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A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision

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Abstract: In this paper, a review of the recent scientific literature contributions on innovative strategies for last mile logistics, focusing on externalities cost reduction, is presented. Transport is causing problems in urban areas, in particular in freight transport: modern cities need solutions to reduce externalities costs such as congestion, pollution and others, which have increased in the last few years, especially due to the growth of goods delivery. Online sales and globalization lead to new trends in freight transport, and moreover, a larger quantity of goods is expected to be delivered in the next future. In this context, most of the delivered goods end up in the city centers. Last mile logistics is the least efficient stage of the supply chain and comprises up to 28% of the total delivery cost. Therefore, the improvement of last mile logistics and a significant externalities reduction are very important challenges for researchers. New technologies and transport means, innovative techniques and organizational strategies allow handling in a more effective way the last mile delivery in urban areas. Based on the Systematic Literature Review (SLR) method, recent papers that significantly contributed, with original proposals, to the reduction of externalities in urban logistics are identified and analyzed in this work. Furthermore, a classification of the papers dealing with the externality reduction problem is presented. It is consistent with a general formulation proposed to evaluate external costs in urban area. The innovative contributions are classified into five main categories: innovative vehicles, proximity stations or points, collaborative and cooperative urban logistics, optimization of transport management and routing, innovations in public policies and infrastructures. The new paradigm of smart logistics is based on the combination of these concepts and on the proposed innovations.

Keywords: urban logistics; last mile delivery; smart cities; transport externalities; Systematic Literature Review (SLR)

1. Introduction

Data analysis shows a steady growth in EU freight transport over the last 20 years, with the exceptions of 2007 and 2008 [1]. Globalization and the web market have led to exponential growth in transport, allowing the development of an open market: products can be purchased anywhere; goods travel around the world; and most of the goods are delivered to cities.

The problem of the last mile delivery is dealt with innovative modes thanks to the development of Information and Communication Technologies (ICT), Information Transport Systems (ITS), Industry 4.0 and new transport vehicles.

Another important issue is the urban population growth: about 54% of the population live in the cities today, and about 66% is expected in 2050 [2]. Urban areas require a massive quantity of goods, services and resources, which are causing many problems for citizens. Human activities generate externalities costs, and the transport sector is one of the main causes of these. The EU definition of an external cost, so-called externality, is a cost arising "when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group" [3]. The scientific literature considers externalities as air pollution, climate change, noise pollution, congestion, accidents and infrastructure wear and tear in the transport sector [4–6]. In urban areas, these issues are stressed by the huge amount of people and by the high rate of deliveries.

Recent studies analyzed the various factors that influence externalities and methods to economically quantify their impacts. It is essential to reduce the factors that generate externalities because it would guarantee a better human quality of life and sustainable resources management.

The impacts of transport air pollutant emissions are highly related to geographical position, and they are affected by many local factors, such as existing transport means and traffic. The impacts caused by the emissions are determined by evaluating human health diseases and environmental damages related to a unitary increase in the air pollution concentration. Epidemiological studies indicate that the most important air pollutants in urban area are: Particulate Matter (PM), Nitrogen Oxides (NOx), Carbon Monoxide (CO), aliphatic and aromatic hydrocarbons, Sulfur Dioxide (SO_2) and heavy metal [7,8]; the impacts on humans and the ecosystem are evaluated, and the related monetary costs are estimated [6].

Climate change mainly comes from the Greenhouse Gas (GHG) emissions into the atmosphere. GHG emissions comprise one of the most relevant problems in transport planning: at the global level, this sector is responsible for about 20–25% of emissions [3]. In this context, it is forecasted that residential, industry and tertiary sectors will reduce emissions in the coming years; on the contrary, the transport sector is expected to not have a reduction, and its total emissions rate will increase by about 30%, in comparison with 1990 levels [9]. These results are based on the hypothesis of the transport activities growing, on the vehicles' performance improving with an emissions reduction and transport systems like today's.

Moreover, high use of vehicles in the city produces traffic that dramatically reduces the efficiency of the transport system, with loss of time and money. In the same way, acoustic problems generated from vehicles have an impact on the activities of human and animal life.

Vehicles' transit and parking, especially for freight transport, are furthermore responsible for greater space occupation and infrastructure wear and tear.

In addition, the majority of vehicles are internal combustion engine powered, thus requiring oil. Only a few nations produce oil, while the majority have to import it, determining a strong negotiating power of producers and often wars over the control of territories rich in oil.

On the other hand, transport activities are very important for both economic and social aspects, giving a significant contribution to the economic growth of areas involved. In the last 20 years, the freight and passenger transport volume trends have followed the evolution of the gross domestic product [10]. Two main areas are identified in the transport sector: people mobility (public and private transport) and freight transport. In both areas, different modes of transport are adopted (road, rail, ship, plane).

