand, especially in the CEP market. This is similar to asking a child to run before he/she can stand up and walk.

The convenience of online shopping will contribute to the fragmentation of demand: smaller parcels will be ordered more frequently, increasing freight vehicle traffic. E-shoppers are increasingly demanding, especially in terms of time horizon (same-day or 24-hour home deliveries). In Mexico City, Muñoz-Villamizar et al. (2021) highlighted that fast shipping could result in 15% increase in carbon dioxide emissions and 68% increase in operational costs because this delivery mode reduces the consolidation of demanded goods (the delivery vans run half empty). The impact of food delivery platforms, whose usage has surged in the last few years, on traffic and emissions is still under investigation (Allen et al., 2021). To be environmentally sustainable, the food should be delivered using low-emission vehicles (such as bikes), which is not always the case at the moment and is raising great concerns.

In addition, e-shoppers are not necessarily willing to change their habits to make the system more sustainable. In Germany, even if the parcel locker network is dense and efficient, 90% of customers prefer to have their parcels delivered at home (Morganti et al., 2014a). If the delivery does not suit him/her, the e-shopper will just order from another e-commerce platform offering better conditions.

The impact of the Covid-19 pandemic on the use of e-commerce was tremendous. In a survey conducted by Holguín-Veras et al. (2020), 27% of the respondents declared that they switched from buying in stores to buying online during the pandemic. The sanitary crisis had an impact on people's behavior. Nevertheless, the long-term consequences of the pandemic on e-commerce habits are currently unknown.

Beyond this effect of the Covid-19 crisis, the impact of e-commerce on the behavior of shopping customers is a controversial topic within the research community, which still needs to be investigated. Worldwide, 28% of Amazon shoppers declared they go less often to retail stores because of online shopping (eMarketer, 2019); that is, e-commerce will substitute local retail stores, which is not desired by municipalities if they want to maintain vibrant and livable neighborhoods. However, this result is counterbalanced by other studies, in which the real impact of e-commerce seems to be much more complex. In some cases, e-shopping is seen as complementary to retail stores (Cao et al., 2010; Farag et al., 2006; Lee et al., 2017; UPS, 2018) or even a great opportunity for local retail shops.

To sum up and conclude this first section, very distinct tendencies ranging from new urban planning models to the emergence of e-commerce are hugely impacting carriers' operations, making them more and more complex. This will eventually result in an increase of the final cost of freight transport (worsening the level of service), and its associated externalities if no measures are taken. At a governance level, the movement of commercial vehicles in urban areas is the result of decisions taken by many different stakeholders with opposite objectives (Holguin-Veras et al., 2014), mainly shippers, receivers, local authorities, and carriers. Most of the time, logistic practices that increase shipper profitability or receiver utility are usually those that generate the worst impacts on society and the environment.

3. Last-mile improvement initiatives

Different measures and initiatives have been developed, not only to increase the cost efficiency of last-mile logistics but also to alleviate the negative social and environmental impacts. The deployment of a wide range of initiatives entails an equilibrium between individual and social profitability. This equilibrium, usually attained by regulations set by local authorities and administrations, must consider the overall impacts of logistics services among the agents involved in the system. The social benefits of the distribution activity must be balanced with the negative externalities generated by commercial fleets. In this process, it is crucial to enable economic mechanisms to control and adjust each stakeholder's profitability, i.e. economic incentives may compensate for the negative effects of public measures on affected agents or the low economic return of eco-innovation concepts. Failing in the estimation of the impact experienced by each agent and the economic compensation mechanism usually leads to claims about the nature of the initiative or its failure.

The novel initiatives undertaken by different stakeholders are usually classified into the following groups of measures: (i) logistic infrastructure, (ii) new technologies, and (iii) new organizational schemes. These initiatives in the last-mile distribution have been tested under different research and innovation programs worldwide, demonstrating the feasibility of the new concepts in controlled situations with targeted agents. Nevertheless, the scalability of these measures, especially those related to new organizational schemes that imply collaboration between agents, do not meet the expected target values and present variability. These controversial results are, in part, due to the different levels of stakeholder engagement. Another reason could be the natural reluctance of some stakeholders (mainly carriers) to share data and collaborate with other companies competing for the same market. The latter issue would become important when obtaining data to monitor the results of ongoing measures in freight systems. Thus, there is no consistent set of predefined effective measures to improve the current freight situation in a city. The success of each initiative, especially of those related to new organizational schemes, depends on stakeholder collaboration rather than on the technical specifications or operations of the improved system.

