Journal of Turkish

Operations Management

Novel last mile delivery models in terms of sustainable urban logistics

Ş.Fatih Yılmaz[1*], Nadide Aktaş[2], Neslihan Demirel[3*]

[1]Department of International Trade and Logistics, Graduate School, Kayseri University, Kayseri
e-mail: ylmazfth95@gmail.com, ORCID No: https://orcid.org/0000-0002-4095-7187
[2]Department of International Trade and Logistics, Faculty of Applied Sciences, Kayseri University, Kayseri
e-mail: nadideaktas@kayseri.edu.tr, ORCID No: https://orcid.org/0000-0002-0571-1974
[3]Department of International Trade and Logistics, Faculty of Applied Sciences, Kayseri University, Kayseri
e-mail: ndemirel@kayseri.edu.tr, ORCID No: https://orcid.org/0000-0002-9737-6666

Article Info

Article History:
Received: 08.11.2021
Revised: 04.04.2022
Accepted: 10.04.2022

Keywords:

Last Mile Logistics,
Urban Logistics,
Sustainability,
Out of Home Delivery

Abstract

The development in e-commerce is a factor that increases the quality of life of customers living in cities, however, it also leads to an increase in the need for last-mile logistics activities which causes a rise in traffic density, CO_2 emissions, parking problems, noise, environmental pollution, and even it causes the emergence of health problems. Moreover, not being at the delivery address which is today's often encountered problem causes failure of delivery, a decrease in the efficiency of operations for the logistics service provider (LSP), an increase in costs, and a decrease in the level of customer service. This study aims to conduct detailed research on sustainable last-mile delivery methods in order to provide solutions to the problems that arise in cities with the increase in the last-mile logistics practices as a result of widespread use of e-commerce and to accommodate to the changes in customer lifestyles. In this context, our study surveys the novel last-mile delivery methods alternative to conventional delivery with a broad perspective. These methods have been evaluated from LSP's and customers' points of view, features, advantages, and barriers of the methods are examined, and instances from the practice have been mentioned.

1. Introduction

The advances in internet technologies have brought about great changes in commercial behaviors as well as in many areas. These technologies contribute e-commerce enabling customers to shop whenever and wherever they wish using mobile devices. Besides that, increasing urban population is another factor that has an impact on e-commerce. According to World Bank data, whereas the ratio of urban population to total population in 2000 was approximately 47%, this percentage increased to around 56% in 2019 (World Bank, 2021). Furthermore, statistics from United Nations Conference on Trade and Development (UNCTAD) indicate that in developed economies, 81% of the population is urban (UNCTAD-1, 2020). The prevalence of the internet and increasing urban population has boosted interest in e-commerce as it eliminates inefficient traditional commerce processes for customers such as the obligation to visit the store, finding products in the store, and queuing for purchase. UNCTAD data show that 2018 global e-commerce sales have increased by 8% compared to 2017, reaching 25,6 trillion USD (UNCTAD-2, 2020).

The flexibility and convenience that e-commerce provides the customer results in B2C (business to customer) model becoming more common, which heightens the need for last mile logistics practices. Last mile logistics, which consists of the activities to ensure product delivery to final customer and shows up at the final stage of traditional supply chains, is the most visible phase determining the product value for the customer. While choosing a product, modern-day customers not only assess criteria such as price, speed, service level and delivery method but they also pay attention to the environmental and social effects of purchasing and delivery processes. Therefore, managing their operations efficiently become more challenging for LSP. Also, focusing on effective product delivery to customer at minimum cost has started to become insufficient for suppliers, for whom it has now become inevitable to pay attention to sustainability. Along with the increasing need for last mile logistics practices; failed deliveries due to customer not being at the delivery address, wrong deliveries, working hour limitations for deliveries to offices, legal environmental regulations and heightened customer awareness have made new approaches compulsory for last mile logistics management.