In the last mile delivery, the most widespread transport mode adopted is road, although other modalities are also used according to the cities' characteristics: for instance, in the presence of a river, vessels and barges are mostly used [11]. In urban areas, road freight transport is the major mode responsible for the externalities related to the delivery. For this reason, several studies have been carried out with the aim to increase the efficiency in delivery logistics, as well as to reduce the related externalities [12,13]. Last mile delivery represents a significant problem for the generated traffic volume in the urban area. Usually, it is fragmented and uncoordinated: shippers engage different logistics service providers and carriers for the delivery to the retailers in the cities. This produces a low load factor of vehicles, a large number of routes, high externalities and wide system costs. The main challenge for the last mile delivery is to reduce these externalities and provide an efficient service for citizens. This vision is one of the important themes that leads to the new idea of the city, the smart city [14–16], where through ICT, Industry 4.0, development of new mobility systems and services [17–23], it will be possible to create an efficient and sustainable use of resources. In a smart city vision, citizens are the key actors: ICT tools support humans in different fields, such as education, environmental, social and human relationships [24]; they have to be adopted in synergy with knowledge-intensive and creative strategies in order to enhance the socio-economic, ecological, logistic and competitive performance of cities [25].

The aim of the proposed review is to answer the question whether there are innovative technologies and/or methods presented in recent years that can significantly reduce the externalities produced in the urban area from last mile delivery activities. To this purpose, a comprehensive review of the relevant literature on innovative last mile delivery systems and strategies of the last five years able to reduce externalities in urban areas is presented. In addition, a model to describe the total externalities cost is proposed.

Literature reviews on last mile delivery focus on transport and climate change, and impacts due to urban freight transport in home delivery are faced in [26,27]; however, to the best of the authors' knowledge, there are no works that consider innovations in last mile delivery aiming at reducing externalities costs in urban areas; it is an emerging topic in recent years. Accordingly, the aim of the review in this paper is to provide a useful tool for scholars (researchers), policy makers and practitioners in this field, to understand how the recent innovations could influence the externalities generated by urban transport of goods. The work is organized into five sections: research methodologies are clarified in Section 2; Section 3 describes the motivation behind the research carried out on the new modes and strategies in urban freight transport. Section 4 presents and classifies research papers dealing with the reduction of externalities in urban last mile logistics. Finally, conclusions are presented in Section 5.

2. Methodologies

This section presents the methodology adopted to perform the proposed review. As previously mentioned, a literature review of academic research papers and expert reports on innovative technologies and strategies able to reduce externalities in urban last mile delivery is undertaken based on the Systematic Literature Review (SLR) method. Systematic reviews aim to identify works, critically evaluating and integrating all relevant and high-quality studies addressing one or more research questions. It is a method able to address much broader questions than single empirical studies ever can [28]. To conduct a correct systematic review, the key stages are the following: (i) research scope; (ii) planning of the study; (iii) identification of the works; (iv) screening and eligibility [29]. Literature papers have been collected through an extensive search with electronic databases such as Scopus, IEEExplore, ScienceDirect, Researchgate and Transport Research International Documentation. The inclusion and exclusion criteria that have been applied to the search results are in Table 1. The use of a snowballing technique allowed identifying other relevant sources from the reference lists of the selected literature. The same inclusion and exclusion criteria were applied to articles found by means of this technique.

A number of different keywords/search terms have been used including "transport externalities", "external cost", "last mile logistics", "last mile delivery", "smart cities", "smart logistic", "marginal cost", "urban logistics", "freight transport" and "information and communication technologies". The combination of these keywords has also been applied as a search criterion using Boolean AND (e.g., last mile deliveries AND externalities) and OR (e.g., smart logistic OR last mile logistic) operators. The search was limited to English-language papers, and innovations able to reduce factors affecting transport externalities in urban areas have been considered; no limitations to the geographic area were adopted. Papers in the transportation research area and published in the last five years have been considered.

By reviewing the title, the abstract and the reference list of each paper, a total of 114 publications were considered relevant to the review topic, of which 83 were excluded after the application of the inclusion and exclusion criteria. A further 8 papers were excluded following the full reading, resulting in not being relevant to the selection criteria. Some of the excluded papers were used to provide information on the historical evolution of changes in the last mile delivery, logistics activities in cities and the evaluation of the transport externalities, particularly in the urban areas.

Hence, the selected papers were classified into five main categories as discussed in Section 4.

Table 1. Inclusion and exclusion criteria adopted for the literature review.

Inclusion Criteria	Exclusion Criteria
Full journal and conference proceedings	Lectures, grey literature, presentations, policy documents
English language	Non-English language
Peer-reviewed	Not peer-reviewed
Focus on last mile deliveries	Focus on mobility of people
Focus on urban areas	Focus on regional, national or international travel
Focus on local transport externalities	Focus on all externalities
Focus on innovations able to reduce the factors that affect the externalities cost according to Model (1)	Focus on innovations that do not reduce externalities
Focus on innovation methods, new technologies and strategies of recent years	Focus on methods and technologies consolidated and existing for at least 5 years

3. Transport Externalities

Transport externalities are an important issue especially in urban areas. The citizens' sensitivity to environmental issues and to the problems generated by the transport sector has led policy makers to develop long-term strategies to reduce transport externalities.