The objective of this section is to compile last-mile logistics initiatives that have been emerging these last few years and analyze them based on the agent responsible for their development (shipper, intermediary marketplace, carriers, receivers, and local authorities), along with the cross-effect on other stakeholders. The innovations needed to enhance the considered initiative, in terms of infrastructure, technology or organizational scheme, are also presented. For a more detailed breakdown of policy-related measures promoted by public agencies, readers are encouraged to consult Holguin-Veras et al. (2018a, 2018b). In the following tables, '+' (respectively '-') means that the implemented measure has a positive (respectively negative) impact on the considered stakeholder.

Table 1
Shipper-led innovations.

Concept	Impact on stakeholder (S: Shipper, M: Marketplace, Ca: Carrier, R: Receiver, LA: Local Authority)						Needed innovation		
	S	M	Ca	R (B2C)	R (B2B)	LA	Infrastructure	Technologies	Organizational scheme
Multiple commercialization channels (physical/digital)	+	+	–	+	–	–		Digital marketplaces	Vertical collaboration S/Ca
Demand forecasting	+	+	+	+	+	+		Demand forecasting algorithms	
Returnable packaging and recollection channels	–		–	–	–	+		Reusable packaging Tracking technology	Reverse supply chain

3.1. Shippers

Shippers are product manufacturers or service providers that need to distribute goods and freight through physical networks. They aim to maximize the revenues of product sales while satisfying the expected requirements of potential customers. Shippers have expanded the traditional sales channels and touchpoints with final customers (via retail shops and/or e-commerce) and the combination of product characteristics (specific attributes or extras that can be selected). This customization process, in addition to pull-production and just-in-time strategies, has forced the externalization of logistics operations through LSPs and carriers with dedicated fleets (see Table 1). These agents can provide more efficient and adaptive services by aggregating the demand peaks of multiple shippers.

Carriers and LSPs are now responsible for providing a wide spectrum of logistic solutions to meet the final customer requirements: regular versus express deliveries, distribution in time windows (Zhang et al., 2020), alternative locations to home deliveries using lockers or dropping boxes (Morganti et al., 2014b), and reverse logistic operations for returns (see Table 1). This range of commercialization and distribution channels clearly benefits the producer position in the market. However, it strains the work of LSPs, increases the negative impact of more frequent transport services on the environment, and affects the livability of cities. Moreover, the variable peak demands resulting from the temporal needs of individual customers critically stress the production chain.

Therefore, producers have been promoting new initiatives to forecast customer demand, implementing artificial intelligence (AI) schemes, and new smart home devices. Nowadays, important brands (LG, Samsung) have launched household appliances capable of monitoring the inventory of groceries, chemical products at home, and order new shipments when necessary. The historical analysis of these orders or the consumption rates will become crucial information to plan the logistic shipments of products for the next few days. The increasing interest in the circular economy forces carriers to design new reverse logistics (from the final customer to the manufacturer/producer) to reduce waste and/or foster product recycling (Yang et al., 2021).

3.2. Marketplace companies

The goal of this agent is to become the commercialization channel of the highest number of producers, retailers, or even traditional shops. The aggregation of multiple products and potential customers into a single purchasing platform gives marketplace companies a dominant position in the market (see Table 2). These agents may internalize those parts of the supply chain previously outsourced to LSPs and introduce added value in terms of new services distributed to/from final customers (Janjevic & Winkenbach, 2020). The biggest marketplaces are expected to sign trust-vendor agreements with individuals (B2C) or companies (B2B) to perform unattended deliveries by means of digital door keys. This will also expand the service catalog by picking up objects that require any type of process (laundry, product repair, returns).