On the other hand, a significant part of last mile logistics practices is fulfilled in cities, and so affects urban life. Transportation is regarded as the most essential and costly logistics activity. Urban mobility causes 40% of all CO_2 emissions of highway transport, and 70% of the other contaminants resulting from transportation (European Comission-1, 2021). Part of urban mobility is generated by commercial freight transport. More transportation brings together environmental effects and the traffic density in urban areas becomes a bigger problem by the day. Commercial traffic in European cities constitutes an average of 8 to 15% of urban traffic flow and has 20 to 30% effect on traffic emissions (Pronello, Camusso and Valentina, 2017). As the share of e-commerce increases in the retail industry, so does the share of freight transport-related emissions in the total emission amount resulting from urban mobility. Circumstances that occur in last mile logistics process, such as wrong parking and/or occupation of insufficient parking spaces, also negatively impact urban life (Pronello et al., 2017; European Comission-2, 2021). Although urban logistics initially focused on factors such as travel time, cost, and traffic; nowadays other topics such as safety and pollution draw attention as urban logistics practices have a significant influence on the environmental-social effects and quality of life (Amaral, Semanjski, Guatama and Aghezzaf, 2018).

This study conceptually addresses sustainable last-mile delivery models developed in order to adapt to customer lifestyle changes and find solutions to urban problems arising from the increased need for last-mile logistics practices parallel to the surge in urban population, consumption and online shopping, as well as the operation of these models and the advantages and disadvantages of the same in terms of LSP and customers. The models have been approached from a sustainable urban logistics point of view, with examples of practice. The study has been structured so that Section 2 researches relevant literature, Section 3 analyzes sustainable delivery models in last-mile logistics, and Section 3 includes the conclusion and suggestions of future researches.

2. Literature survey

Last-mile logistics has recently attracted the attention of academics and practitioners alike for being one of the most expensive activities in product delivery process to customers, constituting approximately 28% of the total cost (Zenezini, Lagorio, Pinto, De Marco and Golini, 2018; Pronello et al., 2017). In literature, the conventional delivery method where the order is delivered to customer at home is referred to as "home delivery" (Ostermeier, Heimfarth and Hübner, 2021; Kämäräinen, Saranen and Holmström, 2001; González-Varona, Villafáñez, Acebes, Redondo and Poza, 2020; Arnold, Cardenas, Sörensen and Dewulf, 2018; Song, Cherrett, McLeod and Guan, 2009; Moroz and Polkowski, 2016). On contrary, the delivery method where the order is not delivered to the customer by the LSP and the customer themselves pick up the order is referred to as "out of home (OOH) delivery" (Kawa, 2020; Iwan, Kijewska and Lemke, 2016) or "delivery via collection delivery points (CDP)" (González-Varona et al., 2020; Boysen, Fedtke and Schwerdfeger, 2021; Moroz and Polkowski, 2016). It is known that OOH delivery models decrease last-mile logistics costs by up to 60% compared to home delivery (Punakivi, Yrjölä and Holmström, 2001; Wang, Zhan, Ruan and Zhang, 2014). On the other hand, there are studies which classify home delivery model into two groups as "attended" and "unattended" home deliveries; whereby the customer themselves receiving the order at home is defined as "attended home delivery" as opposed to the order being left at the doorstep, or delivered to a reception and delivery box (RDB), or a neighbor due to the customer not being at home which is described as "unattended home delivery" (Halldórsson and Wehner, 2020; Moroz and Polkowski, 2016).