Recently, the European Union (EU) introduced limitations and targets to be reached in the transport sector in order to improve the citizens' quality of life. In particular, the EU signed an agreement with the car industry to achieve an average CO_2 limit of 95 g/km from 2020 [30,31]. Even using the best technology with the combustion engine, the technical target that can be reached is 103–104 g/km (on average). The introduction of electric or hybrid vehicles becomes necessary to move to zero emissions (at least in urban areas). For this purpose, a percentage of around 10–12% of electric and hybrid vehicles is needed in the market.

In addition, the European Commission (EC) has set itself the objective of decarbonization by 2050 (80% decrease of CO_2 emissions from 1990) with intermediate goals in 2020 and 2030. Target levels of energy saving, CO_2 emissions and production from renewable sources are provided in [32].

EU Members States are required to translate EC Directives into National action plans and operational programs. Some examples of local planning are: Sustainable Energy Action Plan and Sustainable Energy and Climate Action Plan from the Covenant of Mayor [33], Sustainable Urban Mobility Plan [34] and Forum CIVITAS [35]. These plans identify specific actions to achieve the above targets, including externalities reduction in urban mobility. Moreover, several EU projects, on sustainable city logistics and clean last mile transport with many good practices proposed, have been carried out, such as BESTUFS, C-LIEGE, GRASS, NOVELOG, STRAIGHTSOL and others; they classified the negative urban freight transport impacts with different approaches. The C-LIEGE project classifies them into three categories: environment (air and noise), energy (consumption) and economy (transport efficiency, safety, land use and urban planning) [36]. The STRAIGHTSOL project proposes travel time, employment, road safety and environmental pollution as the impacts in an evaluation model based on a Social Cost Benefit Analysis (SCBA) [37]. The BESTUFS project considers the issues caused by urban freight delivery in three main categories: economic, environmental and social impacts; reductions in total vehicle trips and vehicle kilometers are identified as possible solutions to the last mile delivery issue [38]. The GRASS project is a follow-up of the C-LIEGE project, with more focus on environmental and quality of life (air pollution, noise, traffic and road deaths) in the area of Szczecin (Poland) and Oslo (Norway) [39]. The NOVELOG project uses four assessment methods: impact assessment, SCBA, transferability and adaptability and risk analysis in addition to multi-stakeholder multi-criteria evaluation [40]. In particular, the SCBA considers these externalities costs: external air pollution cost, marginal climate change cost, marginal accident cost, congestion cost, marginal external noise cost.

Furthermore, great resources have been allocated in the European program to develop smart cities and communities where smart logistics have a key role [41]. In both EC Directives and local plans, the externalities reduction target is considered.

The United Nations proposed 17 Sustainable Development Goals (SDGs), 169 targets and more than 200 indicators to achieve the objectives of Agenda 2030 [42].

The main externalities, especially due to road transport, are [7,8,43–46]: air pollution, climate change, noise pollution, congestion, accidents and infrastructure wear and tear.

Air pollution is a problem for humans because it causes several illness (like allergies, respiratory and cardiovascular diseases) and non-reversible and incurables damages [47]. Moreover, air and fine dust pollution are responsible for the degradation of building surfaces, especially of historical ones. In fact, these negative factors cause a smog patina and the crushing of decorative elements [7].

Climate change is a consequence of the high values of GHG emissions. It is a phenomenon in progress, and scientists are looking for innovations that may contain the related effects. It is a global problem that requires actions not only at a local level; if all cities reduce GHG emissions caused by transport activities, this externality would be significantly reduced.

Noise pollution is very dangerous particularly in residential areas. Studies show that noise pollution is causing issues such as discomfort, complaints, sleep disorders and hypertension [7].

In urban areas, congestion causes increases in driving time, traffic, higher fuel consumption, as well as lower public transportation efficiency and delay.

Accidents can cause losses of human life and a reduced health condition, producing pain, grief and suffering, medical and material costs, lost income and expenses [7,44].

The presence of several vehicles on transport infrastructures and the intensification of trip frequency produce infrastructure wear and tear, especially in the case of heavy vehicles. Commonly-adopted quantification methods of such externalities can be found both in the scientific literature and official EU reports [5] but are not reported in this paper.

General formulations for evaluating the external costs related to transport activities are in [45,48–50] and in the aforementioned EU projects. In this paper, a simplified model proposed by [51] is adopted, where the external costs are related to the principal identified factors in the last mile delivery:

$$EC_{k,i} = f(D, M, E_i, v, c_k) \tag{1}$$

where:

- $EC_{k,i}$ (€) is the cost of the k-th externality caused by the transport performed with the i-th transport mode.
- D (km) is the demand of freight transport, that is the total overall distance travelled by all the transport means adopted to delivery all parcels. A reduction in the trip number and length reduces this factor, and consequently the overall externalities.
- M (ton) is the load transported; the improvement in the load factor of each vehicle influences the D factor with a reduction in trips or kilometers travelled.