3.3. Carriers and logistic service providers (LSPs)

The objective of this agent is to run a physical network that enables goods to arrive at the location of the receivers. Although most of the effects caused by the last-mile distribution are related to the operation of carriers, this agent has a limited range of decisions. In fact, shippers and receivers impose the vast majority of requirements that carriers must fulfill to provide a more reliable service to final customers. Hence, carriers deploy new systems capable of providing tracking information of deliveries or the installation of alternate location facilities (dropping boxes or collaborative retail shops, see Table 3). Although these systems are required by other agents, they may also result in a reduction in delivery failures and, consequently, in the operational cost of carriers. They will also make the distribution more efficient with the deployment of routing optimization algorithms (Crainic et al., 2009; Janjevic et al., 2020), considering real traffic data and loading/unloading (L/U) parking occupancy and the amount of product to be picked up at destinations (on-street waste or second-hand clothes containers).

The pressure imposed by local governments to reach target emission goals has encouraged carriers to purchase eco-friendly vehicles with alternative powertrains, such as electric cargo bikes, full electric vehicles (Caggiani et al., 2021), and fuel-cell trucks (Toyota, 2021, Daimler Truck unveils fuel cell concept truck, 2020). Despite a smaller energy consumption cost and broader use in restricted zones, electric or hydrogen vehicles have not always justified net cost savings owing to the high capital purchasing cost and the restrictions in terms of maximal kilometer range with a loaded battery. These constraints are causing the utilization of two commercial fleets in cities with historical centers, one for accessing the city and another, of smaller capacity, for performing deliveries to customers (see Table 3). Several carriers are exploring strategies for pre-classifying parcels to be distributed by the same vehicle at the shipper location, with the development of standardized small urban containers or small vehicles. These containers or small vehicles are transported in heavy trucks accessing the city, thereby reduc-

Table 2
Marketplace-led innovations.

Concept	Impact on stakeholder (S: Shipper, M: Marketplace, Ca: Carrier, R: Receiver, LA: Local Authority)						Needed innovation		
	S	M	Ca	R (B2C)	R (B2B)	LA	Infrastructure	Technologies	Organizational scheme
Aggregation of multiple producers	+	+	+	+	–	–		Scalable digital marketplaces	
Internalization of logistic operations		+ –	–						

Table 3
Carrier-led innovations.

Concept	Impact on stakeholder (S: Shipper, M: Marketplace, Ca: Carrier, R: Receiver, LA: Local Authority)						Needed innovation		
	S	M	Ca	R (B2C)	R (B2B)	LA	Infrastructure	Technologies	Organizational scheme
Driver education program			+ –			+			Vertical collaboration LA/Ca
Time information and tracking	+	+	+ –	+	+	+		Data treatment system	Vertical collaboration S/R RGPD compliance
Alternative delivery locations (lockers, local shops…)			+ –	+ –	+	+	Integration of lockers in urban landscape	Agnostic parcel locker tech.	Horizontal collaboration (deliveries in same locker) Vertical collaboration Ca/R (B2B)
Route optimization (depending on traffic, L/U parking slot)			+	+		+	L/U parking slot digitization	Dynamic en-route routing	Vertical collaboration Ca/LA
Low-emission vehicle			–			+	Micro-hub network (for e-cargobikes) Deployment of recharging stations (for e-vehicles)	Modular vehicles More efficient e-vans Fast recharging stations	Vertical collaboration Ca/LA
Standardized urban containers	–		+			+		Vehicle trailer concept	Common classification and palletization Vertical collaboration S/Ca
Automation			+	+		–	Vertiports Infrastructure mapping	Orchestration systems Air delivery drones Ground autonomous delivery robots	Collaboration Ca/LA New regulation
Off-peak distribution			+		–	+ –		More silent vehicles	Vertical collaboration Ca/R
Use PT capacity during off-peak hours			+ –			+	Adaptation of PT infrastructure to freight handling	Flexible freight handling system	Vertical collaboration Ca/LA
Use city "blue layer" (waterway, seaside…)			+ –			+	Freight multimodal hubs	Autonomous freight boat Efficient transshipment system	
Underground "hyperloop"			+ –	+	+	+ –	Freight "hyperloop" infrastructure	Standardized container Orchestration tools	Horizontal collaboration Standardized sending protocols Vertical collaboration Ca/LA/R

ing costs and time (the mobile depot concept in Marujo et al., 2018 and Verlinde et al., 2014).

