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On-Demand Logistics: Solutions, Barriers, and Enablers

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Abstract: The urban freight sector provides an essential service by delivering goods that are required by shops, companies, and households at a specific place and time. However, the growth of e-commerce and the dawn of on-demand logistics (hereinafter ODL) have raised citizens' expectations of logistics systems, further stressing them and thereby increasing their operational and environmental costs. To the authors' best knowledge, there are no extensive literature reviews specifically on the topic of ODL and on suggestions for policy prioritisation for tackling its effects. This paper aims at addressing this issue by providing an extensive literature review of ODL and its enablers. This research, after a thorough explanation of the ODL rationale, its trends, and its effects, analyses possible solutions to its inefficiencies, focusing on enablers and barriers. Furthermore, it illustrates and clarifies the role of external factors in influencing ODL. Finally, it proposes a systematic evaluation approach by identifying knowledge gaps and consequently defining the subsequent actions needed, broken down by the individual influencing components, rendering these solutions compatible with the *status quo* and effective for solving the highlighted issues.

Keywords: last-mile delivery; sustainable mobility; on-demand logistics; urban freight transport

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1. Introduction

In 2020, around 56% of the world's population resided in urban areas [1]. Cities consume huge amounts of available resources and energy and generate most of the overall CO2 emissions produced, while occupying only a small portion of the land [2], which highlights the role cities play in the current economic development model [3].

The increasing amount of people located in cities and also the number of tourists now starting to travel again implies new challenges, including mobility and logistics-related issues [4,5]. If cities are the centre of a globalized society, the transport sector is its foundation. The flow of goods and services, people, and information, and the worldwide supply chain are made possible by infrastructure, logistics capabilities, and the resilience of the transport system, as the crisis caused by the COVID-19 pandemic has clearly proven [6,7].

The inefficiency of the transport sector is even more noticeable in cities because of the consequences it generates. High density and new commercial paradigms, such as e-commerce and on-demand economy, exacerbate negative externalities (e.g., air pollution, noise, accidents, and congestion), which not only undermine the productivity of urban economies but directly affect the people's quality of life.

The increase in external costs can be attributed to the higher number of freight commercial vehicles (FCVs) used for last mile deliveries. FCVs, although representing a minor proportion of the total number of vehicles circulating within a city, play a fundamental role in explaining urban road-space occupation and the insurgence of negative externalities. FCVs travel 15–25% of the overall kilometres travelled in cities, occupy 20–40% of the urban road space, cause between 20% and 40% of CO2 emissions related to urban transport and are responsible for 30–50% of the main air pollutants (PM and NOx) [8].

Negative performance in urban logistics would have detrimental consequences for the liveability of cities and globally in the overall fight against climate change. Some scenarios today predict a 78% increase in last-mile delivery by 2030 [9]. The subsequent increase in delivery vehicle movements in cities would provoke a 21% increase in congestion, equivalent to an additional 11 commuting minutes in 2030 compared to 2010. Moreover, ton-kilometres by goods vehicles are estimated to triple by 2050 compared to 2010 [10].

The increase in commercial vehicles used for freight transport not only depends on the increased demand for goods and services due to the growth in the number of city dwellers and the growing logistics sprawl but also depends on the increase in e-commerce and ODL. E-commerce is now experiencing more than 10% growth per year worldwide. Over five years, e-commerce sales ratios nearly tripled globally [11]. Internet usage is undergoing further acceleration due to the COVID-19-related restrictions. Remote working and e-commerce have spread rapidly, reducing the passenger traffic flow on city streets [12]. Households have lowered their demand for traditional purchases from nearby stores, and the consequent boost in e-commerce platforms has increased the demand for home deliveries [13]. The increase in the number of e-commerce operations translates into an increase in urban freight transport (UFT) and light commercial vehicle use; B2Ce-commerce deliveries rose by 25% in 2020 [14]. One in ten citizens receives one parcel a day, and in major cities like Paris, up to 60% of people use home food delivery services. Moreover, for every 1000 urban inhabitants, 300 to 400 freight journeys are carried out [15]. If this trend continues over the coming years, the growing demand for e-commerce delivery will result in a 36% increase in delivery vehicles in inner cities by 2030 [9]. In theory, online shopping can make people shop less in physical stores and therefore travel less–thus, reducing the total amount of kilometres travelled. Nevertheless, the total amount of kilometres travelled, considering both freight and passenger transport, has not seemingly decreased [16]. E-commerce appears to be complementary and, at the least, not a substitute for traditional retail-generated trips, proving itself to be an additional source of externality as a result of the development of the on-demand economy and the *just-in-time* logistics paradigm. Moreover, the high proportion (up to 35%) of failed first-time deliveries generates additional trips and poses hard-to-solve sustainability issues [9,17,18].

The on-demand economy refers to a new economic paradigm based on the use of online platforms that allow immediate matching between a user requiring goods or services and another who can provide these by sharing the goods, skills, or time he/she is in possession of [19]. The term on-demand refers to the almost immediate use of a service. ODL conceptually refers to a service that, taking advantage of professional crowdsourced delivery capabilities, aims at providing a tailored yet low-cost delivery service capable of satisfying customers' desired time and place at short notice. In the e-commerce sector, this translates into the sale of immediately deliverable products. Amazon Prime and Amazon Now, for example, allow online products to be received within a day or even one hour. This scheme creates stiff competition among operators who are inclined to act with half-empty vehicles to deliver products as quickly as possible and gain customers' trust at the cost of incurring short-term losses. Returns represent a significant cost too for both transport companies and the community.

Many solutions have been developed and tested to deal with ODL issues (see the next section), but more needs to be done to implement them in the urban environment.