- E_i (unit/ton·km) is the emission factor of the i-th transport means adopted at a given transport speed; the factor is mainly related to vehicle technology and driving behavior.
- v (km/h) is the average speed of travel; this is a particular factor because it is inversely proportional to some externalities: the emissions are reduced at a certain speed and then increased again as a reverse bell curve; the noise pollution increases with speed; therefore, an optimization is necessary.
- c_k (€/unit) is the unit cost of the k-th externality; there are several works with economic values of individual externalities, such as in [3,5].

In last mile logistics, the factors D, E_i and v can be optimized, and therefore, the externalities can be reduced. The optimization of these factors can be done by adopting innovative technologies, strategies and new organizational models. The scientific literature of the last five years on the topic of externalities reduction in last mile logistics is analyzed in this work. Innovative contributions provided in the literature are collected based on Model (1).

4. Last Mile Logistics

In the supply chain, last mile logistics is the least efficient stage and causes up to 28% of the total delivery cost [52]. Recently, several innovations have been introduced in urban logistic and transport systems, mainly thanks to the development of ICT [53].

In particular, the ICT technologies are adopted for:

(a) capillary tracking of displacements with localization technologies (Global Positioning Systems and mobile network);
(b) retrieving and providing information/data from and to the user with satellite or other technologies;
(c) developing of mobile applications with user-friendly interface technologies;
(d) smart collecting and elaboration of information through Internet of Things and big data tools.

The smartphone is a powerful instrument that includes most of these technologies in one device. Many scholars indicate that the future innovations in the transport sector will be related to the use of this device and apps that can be developed for it with an open communication channel for logistics providers [54].

In the following, a classification is proposed, based on the different aspect of innovations, such as new technologies proposed for transport or applied in this sector, or innovative methods and strategies used to improve existing infrastructures and transport systems.

The proposal of the Urban Consolidation Centers (UCC) concept, with innovative management strategies and business models, is an example to improve solutions to problems of urban logistics. The UCC idea, already proposed in the 1970s, is based on a depot place close to the city where the goods are kept before being delivered to the individual retailers and the reduction of city center traffic congestion, emissions and externalities. Another policy adopted in some cities is the restriction of transit of freight transport in specific time windows, in order to reduce congestion in urban areas. A research opportunity is the correct planning for last mile deliveries with time windows; as an example, in [55], a reduction in miles per delivery with the increase of delivery time windows is observed.

An interesting problem is the last mile delivery of perishable goods even though on this topic, relatively few papers exist in the scientific literature. Some authors [56–60] analyze the transport problems of perishable goods related to the stability and perturbations of parameters to have the appropriate quality (with acceptable levels of product waste). Furthermore, the inventory routing problems of perishable goods to reduce environmental impact and CO_2 emissions from vehicles, using time-windows, are considered. In smart urban areas, a transport model based on the adoption of automated electric vehicles for both people transport and fresh food delivery that minimizes empty kilometers, while meeting the constraints on passenger transit time and food freshness, is proposed [61].

The analysis carried out in the scientific literature of the last five years about last mile logistics in urban area and in smart cities allows classifying the innovations able to reduce transport externalities costs into five main categories: innovative vehicles, the proximity stations or points, collaborative urban logistics, optimization of transport management and routing and innovations in public policies and infrastructures. They are detailed in the following section.

4.1. Innovative Vehicles

The innovations introduced in the vehicles market have been disruptive: new engine technologies, autonomous vehicles and novel delivery means are the real driving force behind what the car industry has presented in the last century. Electric, hybrid and Fuel Cell Electric Vehicles (FCEVs) are technological innovations able to reduce externalities: they have positive impacts on environmental and noise pollution, and they are mature for the market. The main constraint of Electric Vehicles (EVs) is linked to battery autonomy (on average, less than 150 km, with few exceptions) and the long charging time. Researchers are focused on improving battery performance and optimizing routing in last mile delivery. People think that FCEVs have safety problems (hydrogen reactivity), but the systems used are very reliable. Moreover, they need fueling network infrastructures not yet developed with few exceptions: in 2016, only 183 fueling stations were operated all over the world, mainly concentrated in the USA (53) and Japan (86) [62]. However, they have the advantage of high autonomy (600–700 km) and short recharge time. Hybrid vehicles are the most sold among those listed, as they have a lower investment cost and high autonomy (fuel + electric battery). Electric L-category Vehicles (EL-Vs), such as mopeds and motorbikes, as well as quad, tricycle and other small vehicles with three or four wheels, comprise another innovative proposal with the introduction of light means for mobility and delivery, suitable for urban areas. They are agile, with low impacts on the city, the need for few spaces for parking and are useful for delivering small parcels. EL-Vs, smaller and lighter than traditional means, are very useful to achieve these goals because they reduce delivery time with no lost parking time required, fuel consumption, air and noise emissions.