A promising concept that may change the current paradigm of city logistics is the automatization of commercial ground vehicles (Chen et al., 2021) and drones. Despite the higher purchasing cost, this technology reduces the human workload in the physical distribution and the relaxation of constraints associated with driver shifts. Although driverless technologies are becoming more mature, the crucial challenge is not the vehicle itself, nor the trip, but how these unmanned vehicles will deliver or pick up parcels to/from final destinations without human assistance. Carriers are also willing to reduce the impact of congestion and crowded L/U parking operations in dense cities by changing the time of service and transportation mode. Several successful results have been obtained in off-peak or night delivery programs in terms of cost reduction and emission savings. Nevertheless, receivers must accept deliveries out of the normal period by means of public–private campaigns promoted or incentivized by local authorities. In addition, there are initiatives to transport freight through the city "blue layer" (rivers, channels, or seafront), public transport networks (Thompson & Taniguchi, 2014; Kikuta et al., 2012; Nuzzolo et al., 2008), or even underground paths to alleviate road networks from commercial vehicles. Despite the promising results for specific large freight demand attractors, the generalization of these improvement concepts to all distribution chains presents challenges in terms of accessibility and load breaks (see Table 3).

3.4. Receivers

Although receivers are not responsible for any physical operation in the supply chain, their decisions in terms of the number of products purchased, reception times, and delivery address clearly affect the entire distribution system. Shop associations in city districts (B2B) or different departments in big pole attractors (B2B or business-to-administration) are performing receiver-led consolidation programs, in which demand requests of individual shipments are centralized in a neutral body or mobility manager (see Table 4). Hence, the aggregation of these requests can be served with a significantly lower number of vehicle routes. Based on these collaborative practices, receivers may benefit from lower transportation costs because the number of shipments is reduced. In recent decades, these shop associations have also organized home deliveries to compete with internet marketplaces, sharing the cost of drivers or offering micro-jobs via crowd-sourced deliveries (Buldeo Rai et al., 2017).

3.5. Local authorities

They are responsible for deploying public infrastructure, enabling the freight flows derived from economic transactions in the city. At the same time, they face the challenge of alleviating the negative effects on citizens and the environment. Therefore, public policy-oriented initiatives focus on balancing the welfare of citizens with the economic activities of stakeholders involved in urban distribution. Possible initiatives can be summarized as follows: (i) promotion of new pathways and logistics facilities (relocation of logistics centers), (ii) adaptation of urban spaces to urban logistics operations, (iii) flexible management logistics facilities, (iv) network and parking pricing, (v) access restrictions, noise compliance, and (vi) land use management (see Table 5).

Nevertheless, city councils are also in favor of public–private partnerships to promote new organizational schemes between stakeholders to reduce access to commercial vehicles in city centers. In fact, public

Table 4
Receiver-led innovations.

Concept	Impact on stakeholder (S: Shipper, M: Marketplace, Ca: Carrier, R: Receiver, LA: Local Authority)						Innovation		
	S	M	Ca	R (B2C)	R (B2B)	LA	Infrastructure	Technologies	Organizational scheme
Crowd-sourced last-mile logistics			–	+ –		+ –			Horizontal collaboration R/R Vertical collaboration S/R
Receiver-led consolidation strategies	+		+	+ –	+ –	+			Horizontal collaboration R/R

Table 5
Local authority-led innovations.

Concept	Impact on stakeholder (S: Shipper, M: Marketplace, Ca: Carrier, R: Receiver, LA: Local Authority)						Innovation		
	S	M	Ca	R (B2C)	R (B2B)	LA	Infrastructure	Technologies	Organizational scheme
Access restrictions			–			+	Relocation of logistic centers		Vertical collaboration Ca/LA
Road and parking pricing			–			+	Monitoring sensors	Pricing management system	
Urban consolidation center			+ –			+	Creation of urban freight facilities	Data exchange platform	Horizontal collaboration Ca/Ca Vertical collaboration LA/Ca
Adaptive infrastructure to urban logistics (L/U parking slots, geometric constraints removal)			+			–	L/U parking slots Removal of geometric constraints	Parking slot management system	Vertical collaboration LA/Ca

authorities can promote or compel by regulating the implementation of these new logistics practices, but the success of each measure depends on stakeholder engagement. The most promising strategies that imply vertical collaboration among stakeholders are as follows.