Upon review of literature handling last-mile logistics, it is observed that studies focus on only one or few of the novel last mile delivery models. In literature, besides studies researching practices for selected delivery model in terms of efficiency (Wang et al., 2014), preferability or acceptability for customers (Iwan et al., 2016; Barthuly, 2019), benefits (Jara, Vyt, Mevel, Morvan and Morvan, 2018), utilization by customers (Rai, Cetinkaya, Verlinde and Macharis, 2020; Gielens, Gijsbrechts and Geyskens, 2020; Morganti, Dablanc and Fortin, 2014), and influence on customer loyalty (Kawa, 2020); it is also identified that effects of the analyzed model on factors such as the cost, distance covered, CO_2 emission, traffic density, etc. are often studied via a case. Amongst these case studies are, Kämäräinen et al. (2001) focusing on the effects of using RDB instead of conventional attended home delivery on costs; Punakivi and Tanskanen (2002) researching the effects of shared multiple-user RDB on costs; Song et al. (2009) and Zenezini et al. (2018) analyzing the effects of using pickup drop-off (PUDO) points on distance covered and CO_2 emission; Reyes, Savelsbergh, and Toriello (2017) exploring the influence of in-car delivery models on distance; Silva, Magalhães, and Medrado (2019) examining the effects of using pickup point (PP) on costs and distance; Arnold et al. (2018) investigating the effects of using PP and cargo bikes on costs; Nürnberg (2019) researching the environmental effects of using cargo bikes; Perboli, Rosano, Saint-Guillain and Rizzo (2018) reviewing the effects of delivery via van, cargo bike, parcel locker (It will be mentioned as 'locker' in the rest of the paper) and the integrated utilization of these methods on costs; González-Varona et al. (2020) studying the effects of locker usage on CO_2 emission; Schwerdfeger and Boysen (2020) analyzing the effects of using mobile lockers instead of fixed lockers on costs; Koiwanit (2018) examining the environmental effects of drone usage; Agatz, Bouman and Schmidt (2018), and Pugliese, Guerriero and Macrina (2020) researching the effects of delivery trucks, drones and the integrated usage of these on costs, CO_2 emission and traffic density; Figliozzi and Jennings (2020) focusing on the effects of autonomous ground vehicles (AGV) on distance covered, energy consumption and CO_2 emission; Ostermeier et al. (2021) investigating the effects of the integrated usage of trucks and AGV on total cost, distance and emission; and Halldórsson and Wehner (2020) exploring the effects of click and collect (C&C), PP, locker, in-car delivery and home delivery options on energy efficiency. Studies mostly use vehicle routing problem, simulation, and survey method. On the other hand, Boysen et al. (2021) have analyzed studies in literature handling decision problems regarding the design and operation of contemporary delivery models in last-mile logistics from an operational research point of view.

Upon review of last-mile logistics studies in literature, it is observed that there is no conceptual integrity where most studies compare conventional home delivery to one or a few novel last mile delivery models analyzed over a case study, and the remaining studies focus on decreasing the cost or environmental effects using optimization or simulation techniques for the selected delivery model within a certain region. There is a lack of studies comprehensively and holistically researching new generation delivery models most of which are OOH or carbon-free which is crucial for sustainable urban logistics. Within this context, this study thoroughly explores the 10 most common last-mile delivery models in literature and practice from a sustainable urban logistics perspective, displaying similarities and differences between models. Furthermore, it refers to global practices of aforementioned models as well as practices in Turkey. It is believed that this study will be beneficial for LSP in developing countries in their decision-making processes to make their last-mile logistics practices more efficient, to develop sustainable policies, and to gain competitive power resulting from cost savings; as well as improving customer perception on the sustainability of new generation delivery models.

3. Sustainable delivery models in last mile logistics

Last-mile logistics practices which are essential in urban logistics and continuously increasing parallel to the surge in e-commerce create value via timely delivery of products to customer location while they also lead to traffic density, parking problems, noise, increased emission, and health problems. On the other hand, customers not wishing to stick to a certain address during a certain delivery timeline causes failed deliveries due to customers not being in the indicated address, which leads to economic, environmental, and social costs. Within this framework, various delivery models alternative to conventional home delivery have become more widespread around the globe. This study researches the most common novel last mile delivery models in literature and practice; classifying them in Table 1 in terms of whether delivery staff is involved (manned-unmanned) in the transport and delivery phase, whether customers are involved in the delivery phase at home (attended-unattended), whether orders are delivered home or collected by customer (home delivery-OOH delivery), and finally whether the delivery option is sustainable or not.