In particular, in order to obtain wide acceptance of the implemented solutions, it is crucial to raise awareness of the problems encountered by urban freight distribution among all stakeholders and actors involved. This also applies to citizens who are often unaware that they are the natural recipients of the goods handled and thus the cause of all logistics activities in a city, especially in light of the recent e-commerce increase. And it is even more true for operators and administrators who are confronted on a daily basis with a need to adopt measures that ensure sustainable mobility in urban centres. The main goal of this paper is, thus, to provide a comprehensive review of ODL innovations and to highlight their enablers and barriers. In particular, the results obtained by this research provide managers and local administrators with recommendations about areas of interventions to be prioritised, in order to favour the uptake of these ODL innovations while considering the external influencing factors.

In this study, three major research questions are formulated to address knowledge gaps within the extant reviewed literature:

Q1—What are the main innovative solutions for ODL?

Q2—What are the enablers and barriers characterizing and influencing their effective uptake and upscale?

Q3—What are the priority intervention areas for removing the barriers, and how can we define specific influencing components?

Apart from the first two analytical and more descriptive questions, the real added value and novelty of this study consists in proposing and prioritising the measures to be implemented.

The paper is structured into five sections. After this introduction, Section 2 briefly presents the five-step methodology used, including the ten selected solutions and their enabler and barrier factors. Section 3 illustrates the results, while Section 4 concludes, providing policy implications and suggestions.

2. Literature Review/Overview

The literature review reported below aims to clearly position this paper in the extant scientific literature on the topic.

The aim is twofold:

individuating the gap in the literature that this paper will contribute to bridge;
clarifying the goal of the research.

The theme of ODL has been widely explored.

There are several studies that offer an overview of the most promising ODL solutions [9,20–27].

In particular, grey literature highlights the best practices in the field, especially in the context of European projects. The BESTUFS project [28] and BESTFACT [29] provide a succinct list of best practice in Europe, while the results of the NOVELOG project [30] present a decision support system tool by selecting the best measures, with their estimated/measured effects according to the urban freight logistics profile of a chosen city.

Many studies provide classifications of ODL innovations. For instance, [23] grouped them into material/immaterial, equipment, and governance measures, while [31] divided UFT solutions in six classes: stakeholders' engagement, regulatory measures, market-based measures, land use planning & infrastructures, new technologies, and eco-logistics and awareness raising.

By contrast, a systematic analysis of the influencing factors in urban freight transport, namely the enablers of and barriers to ODL solutions, is less common.

Reference [30] in the NOVELOG project defines a list of five potential influencing factors, showing that user requirements, logistics solutions, and economy and demographics are the most important factors according to the stakeholders.

Instead, it is noteworthy that several literature reviews exploring specific ODL solutions provide information on enablers and barriers:

(1) Reference [32] offers an overview of the operational characteristics and challenges of crowd-shipping platforms; (2) the authors of [33] deliver a comprehensive state-of-practice review of UCCs in Europe, highlighting the success factors, viability drivers, and common sources of failure; (3) reference [34] examines the potentials and challenges of drones; (4) reference [35] analyses drone logistics barriers; (5) the authors of [36] show the emerging responses for safety, liability, privacy, cybersecurity, as far as automated vehicles

are concerned; and (6) reference [37] explores the enablers of and barriers to automated solutions in ODL.

However, there are no papers that systematically connect grouped ODL innovations with those influencing factors that act as enablers and barriers.

Furthermore, there are no studies that prioritize these innovations according to the influencing factors.

For these reasons, this paper focuses on the aforementioned questions.

3. Theoretical Background and Analysis Process

This section describes the well-structured process, firstly presented in the H2020 project LEAD (Low-Emission Adaptive last mile logistics supporting 'on Demand economy' through digital twins; www.leadproject.eu accessed on 20 April 2022), and adopted to identify different typologies of agile storage and last-mile distribution schemes and their critical factors.

It provides ten solutions, offering the potential to rationalise and reduce the negative impacts of urban ODL operations (Section 3.1) and further discuss their 'enabling and barrier' factors, which affect the deployment and upscale of ODL solutions (Section 3.2).

3.1. A Five Step Approach

The analytical framework adopts a five-step approach that are illustrated in Figure 1.

Figure 1. Five-step approach of the methodology.

The first step mapped ODL solutions using journal articles and the grey literature (e.g., European project deliverables or technical reports). Literature research includes academic research and articles published between 2000 and 2022. The searching strategy was based on six strings separated by proper Boolean operators as follows: last AND mile AND logistics AND solutions OR innovations OR measures. The initial number of 375 documents on the SCOPUS database, combined with the grey literature also based on the authors' knowledge of technical reports and European projects—e.g., CITYLAB (http://www.citylab-project.eu accessed on 20 April 2022), STRAIGHTSOL (http://www.straightsol.eu/ accessed on 20 April 2022), BESTUFS (http://www.bestufs.net/ accessed on 20 April 2022), C-LIEGE (http://www.c-liege.eu/home/ accessed on 20 April 2022), CITYLOG (https://cordis.europa.eu/project/id/233756/reporting/it accessed on 20 April 2022), and NOVELOG (http://novelog.eu/ accessed on 20 April 2022)—were refined thanks to abstract and keyword-related considerations. Finally, a snowball approach was also applied. The output of the first methodological part consisted in identifying the ten solutions supporting the implementation of agile storage and last-mile distribution schemes.

Secondly, the solutions were grouped into four categories, considering their intrinsic characteristics: (i) delivery locations, modes and times; (ii) loading and unloading area management; (iii) consolidation; and (iv) automated deliveries based on [38].