- Consolidation strategies. The basic idea is to consolidate freight trips before the last distribution leg in an existing or new economical urban facility (carrier-led). In carrier-led consolidation, freight from different carriers arrives at urban facilities, known as urban consolidation centers (UCC). The cargo will be loaded in exclusive or shared vehicles with a load factor higher than the regular distribution (HALLO project, 2021; SMUD project, 2020). Despite the positive results from the city perspective, the crucial issue is a successful business model of the agent that runs the UCC and last-mile service (Allen et al., 2012; Browne, Sweet, Woodburn, & Allen, 2005; SMILE project, 2015). In the receiver-led strategy, the goal is to coordinate freight arrivals in the same shipments, so that the existence of a dedicated facility is not required (Holguín-Veras & Sánchez-Díaz, 2016; van Rooijen & Quak, 2010).
- Off-peak distribution. City councils may lead vertical collaborative programs between different agents to increase the acceptance of receivers to switch to non-peak periods or use of time slots. This strategy does not require significant incentives when carriers can perform unattended deliveries (McKinnon & Tallam, 2003). It has obtained outstanding results in terms of emission and operational cost savings in different demonstrations in New York, Bogotá, Copenhagen, Barcelona, and Brussels.

In the future, it is expected that local authorities will undertake educational programs for citizens, retailers, and carriers to introduce them to sustainable logistics and behavioral practices.

Many innovative measures can be envisioned to improve last-mile logistics considering the challenges presented in Section 1. These innovations are led by a given agent but have an impact on the rest of stakeholders present in the supply chain, meaning that compensatory mechanisms should be designed. Disruptions that mostly rely on policy and governance innovation have been largely studied by the research community. However, even if policy plays a key role, some of these initiatives cannot be implemented without the application of particular technologies to the given context of last-mile logistics. To the best of our knowledge, this aspect needs further investigation and will be the object of Section 4.

4. Last-mile logistics technological challenges

The technological challenges that the last-mile industry will have to face in future years are not fundamentally different from those that appear in passenger mobility. The authors identified three main transformation and improvement opportunities: (i) digitization of the logistics sector to generate better monitoring of the last-mile operations, (ii) development of more sustainable and flexible delivery vehicles, and (iii) automation of last-mile operations. Each of these opportunities will be further detailed in the following sections.

4.1. Digitization of last-mile operations

The first main technological developments that will affect the last-mile industry are the emergence of the Internet of Things (IoT) and shared data platforms. They will depict the “big picture,” providing information to establish global optimization schemes, resulting in a decrease in both operational costs and externalities. In the particular case of last-mile operations, the technologies at stake are radio frequency identification (RFID) chips (Rey et al., 2021), which will ensure a much better traceability of goods along the supply chain, low-cost GPS devices (Nuzzolo et al., 2020; Taniguchi et al., 2016) to monitor the real-time location of delivery vehicles accurately, and a network of wireless sensors that could be used, for example, to monitor the occupation of the different L/U parking spots. By connecting different sources of information, logistics operators will be able to (i) optimize the use of its assets, (ii) decrease the significance of human error, and (iii) increase transport control (Rey et al., 2021). IoT will enable the carrier to have an exhaustive real-time overview of the state of its fleet. In addition, implementing IoT and taking advantage of its assets could generate new revenue streams for the carrier. As an example, SEUR, an important CEP company in Spain, equipped its city vehicles with sensors to measure real-time air contamination (SEUR, 2020). If adequately shared and analyzed with local public authorities, these data could be very valuable.

The expansion of IoT within the logistics sector will generate a huge amount of (high-quality) real-time data, which, if adequately processed, could result in important operational improvements. To analyze these data efficiently, new algorithms, including machine learning and artificial intelligence (AI) techniques, should be investigated and implemented. Roca-Riu et al. (2015) developed a parking slot assignment system for urban distribution. The objective is to use optimization algorithms to maximize the usage of urban L/U parking spots with a slot reservation system. To implement these numerical methods in a real-life use case, parking spots must be equipped with IoT sensors to track their real-time occupation. In addition, collecting, storing, and analyzing real-time data will enable logistics operators to optimize the routing and scheduling of their operations (Taniguchi et al., 2020). Real-time vehicle location can be crossed with traffic data for more efficient routing, thus avoiding congestion.