Table 1. Delivery methods used in last-mile logistics

Last mile delivery model	Transport phase		Delivery phase		Home delivery		OOH delivery	Sustainability
	Manned	Unmanned	Manned	Unmanned	Attended	Unattended		
Crowdsourced	✓		✓		✓	✓	✓	✓
C&C	✓		✓				✓	✓
PP	✓		✓				✓	✓
PUDO	✓		✓				✓	✓
Locker	✓			✓			✓	✓
RDB	✓			✓		✓		✓
In-car delivery	✓			✓			✓	✓
Cargo bike	✓		✓		✓	✓		✓
Drone delivery		✓		✓	✓	✓		✓
AGV		✓		✓	✓	✓		✓
Conventional delivery	✓		✓		✓	✓		

There is no agreed terminology in literature for these models which are relatively new practices, and since the methods are intertwined, there exists a conceptual confusion. To detail the differences and similarities, Table 2 correlates various delivery models.

Table 2. Correlating the last mile delivery models

	Crowdsourced	Click and Collect (C&C)	CDP
PP	✓	✓	✓
PUDO	✓	✓	✓
Locker	✓	✓	✓
RDB			✓
In-car delivery			✓
Cargo bike	✓		

Delivery models discussed in the study have similar and common advantages and disadvantages which for customers, e-retailer, and LSP, although they have also their specific features. The advantages and disadvantages of delivery models are evaluated individually in Tables 3-4. Table 3 demonstrates details for C&C and PP, PUDO, locker, RDP, and in-car delivery models which are gathered under the heading CDP while Table 4 demonstrates AGV, drone, and bike that may be considered as vehicle options in last-mile delivery.

Table 3. Advantages and disadvantages of C&C, PP, PUDO, locker, RDP, and in-car delivery

Advantages	**C&C**	**PP**	**PUDO**	**Locker**	**RDB**	**Car***	**C***	**R***	**LSP**
Provide flexibility in terms of choice of time and place		✓	✓	✓	✓	✓	✓		
Remove the obligation to be present in the delivery address	✓	✓	✓	✓	✓	✓	✓		
Eliminate failed deliveries for not being at the address	✓	✓	✓	✓	✓	✓	✓		
No queue in store for the products		✓	✓	✓	✓	✓	✓		
The pickup transaction can be combined with other errands	✓	✓	✓	✓	✓	✓	✓		
Reduce last mile delivery times	✓	✓	✓	✓	✓	✓	✓	✓	✓
Increase reliability	✓	✓	✓	✓	✓	✓		✓	✓
Increase the customer traffic and reputation of the stores acting as CDP and provide them with additional income		✓	✓						
Significantly decrease the fixed and variable last mile logistics costs	✓	✓	✓	✓					✓
Increase the operational efficiency by enabling multiple deliveries to a single point		✓	✓	✓	✓	✓			✓
Eliminate the distance, cost, traffic problems, CO_2, noise, pollution	✓	✓	✓	✓	✓	✓			
High successful delivery rate at first attempt	✓	✓	✓	✓	✓	✓	✓	✓	✓
Enable 24/7 customer service				✓	✓		✓		
Disadvantages	**C&C**	**PP**	**PUDO**	**Locker**	**RDB**	**Car***	**C***	**R***	**LSP**
Last step of delivery is performed by the customer	✓	✓	✓	✓	✓	✓		✓	✓
Not always possible to pick up all online orders from a single point	✓	✓	✓	✓	✓	✓	✓		
In case of multiple orders that need to be delivered by various LSP, the use of common CDP require competitors to cooperate (Kawa, 2020)		✓	✓	✓					✓
May cause lower service quality, reduced customer loyalty and inefficiency due to selection of uncommon CDP		✓	✓					✓	✓
Require digital aptitude, so, can bear a risk of inefficient use by technology-resistant users				✓		✓	✓		
Can cause volume limitations in order sizes		✓	✓	✓	✓	✓	✓	✓	✓
Indoor access is limited to working hours/days	✓	✓	✓						✓

*Car: In-car, C: customer, R: e-retailer

Models in Table 3 are sustainable in different ways such as customers choosing PP on their way reduces distance covered, traffic, and parking problems, also returning the orders from the nearest PUDO has the same benefit. Additionally, models allow the delivery of many orders at once. Apart from these, delivery models as such RDP and in-car enable customers to collect deliveries easier, since delivery point is at close range.