As a third step, for each of the solutions identified, a literature review was carried out to consolidate the knowledge about the enablers and barriers that characterise and influence each solution's effective uptake and upscale–initiated in [39]. For each of these, the searching strategy was based on seven strings separated by proper Boolean operators as follows: name_of_the_solution AND enablers OR barriers OR challenges OR issues OR factors OR problems.

As a fourth step, the enablers and barriers were identified, distinguished, and analysed considering the main critical factors influencing UFT, namely: stakeholders' engagement, regulation, organisation, and technology–described in Section 3. Enablers and barriers were matched with the influencing components to determine which are the most promising and most critical elements for each, providing suggestions for the prioritisation of specific intervention areas (fifth step).

3.2. Influencing Components

Many solutions could support the implementation of agile storage and last-mile distribution schemes. However, none of them can prove effective without considering exogenous influencing components. These are intended as follows and are based on an adaptation from [39]:

Stakeholders' engagement;
Regulation;
Organisation
Technology.

3.2.1. Stakeholders' Engagement

Freight transport at the urban scale includes a wide range of stakeholders who [40] might be interested in the urban freight system or be able to directly influence it. According to their needs and values, they may pursue distinct objectives and hence are expected to be differently affected by different intervention measures [41]. For example, as often reported, some actors may reject possible urban freight solutions, hinder their implementation, and cause their failure [42]. Stakeholders' engagement in transport planning, under specific conditions [43], can help overcome this since it produces a sense of decision ownership that, in turn, generates a sense of responsibility and trust among these actors [44]. In turn, this leads to shared solutions between the actors, which may be both long-term efficient and sustainable [45,46]. Living labs and freight quality partnerships represent participative schemes widely applied in UFT planning based on stakeholders' engagement [47,48].

3.2.2. Regulation

Traditionally, UFT regulation focuses on traffic flow and public land use. Regulation, by influencing urban freight spaces (e.g., hub location, loading and unloading areas, parking, bike lanes, electric charging stations, and parcel lockers) and accessibility (e.g., LEZ and time windows), also impacts UFT operational decisions. However, recent innovations in UFT urged local authorities to set up regulations in other UFT-related fields. Notably, new logistics modes (e.g., crowd-shipping and parcel lockers) and technologies (e.g., drones and automated robots) require new laws concerning privacy, safety, security, liability, and ethics, as well as amendments to the existing labour and competition laws (e.g., crowd-shipping and instant deliveries). In other cases, the operational requirement of several logistics solutions shall be enabled via a comprehensive set of regulatory interventions (e.g., drones, automated robots, and low-emission vehicles). Pricing, incentives, and taxation represent other crucial regulation tools [49]. In summary, regulation has an impact on the possibility to rigorously test and deploy innovative solutions, as well as on creating the necessary preliminary requisites for developing new and financial, as well as environmentally sustainable, business models, which are currently facing substantial uncertainty [50,51].

3.2.3. Organisation

When dealing with daily activities, UFT actors interact with many other supply chain stakeholders whose future actions are not always predictable, are often under time pressure, and characterised by an uncertain demand and/or supply contexts. All these elements make organising logistics a daunting task. Stakeholders, in order to reach a break-even point, should properly define:

- a cost-benefit distribution model among the actors involved;
- services offered;
- strategic conditions (e.g., location of the hub/warehouse, area served, fleet range, product types, etc.);

- new technologies integration (e.g., IT platforms).

3.2.4. Technology

It is essential to consider to what extent and how the development of new technologies makes ODL more efficient and sustainable. In this century, in fact, disruptive technologies have seen, or will see, application in cities. Some of them (e.g., intelligent transport systems) have already been applied with success, while others could be deployed in the near future (e.g., driverless technology and digital twins), have limited use (e.g., augmented reality), or will follow a long and challenging path before their implementation (e.g., physical internet). Overall, these innovations will enhance the productivity of the UFT system by:

- predicting UFT operations;
- increasing visibility of the whole supply chain;
- automating specific tasks (e.g., warehousing and transport delivery).

4. Results

This section provides an overview of the main logistics solutions identified (Table 1), together with their enablers and barriers. Subsequently, it extrapolates the enablers and barriers for each macro-category (Tables 2–7), distinguishes, and characterisees them based on the influencing components described in Section 3.

4.1. On-Demand Logistic Solutions

This section discusses the ODL solutions that support agile storage and last-mile distribution schemes, which offer the potential to rationalise and reduce the negative impacts of urban ODL operations. Table 1 identifies four categories: (i) delivery location, modes, and times; (ii) loading and unloading area management; (iii) consolidation; and (iv) automated deliveries [38]. These categories are different yet complementary and should be investigated and validated through an integrated approach to define policies for the rationalisation, efficiency, and greening of ODL. Nevertheless, this categorisation also allows the separate consideration of the impact of external factors, such as stakeholders' engagement, regulation, organisation, and new technology, for each category, looking at specific enablers and barriers.

Table 1. Innovations and solutions for agile storage & last mile distribution schemes.

Delivery Location, Modes, and Times	Loading/Unloading Area Management	Consolidation	Automated Deliveries
Innovations and solutions to improve the delivery process, i.e., where the goods are delivered, how, and at what time.	Innovations and solutions to improve the management of scarce urban space, in a flexible and integrated way, and of the contested kerbside.	Innovations and solutions to better consolidate and improve the management of flows. This includes both delivery and demand consolidation.	Automated solutions (e.g., drones an droids) can make the freight distribution process more efficient.
Parcel lockers Pickup Points Click and Collect Crowd-shipping Off-hour deliveries	Management of loading/unloading areas	Urban Consolidation Centre Micro-hubs	Drones Automated robots

Source: Authors' adaptation of [38].