Within the category of bicycles and tricycles, cargo bikes have been developed in recent years. Electric traction has allowed improving the capacity, becoming in the new generation of cycles almost equal to traditional vehicles. Therefore, the electric ones are classified as EL-Vs.

Fully-electric-powered vehicles are very important to reduce urban externalities produced by last mile delivery. In this framework, a reduction externalities evaluation is proposed in [63], while in [64], a performance assessment and comparison with diesel trucks are presented. Smart logistics with EV and ICT in urban areas is proposed in [65,66]. The market evaluation shows a considerable interest in EL-Vs, as shown in [67].

Commercial EVs' purchase costs are more expensive than conventional diesel trucks, but the operating costs of conventional trucks are higher than EVs [68]. The EV maintenance is related to the life and long-term costs of batteries, as well as the limited distance without recharging, as analyzed by [69]; in addition, an assessment of support policies for EVs in urban freight transport is proposed by [70]. EVs can help the smart grid with the use of Vehicle-to-Grid (V2G) technology and valley-filling algorithms to reduce hourly electricity price [71] or increase renewable energy use. In this case, the reduction in externalities is a consequence of the reduction of traditional power plants' use.

Autonomous vehicles and autonomous vehicles on demand are considered to be some of the most attractive technologies of the next few years according to [72]. This allows vehicles to be guided without human intervention. Related literature proposes different levels of vehicle automation from no-automation to full automation. Semi-autonomous and fully-autonomous vehicles are in the testing phase; many companies are investing in this technology today also in freight transport.

Derived from the military sector, the autonomous and unmanned systems are divided into Unmanned Aircraft Vehicles (UAVs), ground unmanned systems and maritime unmanned systems; they are also called drones. UAVs have been the most used in civil application in the last few years. In both the public and civil sectors, UAVs open new opportunities. Transport and delivery companies have tested drones to deliver parcels: DHL with PaketKopter, Amazon with Amazon PrimeAir [73], Google with Project Wing [74] and recently GeoPoste with GeoDrone [75]. According to [76], new issues in logistic support services for drones in urban delivery are opened. Another interesting project is presented in [77], where a ground drone-robot is used in last mile logistics for parcel delivery in urban areas. In addition, other related projects with UAVs are ongoing as explained in [78].

4.2. Proximity Stations or Points

The use of proximity stations or proximity points is an innovative strategy to improve the last mile delivery efficiency, particularly to distribute small- and medium-sized goods. This approach is based on the use of a depot station where goods can be stored when the customers are not at home until they can pick them up, thus avoiding the risk of unsuccessful delivery [79].

The proposed idea reduces factor D of Model (1) due to a lower distance travelled by transport means and a higher load factor of transport means. Moreover, with appropriate measures, the delivery time is reduced, and the factor v increases: it is possible to fill the stations during the night, when the traffic is low. This approach leads to both economic and environmental benefits. The use of a proximity point is faced in [80], where a modular bento-box system for storing the delivering goods (parcel) until the customer picks them up is proposed. They may be located in residential districts, inside shopping malls, central squares, etc. The proposed delivery system uses electric vehicles since transport distances are very short. A similar strategy is parcel lockers; they achieved great use in recent years as in the case of the Polish InPost Company system [81]; these systems have been adopted by many logistics operators such as DHL for customer deliveries; the Austrian Post introduced the Post24 Parcel Machines to store and send parcels at any time of the day and of the night. Today, several e-seller companies (e.g., Amazon, eprice and others), in addition to home delivery, use the concept of the proximity point for the withdrawal of goods by customers. The place can be a pick and pay point or electronic locker self-service. In the first case, after online ordering, it is possible to pick the good up and pay at the same point. In the second one, a locker can be opened with a unique pickup code sent by e-mail or short message service on one's own phone. Automatically, all information about availability, location and pick up is online in real time through ICT. International retailers using online selling channels (e.g., MediaWorld, Zara and others) give to customers the opportunity to buy on a website and pick up the goods, after some days, in the physical store without home delivery.

An innovative approach for a proximity station is proposed in [52], with the pick-own-parcel station (pop-station). The proposal is based on the use of stations and ICT to delivery parcels and on crowd-workers to enhance the last mile delivery. A certain amount of money will be rewarded to a worker for the delivery according to the additional travel cost from his/her historical route patterns. The goal is to assign all the parcels in the pop-stations to the most convenient workers so as to minimize the total reward paid by the logistic companies. As in other sharing economy scenarios, the main aim of this application is to maximize the resource use on the basis of a collaborative approach.