Table 4. Advantages and disadvantages of AGV, drone, and bike

Advantages	**AGV***	**Drone**	**Bike**	**C***	**R***	**LSP**
Cause no noise	✓	✓	✓	✓	✓	✓
Support the use of green energy	✓	✓	✓	✓	✓	✓
Reduce last mile delivery times		✓		✓	✓	✓
Need to integrate with larger delivery vehicles such as trucks	✓	✓	✓		✓	✓
Ease of use in traffic density or the areas without parking space	✓	✓	✓	✓	✓	✓
Eliminate failed deliveries that courier related	✓			✓		✓
Cause very low or zero-emission during use	✓	✓	✓	✓	✓	✓
Decrease delivery cost			✓		✓	✓
Lower initial investments			✓			✓
Enable customers to set flexible delivery times	✓			✓	✓	✓
Disadvantages	**AGV***	**Drone**	**Bike**	**C***	**R***	**LSP**
Last step of delivery is performed by the customer	✓			✓		
Cost of maintenance, repair, and replacement parts are high	✓					✓
Low carrying capacity and battery capacity	✓	✓		✓	✓	✓
Suitable for short delivery distances	✓	✓	✓		✓	✓
Low-speed mobility	✓		✓	✓	✓	✓
Suitable for small size and low weight packages	✓	✓			✓	✓
Need certified employees or couriers for use		✓				✓
May require legal permission, licenses, and regulations	✓	✓				✓

*AGV: S-AGV, C: Customer R: Retailer

The use of drones provides a fast delivery advantage for the customer, especially without obstacles such as traffic congestion. However, it requires training to be used, and that can cause a loss of cost and time for LSPs. Owing to no fuel consumption, bike delivery methods have an important advantage for retailers and LSPs in terms of delivery cost and zero emission. On contrary, AGV can cause excess costs for LSPs such as maintenance and repair due to the fact that it is autonomous and high-tech.

3.1. Crowdsourced delivery

Crowdsourcing means the completion of one or more tasks by benefiting from a group or groups outside of the internal work components. It has become one of the practices in last-mile logistics which benefits from local resources in the delivery of orders to customers. Crowdsourced delivery models can be in the form of home delivery (such as using courier support service from an individual with a car, bike, or motorbike or their own) as well as OOH delivery (such as an agreement with a local business which allows the business place to be used as a PP or PUDO point). Deliveroo, Amazon Flex, DoorDash, GoShare, Roadie and UberEats are global examples of businesses using crowdsourcing in their delivery process, whereas crowdsourced delivery in Turkey is rather new with example practices such as Yurtiçi Kargo (YK Plus) and Trendyol (Trendyol Express). Application of the nowadays popular crowdsourcing to last-mile logistics brings together essential advantages, such as:

- Significant decrease in logistics costs.
- Help e-retailers and LSP meet more customer demands in a short time within an increasingly competitive environment.
- Opportunity to enhance customer service levels for e-retailers and LSP via faster delivery without high capital costs.
- Stock flexibility and easier management of imbalanced demands for e-retailers.
- Decrease in CO2 emission, traffic density and resource utilization.
- Additional income for individuals and businesses who aren't professional couriers.
- Increased customer traffic and hence increased brand awareness for businesses.

Despite its advantages in the efficient management of last-mile logistics operations by LSP, this model also comes with some problems such as differences in regional policies and regulations, reliability, and brand consistency (Broadhurst, 2020).

3.2. Click and collect delivery

Differing from the traditional in-store shopping process, this delivery model is based on the customer placing the order online and then going to the store to collect the order once it is ready (Figure 1). Although this model has been in use for a long time in fast food chains, it's a relatively new method in retail chains (Jara et al., 2018). The C&C model is the most popular delivery model in the United Kingdom and C&C service ratio has increased from 63% in 2014 to 76% in 2017 (Köydedurmaz, 2017). According to a study by Forrester Research conducted in six European countries consisting of Germany, United Kingdom, Netherlands, France, Italy, and Spain with the participation of 15 thousand adult consumers, 54% of consumers prefer C&C delivery for various reasons such as cost saving and avoiding cash register queues (Fintechtime, 2016).