4.2. Delivery Location, Modes, and Times

4.2.1. Parcel Lockers

Parcel lockers are automated lockers located in places usually frequented by many and diverse users, such as post offices, supermarkets, petrol stations, commercial roads, metro stations, railways, parking lots, etc., to pick up and/or return e-commerce products via the consumers themselves [52,53]. From a logistics point of view, they allow for the consolidation of goods delivery and avoid attendance delivery issues, thereby reducing internal and external costs [20,54–56]. The existence of consolidated operational models makes parcel lockers a commonly adopted solution by transport and logistics service providers in several countries (e.g., Denmark, Poland, Finland, and Germany) and paves the way for expansion in many other countries where it still has a low market penetration [20,57–59]. Nevertheless, there are still several barriers limiting its generalised and widespread adoption. First, from a regulatory point of view, when it comes to parcel locker installation in public spaces, the absence of specific regulation and bureaucratic delays limits the possibility of creating an extensive and coordinated parcel locker network [59]. Second, the psychologically-perceived risk of parcel locker usage (i.e., financial, security/privacy, performance, and time risk) and poor parcel–locker network design can reduce consumer preference toward parcel lockers [60]. Finally, the high fixed costs of the parcel locker network infrastructure can thwart investors' interest since profitability requires high sale volumes, and the market does not always comply with this requirement [61].

4.2.2. Pickup Points

Pickup Points are stores where consumers can pick up or return their purchases. Similar to parcel lockers, they aim to maximize goods consolidation, minimize missed deliveries, and produce positive impacts on internal and external costs [62]. In some cases, they present a consolidated operational model capable of offering advantages to transport service providers (i.e., optimising delivery rounds and increasing the number of successful first-time deliveries), shop owners (i.e., a potential increase in the number of customers), and consumers (i.e., more flexibility), and are also cheaper compared to parcel lockers [63,64]. This delivery solution is generally preferred over parcel lockers and is widely adopted in France, the Netherlands, Sweden, Denmark, Finland, Norway, and Belgium [58]. However, in some cases, IT integration across the supply chain partners and the management of huge pickup point networks could represent a significant barrier to their deployment (*ibidem*), especially if transport providers adopt pickup points as their only service and cannot achieve economy of scale [64,65].

4.2.3. Click and Collect

Click and collect is a delivery mode whereby products are picked up at the e-retailer's physical store or at a centralized collection point (i.e., dark store). This solution is widespread, but is still not consumers' most preferred option [66–68]. For instance, in Norway, only 13% of e-consumers would choose it as their first delivery option [58]. It aims to limit home deliveries by bringing customers to special stores, and then secondly, by encouraging online buyers to make additional purchases once they arrive in the store. In fact, according to [69], 11% of the individuals using this method always make an additional purchase at the store, with 60% sometimes doing so. The low cost and the possible extra profits from this represent the enablers of this solution, with respect to more traditional home delivery. However, the extra labour costs due to setting up the pick-up and packing services can make this activity unprofitable, especially when inducing low order volume and/or many low-value items [70].

4.2.4. Crowd-Shipping

Crowd-shipping, originally developed in Mumbai [71], operates by outsourcing deliveries to a fleet of non-professionals [72]. It represents a passenger–freight transport integration example [73]. A restrictive interpretation of this notion, adopted in this paper, focuses on the goods delivery as an event within a predefined route and a recurrent action of an individual, preferably using public means or active modes. In fact, only in this way can it achieve clear environmental gains [74–76]. Recently, several e-retailers and start-ups started to employ crowdsourced workers, pushed by cost reduction and by new market segment exploitation (e.g., instant deliveries). In fact, this solution eliminates the costs associated with maintaining warehouses, vehicle fleets, fuel consumption, and professional drivers [32]. Considering the definition of crowd-shipping adopted, several success stories have emerged worldwide (e.g., TakemyThings in Italy and Hitch and Roadie in the US). Other positive examples pertain to public-transport-based crowd-shipping (e.g., BussGoods in Sweden, Maktuahuolto in Finland, and BusMyThings in Italy [77–79]). These experiences highlight the importance of a clear business model and, in some cases, the role of public transport providers and their partnership with the private sector. Other enablers come from modelling innovations and analytical machine learning tools, and artificial intelligence software capable of dealing with uncertainty in demand, supply, and system conditions [32]. The barriers here concern the difficult management of the platform and the role of regulation. The former consists of simultaneously incorporating crowd-shippers' needs (e.g., adequate compensation/wage and other benefits) into real-time pricing and matching decisions to maintain a satisfactory number of couriers and, at the same time, provide an attractive service to users [32]. Furthermore, on the demand side of things, trust-related issues (i.e., service reliability and privacy) contribute to enhancing the difficulty of this method. Consequently, choosing the proper combination of delivery service, time, and costs can be challenging. As far as regulation is concerned, labour law, minimum wage, social protection, health insurance, third party damage liability insurance, privacy protection regulation, and tax regulation could all imply extra costs, curbing profits and thereby discouraging these activities [80,81].

4.2.5. Off-Hour Deliveries

Off-hour deliveries constitute a well-known last-mile logistic strategy. Off-hours deliveries could be combined, for example, with the use of parcel lockers, electric vehicles, or urban consolidation centres (UCCs) [9,82]. The rationale of this implementation rests upon the idea that more evenly distributing traffic over time and shifting freight deliveries from peak hours to off-peak hours would lead to decongestion and more efficient operations.