4.3. Collaborative and Cooperative Urban Logistics

The collaborative urban logistics concept is a new vision of the last mile delivery where the processes have a better consolidation and synchronization of existing resources. The cooperative urban logistics concept is based on the sharing of the resource and the revenue in the last mile delivery. Coordination is a key element in this process to ensure a synergy between the actors [82]. These approaches are essential in an eco-friendly sector and in a reducing externalities vision, because their use leads to the following advantages: less vehicles used, use of light transport means and with low or zero emissions (e.g., EVs, EL-Vs, FCEVs). Less and smaller vehicles circulating in the city also reduce congestion and infrastructure wear and tear.

The main concept is sharing the resources, infrastructures and transport means to make the last mile delivery in urban areas. The idea is similar to the service of the codeshare agreement among different airline companies at airports [83]. The main advantages are: investments and management cost saving, better use of resources and performance improvement of deliveries in urban areas.

An interactive freight pooling service to reduce undesirable effects and the cost of freight transport in urban areas is proposed in [84]. The problem is decomposed into three distinct phases: collecting user-specified constraints, clustering the delivery points and constructing the actual routes. The proposal is to minimize the total freight distance travelled to reduce the cost of hiring a carrier. The proposed model is based on the money saved to encourage suppliers to participate in this collective effort.

Several researchers treat the use of UCC with a new organizational model and ICT tools for the last mile delivery. An interesting approach is proposed in [85] with a task and a profit-maximizing auction mechanism, to determine the amount of the demand to be fulfilled. The use of UCC in a medium-sized city with ICT tools is proposed in [86]; they applied ITS with a design and monitoring framework methodology to engage stakeholders with policy, vehicles and IT technology to improve the sustainability of urban freight delivery.

A variant of the collaborative and cooperative urban logistics concept is developed in [87], in which the delivery of small- and medium-sized packaged goods is carried out using public transport means. The proposal avoids further worsening of urban congestion and, at the same time, allows reducing air emissions. The work investigated the feasibility of the multi-agent-based simulation model for improving cost efficiency, time and energy consumption.

The urban deliveries of parcels, especially in the food sector, have seen the growth of two main kinds of online platforms: "aggregators", emerging about 15 years ago, and "new delivery" players, appearing in 2013. Both allow consumers to place orders from a variety of restaurants. Aggregators simply take orders from customers and route them to restaurants, which handle the delivery themselves. In contrast, new delivery players build their own logistics networks, providing delivery for restaurants that do not have their own fleets [88]. In this context, several new delivery players have been set up, such as Deliveroo, Just-eat, foodpanda and UberEATS, and they use bikes as the means of transport.

4.4. Optimization of Transport Management and Routing

City logistics is a very important concept in urban delivery. City logistics is defined in [89] as the process of totally optimizing the logistics and transport activities by private companies with the support of advanced information systems in urban areas; here, the optimization considers the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of a market economy. The application of innovative technologies of ICT and ITS in a city logistics concept is presented in [90]: urban freight transport management and joint delivery systems are the main proposals.

The development of ICT and Industry 4.0 (a large number of sensors, IoT and big data) are both applied in infrastructures and vehicles, allowing a different approach to mobility. The cost of sensors has dropped considerably over the years, thus allowing one to adopt them to monitor several aspects of the vehicle, both during the trip and in the stationary mode. All this information can be processed to optimize environmental, economic and social performance. It is possible to monitor fuel consumption, tire wear, brakes and other components, the temperature of the goods, vibrations, and more, in order to provide optimized maintenance and/or service interruptions to improve service.

According to [91], big data and analysis, decision support systems, energy saving technologies, co-modality, land use, freight and road pricing are innovations, technologies and practices allowing optimization of city logistics.

Algorithms and optimization systems can be used to improve performance in the last mile delivery: real-time data, dynamic route planning algorithms, fleet management solutions, tracking devices, identification means and devices. These innovations are often offered as apps for mobile phones. Vehicles Routing Problems (VRPs) are optimization problems typically studied in transport activities. Many studies with several approaches have been proposed in the scientific literature. Optimization strategies in urban delivery adopting Autonomous Electric Vehicles (AEV) are presented in [61]; the authors propose a model based on the traveling salesman problem, pickup and delivery problem and ride-sharing problem.

A green VRP to aid organizations with alternative fuel-powered vehicle fleets in overcoming difficulties that exist as a result of limited vehicle driving range and limited refueling infrastructure is formulated and solved in [92]. In addition, the use of EVs in last mile delivery needs to consider the autonomy of vehicles, the charging point position and the recharging time. In the scientific literature, VRP with EV (named green VRP) is solved using two different approaches: fixed autonomy and recharging option. The first approach aims to ensure energy for vehicles to return to the depot as in [93,94]. In the second case, a VRP with pick-up and delivery is solved, and the number of required recharges is computed by dividing the total distance by the vehicle range. Thanks to the increase of EV capacity, the last approach has been less investigated in the last few years.