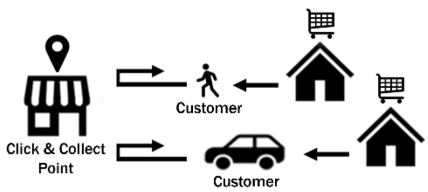

Figure 1. C&C delivery model

In this model where the customer has to collect the order, the process shows similarities to those in 'PP, PUDO, and lockers' which will be mentioned in the upcoming subsections, in that, the methods in question can also be used as CDP for C&C model. In the C&C model when customers visit the store to pick up the product, they can purchase more products and can immediately change or return the product they purchased online. By allowing these, models eliminate the distance, cost, traffic, and CO_2 emission. 1% increase in the use of the C&C model as an alternative to the conventional home delivery model provides a 1% decrease in urban delivery vehicles (Doddle, 2020).

3.2.1. Pickup point

In this delivery model, the product purchased online by the customer is delivered by the LSP to a PP determined by the customer during the purchase transaction. The process is then completed by the customer collecting the product from the aforementioned PP (Figure 2). PPs are mostly places of business operating in various industries (Morganti et al., 2014) which are walking distance from urban areas and located nearby customer's residence address (Halldórsson and Wehner, 2020). Examples of this delivery model in Turkey are the YK Plus service provided by Yurtiçi Kargo and the Bukoli service furnished by Borusan Logistics.

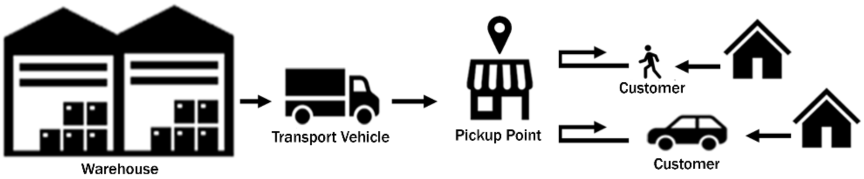

Figure 2. PP delivery model

The model prevents a decrease in customer service levels by determining correct CDP in locations frequently visited by customers (Weltevreden, 2008). Additionally, it ensures an 80% decrease in the distance that has to be covered for delivery in the case of failed deliveries at first attempt in conventional home deliveries (McLeod, Cherret and Song, 2006).

3.2.2. Pickup-drop off point

In PUDO point delivery model, customers can also personally pick up their orders from a place and at a time of their choice (Figure 3). However, this delivery method differs from PP model in that, customers can also send products from PUDO point. Potential PUDO points can be shopping malls, grocery stores or gas stations close to customers' home or workplace.

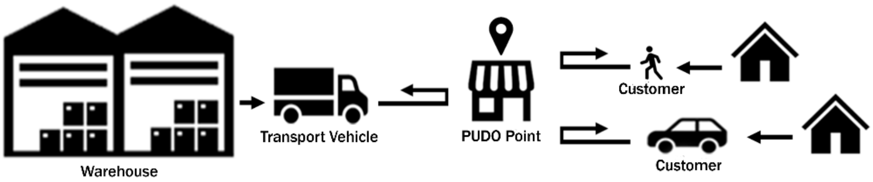

Figure 3. PUDO point delivery model

PUDO model, provides a suitable solution to handle increasing product returns. Depending on the seller's offer, customers can easily return the product at low cost or even free of charge (Kawa, 2020). PUDO point delivery is one of the most preferred OOH delivery methods in Germany, Great Britain, France, and Belgium (Kawa, 2019). Whereas it was estimated that Europe PUDO network consisted of approximately 190,000 points in 2019 (International Post Corporation, 2020), this number has increased up to 336,880 according to a report published in 2021 (Różyckı, Gral and Anson, 2021).