This, in turn, would promote internal and external cost-reduction [9,83,84]. In fact, during off-peak hours, vehicles can travel at higher speeds with lower risks for pedestrians and perform loading and unloading activities in a much more efficient fashion while also guaranteeing higher reliability of deliveries. Unassisted and assisted off-hour deliveries have been successfully applied in several cities such as New York, Barcelona, and Paris [85–87]. The application of this solution, however, is not easy since stakeholders in an urban environment pursue different and often contrasting objectives. The main barriers to their uptake include the following [87,88]: convincing participants to try the scheme (i.e., receivers to accept off-hour deliveries and carriers to invest in low-noise technology); matching carriers and receivers so that the former can overcome break-even point issues during their off-hour tour; convincing local authorities to relax existing restrictions on vehicle circulation rules; and limiting noise-related issues linked to loading and unloading activities. Proper stakeholder engagement represents the key enabling factor to deal with the previously described barriers. Authorities at a different governance level should also cooperate to effectively address regulatory issues, but also key business actors should contribute to the co-definition of the scheme [88,89], accompanied by an incentive framework accounting for all freight supply chains.

4.3. Consolidation

4.3.1. Urban Consolidation Centre

A UCC is a "logistics facility that serves a city centre, a whole town or a specific site (e.g., shopping centre). At this facility, which is located near the area served, consolidation operations take place, and then deliveries are executed with environmentally friendly vehicles for the last-mile journey to the "drop-off point" [90]. Facilities can be large warehouses but also transhipment hubs or containers. A UCC can provide several services, ranging from shipment consolidation to specific services for retailers (e.g., price tagging, storage of stocks of products, return of goods, and last-mile delivery and waste collection). This scheme hinges upon the idea that it is possible to reduce costs (e.g., fuel, insurance, maintenance, and drivers) and trips by consolidating deliveries while obtaining environmental and social external reduction [9,20,91–93]. Freight carriers benefit from the reduced time needed to perform deliveries and, similarly, receivers increase their operational efficiency thanks to the improved delivery time reliability, lower delivery frequency, improvements to stock management, and other inventory services provided by the UCC [94].

However, only 35% of total cases for this solution proved effective without public funding [33,95]. The main barriers to effective deployment of this solution include: (i) stakeholders' conflicts (e.g., conflicts between the carriers and local authorities or between the carriers and receivers) often due to "the extent to which the various participants (e.g., carriers, receivers, and local authorities) are willing and able to meet the financial costs of the UCC in return for the benefits that they receive" [90]; (ii) lack of participation due to reasons of convenience (e.g., retailers prefer to manage the deliveries process on their own); (iii) the lack of a clear allocation of costs and responsibilities along the supply chain; and (iv) low public support (i.e., regulation and funds).

The extensive literature on the subject does not indicate a specific winning business model, yet it pinpoints some pivotal factors for the success of a UCC. When setting up the UCC, one must properly consider city size, location, catchment area, density area, and product typology. Public subsidies and regulatory incentives (e.g., restrictions on other goods vehicle operations) represent key supportive elements for implementing financially viable business model so as to support the initiative and reach a break-even point [33]. Structured stakeholder engagement procedures are essential for involving carriers and shippers from the very beginning [33]. Proposing innovative services coupled with an appealing value proposition is important in providing an additional, yet at times fundamental, source of revenue streams. Finally, all success cases were characterised by the presence of a key actor knowledgeable about the whole supply chain [95].

4.3.2. Micro-Hubs

The idea of UCCs, after several failures of the large UCCs in the 1990s, has, in some cases, evolved. In fact, the new and smaller UCCs, with a shorter delivery range [96], can, in principle, be assimilated to transhipment points rather than full-blown UCCs. They typically offer less services and are located near the final delivery point in a dense urban setting [97,98]. These new logistics facilities go under the name of micro-hubs, micro-consolidation centres, micro-distribution facilities, and micro-depots. The adoption of lighter and clean vehicles and modes (i.e., small electric vans, cargo-bikes, walkers) represent the most relevant feature of the scheme [99]. In addition to the environmental benefits, researchers emphasise the potential economic benefits for society (i.e., less congestion, noise, and accidents) and transport operators since under specific conditions, this solution could reduce delivery time, travel, and cost in comparison to traditional deliveries [100–102]. Recently, several initiatives have tested either single (i.e., every transport provider has their own private hub and delivery goods) or multi-carrier consolidation (i.e., deliveries are performed sharing hubs and cargos) [98,103,104]. However, even in this case, different barriers hinder large-scale deployment and adoption. In fact, operational cost advantages are strictly linked to the presence of certain service area features (e.g., limited road space, high congestion levels, vehicle restrictions, limited space available for delivery vehicles to stop along the kerbside, and infrastructure that prioritises pedestrians and cyclists and electric charging stations), while high start-up costs require initial financial support by the public authorities.

The main barriers can be summarized as follows:

- a lack of public initiatives which promote competitive advantage creation via micro-hubs and cargo bike schemes (i.e., making it difficult and expensive for vans and trucks to deliver in certain areas and, by contrast, favouring deliveries by cargo bikes and electric vans. References [98,102] provide a detailed list of the possible measures;
- a lack of public action that directly supports trials and implementation (e.g., providing incentives or financial supports for green-vehicle uptake and micro-hub rental/purchase);

Cost and benefit distribution issues among stakeholders who are usually competitors in a shared micro-hub.

Given the specific context, this solution requires deep changes in a whole urban mobility system or, at least, in the specific service area (e.g., low-emission zones). Therefore, stakeholders' integration in a long-term vision engaging all the main actors, with the public sector taking a leading role (e.g., for instance, within a living lab approach or SUMP framework), constitutes the pivotal enabling factor. Furthermore, the actors, as well as UCCs, should foresee additional added value services as described by [98].