4.5. Innovations in Public Policies and Infrastructures

The use of proper policies and regulation is fundamental to reduce externalities, in particular congestion, noise and air pollution, produced by delivery activities in urban area. In addition, ICT and ITS are very important to achieve great results with the same objective. The diffusion of sensors, the development of ICT, ITS and Industry 4.0, even within cities, comprise a new strategy to control smart cities, in particular for smart mobility. The use of video and the collection of data on vehicles, flows and traffic allow the municipal authorities to be able to modify the traffic conditions in real time. Examples of innovative approaches to the traffic management systems for smart cities are proposed in [95]: a traffic management system is able to collect data from several sensors, processing and aggregating data to improve the system.

Moreover, a smart traffic light management system is an interesting research field, since the synchronization of multiple traffic light systems at adjacent intersections is a complicated problem given the various parameters involved. In [96], an approach to solve this problem using Infra-Red (IR) sensors and accomplishing dynamic timing slots with different levels is presented, but much research is still required on this topic: optimization of traffic lights at intersections in order to increase the performance of delivery vehicles on dedicated lanes in specific time windows is still an open issue.

Time windows are a solution adopted by many cities to reduce these externalities, and the scientific literature shows that delivery activities can have the same performance with a correct setting of the VRP. Electric VRP with time windows and recharging stations is presented and solved in [97]. In [98], a mixed vehicle routing problem with time windows, recharging stations and an electric fleet with different vehicles capacities is solved; vehicle types differ in battery size and acquisition cost. The electric modular fleet size and mixed vehicle routing problem with time windows is proposed in [99], in which recharging at the customer location is considered; a genetic algorithm-based approach to solve the problem is formulated.

Urban pricing area and mobility credits are recent solutions adopted in many cities to reduce the number of vehicles in the city center or in specific city zones. Based on the European principle of "pay for use", different urban pricing systems have been developed: (i) pricing area, (ii) cordon pricing and (iii) distance-based pricing are the main forms. They differ for the application of the charging cost: in the first case, the vehicle pays for daily access to the restricted area; in the second case, the vehicle pays for every crossing of the restricted area; in the third case, the cost is related to the distance travelled by the vehicle in the restricted area. An urban pricing scheme can be used also with time windows to enable free access in no-peak time periods, e.g., the night. Mobility credits are a particular form of incentives based on permits and not on restrictions: a limited budget is allocated to every user by a public administration, and a self-regulation system is adopted. Cities currently adopting these systems and regulations for last mile delivery are still few, and their potentialities deserve to be more investigated in the scientific literature.

Recent research findings on the last mile delivery issue classified into the five categories discussed above are in Table 2.

Table 2. Last mile logistics innovations to reduce externalities in urban areas.

Logistics Innovation	Paper, Year	Research Finding	Impact on		
			D	E_i	v
Innovative vehicles	[63], 2013	Assessment of the potential benefits of electric vehicles, especially in urban delivery of goods		X	
	[64], 2013	Assessment of the electric vehicles in an urban delivery center by means of a discrete event model simulation and different scenarios		X	
	[65], 2015	Assessment of the small- and medium-sized fully-electric vehicles used for the last mile in freight transport handling with ICT support		X	
	[66], 2014	Multi-dimensional drivers and challenges for the use of electric freight vehicles in urban areas		X	
	[67], 2016	Assessment of the market of light electric vehicles and the potential application with a forecast scenarios		X	
	[68], 2013	Analysis of the economic and technological factors for electric commercial vehicles compared with diesel trucks for several scenarios		X	
Proximity station	[52], 2016	A crowd-tasking model based on large-scale mobility with citizen workers is used in the last-mile delivery	X		
	[80], 2012	Innovative logistics model for urban deliveries: using a two-vehicle typology (freight bus and delivery van) and modular bento box	X		X
	[81], 2015	Analysis of the efficiency in parcel lockers as a last mile delivery solution	X		
Collaborative and cooperative logistics	[83], 2014	Synchronized last mile concept with multi-objective planning	X		
	[84], 2015	A model of the delivery network through interactive interfaces	X		
	[85], 2014	Regulation and thinning profit margin in the urban consolidation center	X		
	[87], 2016	A system model that uses existing public transport facilities of a city for packaged goods	X	X	
Optimization of transport management and routing	[61], 2016	Minimization of empty vehicle kilometers with automated electric vehicles to provide both people transport and fresh food delivery	X	X	X
	[90], 2014	Application of innovative technologies of ICT and ITS to city logistics	X		
	[91], 2015	New opportunities and challenges for city logistics	X	X	
	[92], 2012	A green vehicle routing problem	X	X	
	[93], 2013	Accurate range prediction for electric vehicles in a routing system that could extend the driving range of electric vehicles	X	X	
	[94], 2013	Determination of the optimal fleet size to transport a known demand of cargo, located at a central depot, to a known set of recipients using vehicles of different types	X	X	
Innovations in public policies and infrastructures	[95], 2015	Improve the efficiency of traffic management systems through advances in sensing, communication and dynamic adaptive technologies	X		X
	[96], 2016	System to evaluate the traffic density using IR sensors and accomplishing dynamic timing slots with different levels			X
	[97], 2014	Electric vehicle routing problem with time windows and recharging stations	X	X	
	[98], 2016	Mixed vehicle routing problem with time windows, recharging stations and electric fleets with different vehicle capacities	X	X	
	[99], 2015	Adoption of an electric modular fleet size and mixed vehicle routing problem with time windows	X	X	