As previously described in Section 2.3, one of the major challenges of last-mile operations is the clear lack of collaboration between the different agents that play a role in this market. To foster this collaboration, which could result in efficiency improvements for the carriers (Estrada & Roca-Riu, 2017), the authors see a huge potential for integrated digital platforms for last-mile operations (Taniguchi et al., 2018). The usage of such a platform would result in a better spatial consolidation of the demand (shared between all logistics operators participating in the project), that is, a decrease in operational costs.

Nevertheless, to obtain support from carriers, the platform and the way it is managed (governance scheme) should be completely transparent and trustworthy (Hribernik et al., 2020). As described in Section 2.3, in such a competitive market as is the last-mile industry, (not) sharing data is of strategic importance for the carriers. To achieve this reliability and trustworthiness, blockchain technology, which is currently a very active research topic, could be used. Irannezhad (2020) highlighted that, in the case of maritime transport management, the use of this technology could improve the efficiency, transparency, and trustworthiness of different actors. He then showed that the governance of such a blockchain-based digital platform is a key element for successful implementation. Three types of governance schemes can be used and depending on the different characteristics of the considered market, a solution could be more suitable.

In last-mile logistics, the potential of blockchain has been less investigated. To the best of our knowledge, Hribernik et al. (2020) were the first to present a decision framework for horizontal collaboration between CEP carriers. When compared to maritime transport, in which some pilots have already been conducted (Irannezhad, 2020), the last-mile market seems to be even more fragmented. One of the main challenges will be to attract medium-sized carriers to these platforms, as they have limited resources for innovation projects and are not necessarily aware of the technological implications. To illustrate this, it is worth noting that the penetration of IoT is much higher in large logistics companies (Rey et al., 2021). Everything indicates that the same type of results can be obtained in the case of blockchain. In an online survey they developed, Hackius & Petersen (2017) emphasized that the main barriers to its adoption by logistics companies are regulatory uncertainty and the fact that “different partners must join forces,” that is, the necessity of a close collaboration between the agents involved in the market. Middle-level managers seem to be less enthusiastic than senior executives (Hackius & Peterson, 2017). There is also a discrepancy that depends on the practitioner’s background. While logisticians have difficulties obtaining a clear idea of the benefits of blockchain and there is a lack of convincing use cases, consultants and scientists are more concerned about the maturity of this technology. More research on the benefits and risks of such blockchain-based platforms is needed (Hribernik et al., 2020)).

4.2. Innovative vehicles

The electrification process experienced by commercial fleets presents significant potential for reducing the air pollution (Giordano et al., 2018) and noise (Campello-Vicente et al., 2017) generated by frequent freight shipments in urban areas (ZEUS project, 2020). Van Duin, Tavasszy, & Quak (2013) estimated that the electrification of the delivery vehicle fleet in Amsterdam (the Netherlands) could reduce the sector’s carbon dioxide emissions by 90%. However, even if the perception of electric vehicles within logistics companies is favorable (Wolff & Madlener, 2019), the penetration of electric vans and trucks in the last-mile industry seems to be very slow. In 2015, only 0.5% of the 1.7 million newly registered commercial vans in Europe (including last-mile logistics and service vehicles) were electric, and today 97% of the last-mile fleet uses diesel engines (Morganti & Browne, 2018). The most important barrier to the adoption of electric vehicles is the high cost of ownership (Feng & Figliozzi, 2013; Morganti & Browne, 2018; Van Duin, Tavasszy, & Quak, 2013; Scoranno et al., 2021). In a survey conducted by Morganti & Browne (2018), English and French urban freight operators raised that the redesign of the current supply chain was one of the main concerns. Beyond purely economic and rational considerations, one of the main barriers is the lack of understanding of the technology and “psychological” issues (fear of change).

In recent years, environmental concerns have also motivated the development of non-motorized vehicles, adapted to the last-mile distribution and urban space limitations (electric cargo bikes, bicycles, trolleys; see Nocerino et al., 2016). Although some of these vehicles can be assisted by electric engines, they are allowed to run along sidewalks and pedestrian areas. Apart from the promising emission savings, these vehicles would become a more time-competitive solution than regular vans in restricted areas of historical city centers, where the gage of one-direction streets is limited.