4.4. Management of Loading and Unloading Areas

The management of loading and unloading areas has an impact on transport service providers' decisions in terms of fleet sizes and service costs [105]. Furthermore, freight vehicles, double-lane-parking, and cruising for parking produce a disproportionately high impact on external costs (e.g., congestion and CO2 emissions) with respect to their traffic share [106,107]. Solutions to this issue relate not only to parking but also to land-use management. As far as parking is concerned, strategies aim to change the demand and supply of parking for freight and passenger vehicles via (i) pricing policies that are linked to the prediction of demand for passenger vehicles, (ii) an increase in the number of loading and unloading areas as well as introducing booking and pricing systems, strict enforcement of double-lane-parking fining, (iii) the definition of time and space restrictions to freight and passenger vehicles, according to vehicle type and/or specific time windows [108]. Land-use management instead entails an increase in off-street loading and unloading areas.

In terms of barriers, one should consider it necessary to balance the demand of the loading and unloading areas with those needs other actors might have in terms of road space use [108]. Freight operators, although in principle are interested in measures that make loading and unloading areas more efficient, hardly trust public authorities' enforcement commitments [109] and might prefer the *status quo* option that, in many cases, foresee double parking strategies [105]. Given these constraints, long-term strategic plans adopted by a participatory approach represent the main enabling factor. City authorities should co-design and/or predict the ways in which kerbside space in the main urban streets will be used and allocate additional space to urban logistic activities.

4.5. Automated Deliveries

4.5.1. Drones

Drones, also called unmanned aerial vehicles, represent a promising solution. Many sectors have implemented or are planning to test drone use for diverse applications (e.g., automotive, humanitarian logistic, retail, airline, pharmaceuticals, and the retail and parcel and courier sectors) [110]. As far as ODL is concerned, drones could accomplish several tasks, such as warehousing, inventory management, transportation, and route planning. According to the literature, avoiding delays, minimizing human intervention, and reducing delivery times would correspond to the drone-related factors capable of enabling last-mile logistics cost-reduction, service reliability improvement, and convenience (in terms of time and costs for the customer) [34]. Thanks to their characterising features, drones could perform one-third of "same day" deliveries by 2030 [111]. Furthermore, this solution could improve environmental sustainability since drones are powered by electric engines with rechargeable batteries [112–114]. Despite the theoretical advantages, many hindrances hamper the large-scale deployment of this solution. An entwined net of technological, regulatory, organisational, social challenges poses a threat to its effective implementation. Despite recent technical improvements, attributes such as limited payload capacity, flight duration, battery depletion, scarce resistance to weather conditions, interference and collision management, privacy, and security issues are all a menace to the effectiveness of drones [115–121]. One should also consider that this scheme needs, especially considering we are not yet in a fully automated context, an expensive supporting infrastructure for remote piloting (it is not clear when drone deliveries will be fully automated). Players must evaluate attributes such as the financial feasibility of investing in this technology, the resources necessary for the operations, drone assignment protocols to stations, customer demand for each station, and effective route management [34]. The barriers previously described highlight the need for real-world experiments [37]. Even supposing that these barriers can be overcome, regulatory and social challenges constitute the main difficulty [35]. In fact, drones raise concerns about safety, privacy, and the environment [122]. For instance, drones could collect personal data, spy on people, and could cause accidents or be misused for criminal purposes (e.g., terroristic attacks). Moreover, they raise environmental fears (e.g., harming wildlife, visual pollution, and sound pollution), as well as key issues linked to the creation of aerial traffic jams; in 2035, about 174,521 drone flights per hour would be needed to cover 70% of all parcel deliveries in the metropolitan area of Paris [123].

These elements, combined with the lack of regulation for drone movement, often lead to testing restrictions (e.g., drones have severe limitations in city flights) or prohibitions. From a wider perspective, legal uncertainty (e.g., safety, liability, privacy, and flight obligations) and potential technological developments (e.g., flight endurance) highly affect the possible economic returns [121]. A recent study conducted by the authors of [124] clarifies the key questions that should be addressed when setting effective regulations on drones. In detail, rules should relate to:

establishing safety agencies for controlling drone flights over cities;
determining the flying corridors over roads and buildings;
defining flight requirements (e.g., height, weight, distance, speed, landing, loading and unloading, and relationship to the other moving objects);
identifying drone requirement (construction, steering system, moving system, and control system).

In summary, the creation of unmanned flight space (U-space), coupled with the precise rules that address privacy and liability and, to a lesser extent, technology (e.g., flight endurance) and organizational advancement, constitute the main enabling factors for this solution. Addressing regulation, privacy, and security concerns could help to improve public perception of this solution, thus favouring its deployment.

4.5.2. Automated Robots

Within this category, one can consider sidewalk robots and automated road robots. In recent years, and also in response to the global pandemic, several logistics players and start-ups (e.g., Amazon, Nuro, and Starship) initiated the delivery of products by automated robots [110]. This scheme could also potentially allow for reducing operational costs by reducing human labour costs [37,125]. Furthermore, despite being less advantageous in terms of delivery time in comparison to drones, this solution usually guarantees greater payloads [126]. Similarly to drones, the electric batteries would allow for environmental gains. Automated robots present analogous barriers to drones. Even in this case, proper testing is often limited by safety concerns and by unsuitable regulation, although the regulatory approaches are different across countries. For instance, it is quite uncommon that a pilot project can be conducted without human control or in public streets [36]. Other enabling factors align with those of drones, apart from technology (e.g., full automation and the internet-of-things advancement) and regulatory challenges related to specific infrastructural needs (e.g., infrastructural regulation addressing vehicle-to-infrastructure (V2I) systems, road maintenance, support facilities, staging areas, and curb modification) [127].