3.2.3. Parcel locker

Also known as package locker, package station, locker box, smart locker, parcel automat, and parcel station; parcel locker functions as a safe locker from which the customer can pick up their order. In this model, the process starts with the customer choosing locker as the delivery method during their online shopping. After the LSP picks up customer package from the warehouse and drops it off at the locker determined by the customer, customer receives a message confirming delivery and containing an access code. The process is then finalized by the customer picking up their order from the locker using this code (Figure 4). In the event that the parcel is not picked up by customer within the specified time frame, LSP takes it back to the warehouse (Iwan et al., 2016).

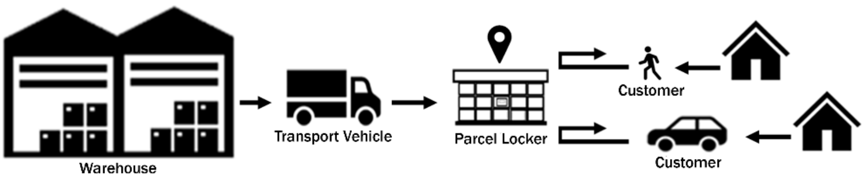

Figure 4. Locker delivery

Lockers from which the customers can pick up their parcels or in some cases even drop them off at are mostly placed in common areas such as petrol stations, bus stations or shopping malls on the way. LSP who operate lockers usually provide customers with an option to identify and select the suitable locker for themselves via mobile applications. Lockers are encrypted and secured by means of technology (Moroz and Polkowski, 2016). Both LSP and customer can monitor parcel status online (Kawa, 2020). With advances in technology, lockers can be improved with innovative practices such as quick barcode scanners that facilitate product recognition, card units, facial and fingerprint recognition as well as infrared scanners that can identify whether the locker is full or empty.

Lockers can be designed for indoor and outdoor usage. Moreover, some lockers come with cooling features and heat control for heat-sensitive products. Besides fixed lockers, one can also come across mobile lockers which can change location throughout the day, hence increasing customer access. Compared to fixed lockers, mobile lockers are more advantageous in that they reduce the number of lockers needed as well as the capital requirement (Schwerdfeger and Boysen, 2020). Mobile lockers can be in the form of carriers transferred by a driver (Figure 5c), or in a more technologically advanced, driverless, and autonomous form. Furthermore, LSP can choose locker designs for brand image and advertising purposes. Figure 5 shows various types of lockers.

(a) **(b)** **(c)**

Figure 5. Types of locker **a.** Generic purpose locker (Rovenma, 2021); **b.** Refrigerated locker (ParcelHive, 2021); **c.** Mobile locker (BoxBot, 2021)

Due to high locker installation costs, e-retailers commonly prefer to work with LSP for use of lockers. This helps make locker utilization more prevalent in last-mile delivery from both B2B (business to business) and B2C. Companies such as DHL, HiveBox, AustraliaPost, UPS Access Point, InPost, FedEx, La Poste Group, and DPD group have locker practices. Różyckı et al. (2021) has indicated that number of lockers in Europe in 2021 is 43,310. Recently, the locker delivery model has been put into practice also in Turkey. Kargopark is one of the examples that has lockers commonly used by multiple LSP in three cities. Kargopark and Opet cooperate in Opet Ultra Parcel Locker pilot practice implemented in İstanbul. Besides, Kargopark common lockers can also be selected as a delivery point in online orders from Trendyol (Kargopark, 2021). Another example of locker practices is the pilot project named "Locker Project" which is implemented by Eskişehir Tepebaşı Municipality. The project allocates 2 encrypted locker shelves free of charge to 850 residents. In this project, lockers are placed in disaster assembly areas where one of the locker shelves is designated for supplies that may be needed in the event of a possible disaster and the other one is used for parcel deliveries (Tepebaşı Municipality, 2021). "YK Plus 7/24" service of Yurtiçi Kargo company also includes locker delivery model. Additionally, the lockers of PTT named "cargomat" are becoming increasingly widespread across the country.