The freight industry has not only fostered the launch of innovative solutions in the tractor element or vehicle powertrain, but also in the receptacle that holds products for convenience of movement (truck box, trailer, or container). In this sense, the tendency is to standardize or create modular freight receptacles in order to speed up handling operations at urban terminals or adjust the size of the trailer. Several vehicle manufacturers are attempting to replicate the principles of the European modular system in heavy trucks (regulated by Directive 96/53/EC) to light commercial vehicles in urban environments. As a result, freight may be loaded into urban-designed containers at distribution centers that can be easily transferred from heavy vehicles (operating the long-haul network) to light vehicles or devices that will perform last-mile deliveries. Modularity may allow different vehicle layouts and sizes to adapt better to the shapes, volumes, and characteristics of the shipments. Indeed, there are initiatives aimed at developing a set of interchangeable modular urban trailers to be powered by common electric tractors (EDAG, 2019).

The previous concepts are being developed together with the last developments of vehicle connectivity with the infrastructure (V2I), travelers (V2P), and other vehicles (V2V) (Fossen et al., 2017). This connectivity may lead to the (semi-)automatization of driving operations, thereby increasing the traffic safety and productivity of resources. Two alternatives provide different latency performances, and data flow at an affordable cost. The first is the ITS-G5, or intelligent transport system, promoted by vehicle manufacturers, which operates in the short range (5 GHz), does not require a licensed spectrum but the deployment of a dedicated field infrastructure, and ensures the minimum latency needed in safety-critical applications. The second one is 5 G, the fifth generation of mobile networks, which could be another option for implementing vehicular connectivity. It has short and long range, high data transfer rates, very low latency, and improved security.

4.3. Automation

In last-mile operations, personal costs represent approximately 80% of the total operational costs of the vehicle (Observatory of Road Freight Transport Costs in Catalonia, Bedoya & Torre, 2021). This figure is a key element in understanding the recent enthusiasm of the last-mile industry for autonomous technologies that have the potential to cut both the carrier’s operational costs (Jennings & Figliozzi, 2019, 2020) and externalities (Figliozzi, 2020). Baum et al. (2019) identified 39 different designs for automated ground micro-vehicles. In addition to this already-long list, air delivery drones are currently raising a great interest within the research community. However, the market is not yet mature, and business models involving this type of technology need further assessment (Lemardelé et al., 2021).

Last-mile supply chains must be adapted to foster an efficient use of these autonomous delivery vehicles (either on the ground or in the air). Because they are medium-sized electric vehicles with limited battery capacity, they have a low range of action. Currently, carriers' distribution centers are located in the outskirts of the city (Dablanc & Rakotonarivo, 2010), and the distance between the distribution center and the final customers cannot directly be covered by autonomous delivery vehicles, especially the smaller ones. As a consequence, there could be new cooperative delivery patterns involving trucks and ground autonomous delivery vehicles (Boysen et al., 2018) or trucks and air delivery drones (Murray & Chu, 2015). This is an opportunity for manufacturers to design vehicles that are more adapted to these collaboration schemes.

In addition, at the moment, autonomous technologies are only able to deal with smaller parcels and, even if the technology were ready, it is not clear whether future regulations will allow larger parcel transportation. This implies that carriers have to increase the complexity of their supply chain by creating two distinct distribution strategies depending on the characteristics of the parcel that is to be delivered. This increased complexity could be a barrier to the implementation of autonomous technologies.

Finally, business models and adequate use cases must be further investigated for wide deployment. Müller et al. (2019) analyzed the emergence of air-delivery drones. Currently, air delivery drones operate only in niche markets, such as in the delivery of medicines to isolated areas (after a natural catastrophe, for example), or in some pilots of e-commerce parcel delivery in rural areas. The automobile industry and other manufacturing companies are integrating drones in the supply chain, but these are still pilots involving the limited transport of small misplaced pieces. In some cases, these pieces are transported from a supplier to the factory, and the drone flies over an external road outside both companies (Bertran & Petit, 2019).