Tables 2–7 provide an overview of the enablers and barriers for each macro-category, as presented in Table 1, broken down by the influencing components (Regulation, Stakeholders' engagement, Organisation, Technology). Regarding the macro-categories of Delivery location, modes, and times, specific tables for (i) Parcel lockers, Pickup Points, Click and Collect (Table 2), (ii) Crowd-shipping (Table 3) and (iii) Off-hour deliveries have been developed (Table 4), given the heterogeneity of the solutions.

Table 2. Overview of the enablers and barriers to delivery location, modes, and times (parcel locker and pickup points).

Enablers/ Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Enablers	Harmonisation of regulation and procedures for the installation of locker infrastructures.	Involves actors interested in sharing agnostic lockers to create mass.	- Possibility of economy of scale. - Allows consolidated goods delivery and avoids attended delivery issues.	Constant overview of flows and demand predictability.
Barriers	Limitations to placement of parcel lockers in public spaces.	Still high perceived risk of parcel locker usage.	- Poor parcel locker network design. - High fixed costs of the parcel lockers network infrastructure. - Closed nature of the system reduces the network benefits.	IT integration across supply chain partners.

Table 3. Overview of the enablers and barriers to delivery location, modes, and times (crowd-shipping).

Enablers/ Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Enablers		- Partnership with local authorities and public transport providers. - Bottom-up approach involving stakeholders to create a sense of ownership and consensus-building.	Light model, reducing fix costs (warehouses, fleets, fuel, drivers).	Advancement in modelling and analysis tools based on machine. learning and artificial intelligence.
Barriers	Shippers working status, liability, regulation of privacy protection, tax regulation.	- Social acceptance: demand side trust issues (i.e., service reliability, privacy).	Match consumer and shipper needs–maintain a satisfactory number of couriers while providing a convenient service for users.	

Table 4. Overview of the enablers and barriers to delivery location, modes, and times (off-hour deliveries).

Enablers/ Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Enablers	Access regulation providing incentives for OH operations.		Associate off-hour deliveries with consolidation.	Silent (electric) vehicles for night operations.
Barriers	Existing restrictions on vehicles circulation and noise.	Convince shippers and receivers to try the scheme and citizens to accept it.	- Higher costs of drivers working non-regular hours. - Organisation of unattended deliveries.	

Table 5. Overview of the enablers and barriers to consolidation.

Enablers/ Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Enablers	- Public subsidies and incentives generating competitive advantage. - Strict time window combined with access regulation. - Obligation to use the UCC/micro-hub for specific operations.	Stakeholders' integration in a long-term vision, engaging all the main actors.	- Proper selection of size, location, catchment area, density area and product typology - Associate off-hour deliveries with consolidation.	

Table 5. *Cont.*

Enablers/Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Barriers	Difficult to control and enforce.	- Lack of participation due to convenience reasons, stakeholders' conflicts. - Need collaboration between stakeholders having heterogeneous preferences.	Lack of clear vision on costs and responsibilities allocation along the supply chain.	

Table 6. Overview of the enablers and barriers to the management of loading and unloading areas (LUAs).

Enablers/Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Enablers	- Increase number of LUAs. - Equalise regulation and penalties of LUAs with disabled parking.	Balance the demand of the loading and unloading areas with the needs of the other actors who use the road space.	- Decrease in double-row parking increase in off-the-road parking and a reduction in parking time at the curb side.	- Geo-reference of public and private areas. - IT systems for dynamic curb side use.
Barriers	Currently, also accessible to citizens for private loading/unloading operations.	- Lack of trust into public authorities' enforcement commitment. - Strong public opposition to parking pricing and the creation of new LUAs.	- Booking of LUAs difficult because of uncertainty of delivery patterns and time.	

Table 7. Overview of the enablers and barriers to automated deliveries.

Enablers/Barriers	Regulation	Stakeholders' Engagement	Organisation	Technology
Enablers	Legislative and regulatory frameworks adapted to enable the use of AVs.		Focus on most promising use cases (e.g., delivery of supplies to hospitals, provide goods to remote areas, monitoring and surveillance, etc.).	- Increased capacity to transmit logistics data between freight providers and to customers - ICT enabling V2V and V2I communications.
Barriers	- Regulatory barriers depend on gaps, uncertainty of the law or restrictions for trials, privacy, security, liability. - Lack of standardisation of the procedures on privacy, cyber-security, safety and ethics.	Concern on privacy, security, environmental pollution, and air-traffic jam.	Lack of support facilities, staging areas and curbing modifications.	Limited payload capacity, flight duration, battery depletion, scarce resistance to weather conditions, interference, and collision management.

5. Discussion and Conclusions

Public authorities and industries need new knowledge-driven logistics solutions to cope with the contemporary challenges as described in Section 1. Each solution features a series of enablers that can be stimulated to facilitate its uptake and upscaling, as well as overcoming their barriers. The main factors influencing increasingly complex city logistics systems were analysed, including regulatory-, stakeholder engagement, organisational and technology-related elements.

The solutions identified can be combined and integrated to facilitate a logistics system that is more sustainable and efficient. However, for these promising solutions to be successful, it is necessary to leverage the elements supporting and facilitating their implementation while, on the other hand, removing the obstacles that limit their diffusion.