5. Conclusions and Discussion

The last mile delivery faces a dual challenge: it must satisfy the demands of globalized trade and meet environmental requirements. In this context, innovation is a crucial topic to enable the transition from the current logistics systems configurations towards more sustainable ones.

Last mile logistics is an important phase in the supply chain. Researchers and practitioners are both involved in jointly increasing delivery systems' efficiency and reducing the related externalities.

Technologies, transport means, model and organizational strategies proposed in the scientific literature of the last five years can address several aspects of the externalities model presented in Section 3: reduction of the overall distance travelled (D, solving VRP problems, increasing the load factor and/or adopting logistic reconfiguration), of the emission factors (E_i, adopting low or zero emission vehicles and/or sharing vehicles) or increase of the average transport speed (v, delivering in appropriate time windows).

The transport externalities in urban areas are of a different nature: air pollution, due to vehicles' emissions; noise pollution, produced by the high number of vehicles in circulation and by conventional engines; accidents, mostly related to driver distraction; congestion, generated by the high number of vehicles in the city; land use, due to the spreading of vehicle; infrastructure wear and tear, generated by the frequency and weight of vehicles; energy dependency caused by traditional power technology and engine inefficiency.

The innovations with a potential in reducing impacts and externalities can be classified into five main categories: new vehicles, proximity stations or points, collaborative and cooperative urban logistics and optimization of transport management and routing. Each of these has strengths and gaps that can be considered as research opportunities.

Combining these innovations and using them together (e.g., using EL-Vs for delivery in a cooperative urban logistic concept integrated with ICT tools and depots distributed in the city districts), a smart logistics system would be created.

From the authors' perspective, literature gaps in each of the aforementioned categories exist. They are discussed in the following.

1. Innovative vehicles can be divided into several types:
    a. EVs: they require more study for the improvement or new technologies able to provide greater autonomy, reduced charging time and lower prices for a complete deployment.
    b. FCEVs are in a mature phase of research; they are on sale on the market. Fueling infrastructure is lacking, and standardization is needed through adjustments of countries' rules and regulations for the operating pressure. Harmonization based on scientific studies capable of demonstrating safety and operational performance is not present.
    c. EL-Vs are an interesting area of research because their use in the city is becoming a remedy to the impacts generated by traditional transport. It is necessary to study the impact on the externalities reduction achievable with their diffusion. Furthermore, their continuous use and the opinions of the stakeholders would allow understanding what are the improvements needed in the field of infrastructure, urban planning and vehicle characteristics required.
    d. Autonomous vehicles are still in the testing phase, to improve hardware and software systems. In particular, the latest research works are focused on the software systems, studying the algorithms that can improve safety performance and decision support systems to manage dangerous situations.
    e. UAVs can be studied for the use of autonomous or remote driving with specific algorithms.
2. Proximity stations or points require more studies on optimizing the capacity of depot stations with high saturation rates, which are expected in the future. Furthermore, it is useful to identify the best position within the city able to reduce externalities.
3. Collaborative and cooperative can be divided into two sub-categories:
    a. UCC with the use of ICT and ITS tools can improve their performance through innovative forms of management. Recently, different modalities coming from other sectors have also been used.

   b. Sharing of resources, both fleet vehicles and other infrastructures, expanded the research fields, as in the case of new delivery players in the food sector.

4. Optimization of transport management and routing is a very important research area for several applications in last mile delivery. The optimization techniques can be applied to several aspects able to reduce externalities in smart logistics. Real-time data, prediction methods and decision support systems still require research attention to make the systems more efficient.
5. Innovation in public policies and infrastructures is one of the areas in which it is still necessary to explore and study new strategies to reduce externalities considerably in last mile delivery activities. Time windows, traffic management systems with sensors, smart traffic light management, urban pricing area and the model of mobility credits are very interesting solutions that require more in-depth analysis.

A smart city will have to use innovative approaches to the last mile delivery problem. The increase of express shipments, caused also by the growing sales of the online market, new ICT and the Industry 4.0 paradigm that allow retrieving a huge amount of data generated from infrastructures, devices and vehicles are factors to be managed in a city that have to be rethought in terms of the mobility of goods. One of the main objectives of a smart city is to considerably decrease the externalities generated by the last mile delivery activities. The commitment of all stakeholders and the application of the proposed solutions are essential to achieve sustainable logistics in urban areas.

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