The main question concerning the air delivery drone technology is to determine whether the techno-economic pressure (the development of the information and communication technology, the emergence of e-commerce that generates smaller parcels and instant or same-day deliveries) and the socio-political pressure (the need to reduce contamination and congestion) will counterbalance the low acceptance of drones by public authorities and citizens. Noise and safety issues remain a major barrier to the introduction of air delivery drones in densely populated urban areas. Because air drones operate in niches in which the customer willingness to pay is higher (instant e-commerce deliveries, for example), the capital invested in this technology can generate more margins than in the standard mass last-mile delivery market that relies on delivery trucks and vans. These high margins attract non-conventional or market players that are not necessarily aware of all logistics constraints. Mostly because of some very restrictive regulation barriers and safety/insurance challenges, the use of drones does not seem competitive in the mass last-mile market. However, the multiplication of successful use cases, such as truck-launched delivery drones in rural areas or for fast emergency response, will contribute to the maturity of the technology, which seems to be today in its stabilization phase (Müller et al., 2019). The ability of drones to disrupt the mass last-mile market is yet to be seen.

5. Conclusions

Last-mile operations in urban environments are currently very inefficient, both from an economic and environmental perspective. The main reasons for this inefficiency are the requirements for the carriers to operate during very restrictive time windows (that most of the time coincide with traffic peak hours), the long distances between the distribution centers and the main service regions, and a lack of loading/unloading parking spots. To solve these issues, high-level cooperation between the stakeholders (shippers, marketplaces, carriers, receivers, and public authorities) is needed, but this is hardly achieved at the moment. The agents pursue different goals (most of the time contradictory), and because of a very intense competition, a lack of trust between each one is observed. In this context of low efficiency, the rise of e-commerce could be seen both as a threat (the freight movements will strain even more some supply chains that are not optimized), and an opportunity (public authorities may be increasingly willing to collaborate and improve operations to avoid externalities).

To make city logistics operations more sustainable, many measures have been proposed within the research community. Each of these initiatives affects the involved agents in different ways, and to guarantee an adequate implementation, some compensatory mechanisms for the most impacted parties need to be designed. Policy and governance aspects are fundamental and have been extensively investigated in the literature. Nevertheless, some technological developments are also needed to guarantee a successful implementation.

As in the passenger mobility industry, digitization greatly affects carrier operations. The efficient combination of IoT, numerical optimization techniques (including big data or machine learning), and the blockchain technology is expected to significantly improve last-mile operations. The emergence of more sustainable and more flexible vehicles, including autonomous robots, will help carriers adapt to increasingly complicated urban environments in which modularity is one of the keys. Here, the participation of manufacturers in providing innovative vehicle concepts is essential. It can be expected that the cost of ownership of electric vehicles will decrease in the future owing to an increase in the demand for this type of vehicle, rendering them more and more economically competitive.

The major barrier to the implementation of many of the initiatives presented in this paper will certainly be the current lack of cooperation between stakeholders. To help improve this, the EIT Urban Mobility, an innovation and knowledge community integrating all involved actors, has a major role to play. Because technology is not an end in itself, it must be tailored to the actual needs of cities to make them more livable and design equilibrated and fair governance schemes. The promotion of successful use cases through innovation projects will undoubtedly help convince the different agents of the validity of the measures presented in this paper. The EIT Urban Mobility, by bringing together local authorities, research institutions and private institutions, seems to be the best framework to help improve last-mile logistics operations. It is worth noting the implication of the EIT Urban Mobility community that has been co-funding several logistics-related innovation projects in the last few years (EIT Urban Mobility, 2021a). 14 start-ups with activities related to last-mile logistics have also been participating in the EIT Urban Mobility acceleration program (EIT Urban Mobility, 2021b). This effort should be pursued in the future.

As presented in this paper, many challenges are still to be overcome. To move towards more sustainable operations, implementing radical, disruptive (and most of the time controversial) measures in the next few years may not be the adequate approach, above all in a so fragmented market. Cities in which the last-mile logistics market is not mature enough should first focus on consensual measures that could have a positive impact on all stakeholders. Some of these measures could be training programs for drivers, the improvement of traceability all along the supply chain, data sharing to help improve routing or demand modeling and prediction (see Section 3). These measures are win-win for all agents. Since no compensatory schemes would be needed, these measures would be better accepted and easier to implement. Once these first steps have been done and trust has been established between the different parties, more innovative operational models could be implemented.

Finally, because replicability is a key aspect to be considered in last-mile logistics, one of the major concerns of the community should be to conduct efficient ex ante and ex post analysis of the different projects and pilots to understand the reasons for success or failure. The authors have no doubt that the newly created Journal of Urban Mobility will be of great help in this purpose.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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