This paper provides an original overview that is illustrated solution-by-solution and is broken down into influencing components in terms of enablers and barriers. The result is a systematic approach which identifies gaps and, consequently, prioritises the actions needed to be taken by the public and private sectors. The fact that an influencing component is not on this list does not necessarily mean that it is already resolved, but rather that it is expected to follow a natural path of maturation that does not require specific policy interventions to be encouraged.

As far as parcel lockers are concerned, regulation plays a key role; there is a need to provide a coherent regulatory framework at a national level for the installation and use of locker infrastructures, while the limitations over their placement in public areas should be removed. At the organisational level, opportunities, in terms of the efficiency of the distribution process and the reduction of delivery rounds, are evident, but the inefficiencies linked to the exclusivity of the network and the high costs of the infrastructure need to be resolved. It is, therefore, the matters of regulation, governance, and infrastructural intervention, which require a central role performed by public authorities and the proactive and collaborative participation of private operators. The network of 24-hour parcel lockers, open to all transport operators, created in Sweden by the start-up iBoxen goes in this direction [128].

Crowd-shipping, which, compared to parcel lockers, is currently much less widespread, has immense potential as a pure ODL solution since it maximizes the use of existing flows and movements. Obviously, it is aimed at a specific market of small packages, which, however, are those that are causing an increase in vehicles and kilometres travelled related to e-commerce [8]. While there are still several challenges related to the regulatory framework and social acceptance of this activity which are linked to privacy, liability, and reliability, advancements in modelling and analysis tools based on machine learning and artificial intelligence make crowd-shipping operations increasingly viable. Therefore, public authorities should regulate the sector, while at the same time undertaking convincing campaigns to involve stakeholders, both citizens and professionals, to increase the awareness and acceptability of this solution. The public–private partnership between the start-up TakeMyThings and the Italian local public transport bus company Autolinee Nuova Benese represent a possible solution capable of overcoming the barriers aforementioned [129].

Another promising measure with a view to increasing distribution efficiency is OH deliveries; that is, taking advantage of times of the day when the roads are less congested to favour the commercial speed of the system. In this case, regulatory interventions are quite straightforward and consist of incentives and access-regulation policies that are favourable to OH operations. The organisational aspects need more attention; that is, the shift of the supply chain activity at various times and, therefore, different operations as well as the availability of the recipients to receive the goods at times when shops are sometimes closed. Success stories have emerged in the off-hour delivery programs in Barcelona and in Paris [88].

In the case of the second macro-category, consolidation regulatory interventions are required in a mixture of carrot and stick approaches to create a favourable business model; subsidies and incentives generating competitive advantages, but also strict time windows and, in some cases, obligations to use the UCC/micro-hub for specific operations, are required. The main risk is that, in fact, in the absence of these interventions, there is no business and operational model that would make consolidation in UCC/third-party micro-hubs viable and profitable. In the cases of London and Bristol, for instance, the combination of ULEZ zones and financial and non-financial incentives (i.e., the possibility to lease 39 car parking spaces in central London to be used as micro-hubs for its deliveries and local authority investment in a cargo-bike fleet in Bristol) favour this solution [130,131].

The management of spaces for logistics is characterized by a high level of political sensitivity; in fact, as urban space is limited and scarce, if the space allocated to freight increases, then by necessity, it decreases for citizens, especially for their cars. For this reason, there is always strong public opposition to parking prices and the creation of new LUAs, which are, on the contrary, advocated for by operators in the sector. Public authorities should balance the demand of LUAs with the needs of the other actors who use the road space, based on evidence and data. In this sense, stakeholder engagement is key to enhancing the acceptance of these interventions, while technology can lend a hand for the mapping, management, and monitoring of parking and kerbside space in a dynamic and efficient way.

Finally, automation and the use of drones pose the most potential but also the most insidious barriers. Indeed, autonomous vehicles (AVs) have the potential to optimize movement and thus reduce city traffic. Drones have the potential to efficiently cover some of the tasks related to traffic management and monitoring, as well as super-fast deliveries of emergency goods, such as medicines [132]. However, they present so many privacy, security, safety, liability, and ethical risks that the first step to be taken by public authorities is the definition of legislative and regulatory frameworks adapted to enable the use of AVs, while the private sector should ensure that technological developments make operations safe and efficient.

Table 8 outlines and summarizes, for each macro-category, the influencing components one might want to act upon so as to remove these barriers while promoting large-scale/sustainable ODL solutions (For further details on the influencing components to be addressed, please see Tables 2–7).

Table 8. Areas of intervention to be prioritised, and the corresponding influencing components.

Macro-Category	Influencing Component to Address
Delivery location, modes, and times	Regulation (parcel lockers, crowd-shipping) Organisation (off-hour deliveries)
Consolidation	Regulation
Management of spaces for logistics	Stakeholder engagement Technology
Automation and drones	Regulation Technology

To provide decision-makers with further guidance on policy priorities for urban logistics, one should combine this exercise with an analysis of stakeholders' preferences and priorities for these solutions [133]. This represents a future line of research we intend to pursue.

In conclusion, this paper identifies several promising solutions in different macro-areas of urban logistics. From the analysis of their enablers and barriers, the importance of the public decision-makers emerges first in (i) identifying the potential contribution of these solutions to pursue the sustainability objectives defined within their planning tools (SUMP, SULP, etc.), (ii) intervening on their regulation to enable their prevalence in terms of competitive advantage over other less sustainable practices, and (iii) collecting and integrating the perspectives of stakeholders.

On the other hand, the role of private operators constitutes their participation in decision-making processes and, at the same time, testing these solutions on a small scale to clarify and improve the organisational context and be ready to upscale them, with the support of technological innovations that make them more attractive.

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