3.3. Reception and delivery box

In this model, the order is delivered to the box at the customer address. In literature, box types are labeled as reception boxes and delivery boxes (Punakivi et al., 2001; Wang et al., 2014). Reception boxes are permanently fixed to the exterior of customer's house, their garage or garden wall. On the other hand, delivery boxes are mobile and fixed to customer's garden wall by means of a locking system, and then following package pickup by customer they are collected by LSP during the next delivery or at any point to be used in other future deliveries (Punakivi et al., 2001). Figure 6 demonstrates the delivery model using RDB.

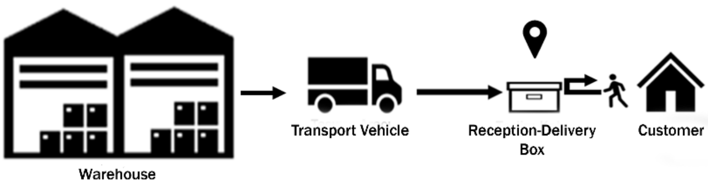

Figure 6. RDB delivery model

Conventional delivery is differentiated from RDB delivery, and that Table 5 demonstrates the differences between two methods.

Table 5. Conventional vs. RDB delivery (Kämäräinen et al., 2001)

Conventional	RDB

Customized service	Yes	No
Last delivery point	Customer	Box
Customer dependency	Has to be present at address	Doesn't have to be present at address
Reception timelines	Fixed time intervals	Always
Delivery frequency	Varies depending on customer requirements	Mostly fixed
Delivery interval	Fixed time intervals	Working hours
Delivery time per house	Long	Short

In some cases, RDB are used commonly to serve multiple customers and save costs (shared reception box). Boxes can be accessed via an electronic code or a key, and once the delivery is complete, customer is notified by SMS or e-mail. Figure 7 shows examples of RDB fixed to the ground (a), fixed to the wall (b) and insulated RDB (c and d).

(a) **(b)** **(c)** **(d)**

Figure 7. RDB samples (**a, b:** PinPod, 2021; **c, d:** Olivo-logistics, 2021)

In addition to the benefits in Table 5, other advantages of this delivery model are listed below:

- Ensures that the package is safe until the customer comes home.
- As opposed to PP, PUDO and locker options, customer doesn't have to travel any distance to receive the product.
- Reduces costs up to 60% compared to attended delivery models (Punakivi et al., 2001).

Although the distance covered in RDB model is the same as home delivery, this model eliminates the travel and costs due to failed deliveries as well as CO_2 emission, traffic, and pollution.

3.4. In-car delivery

Relatively new in last mile logistics and believed to be one of the beneficial delivery methods, in-car delivery model is comprised of the LSP delivering a product purchased online to the customer's car parked in the urban area within a specified time interval (Halldórsson and Wehner 2020) (Figure 8). For the model to be implemented, a car kit previously placed in the car is used to report the location of the car which has been parked for a specific period of time and to enable trunk check. By means of this kit, the courier can open the trunk and deliver the package, upon which the customer is notified via SMS of the delivery completion (Chua, 2012).

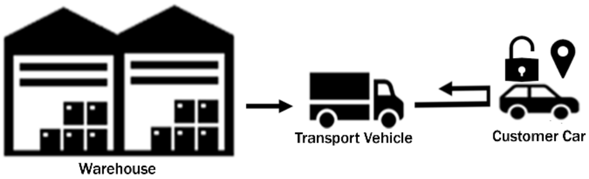

Figure 8. In-car delivery model

This delivery model basically makes use of GPS technology and automobile producers provide customers with the option to use this delivery method by offering new car models equipped with suitable devices. Within this framework, the two major automobile producers Audi and Volvo cooperate with DHL and Amazon for in-car delivery (Figure 9).

Figure 9. In-car delivery cooperation with Amazon, DHL, and Audi (Catalano, 2015)

The majority of the urban population leads constantly mobile lives and the delivery of online orders via conventional delivery methods is nowadays regarded as a factor negatively affecting the freedom of movement for the urban communities. The model promotes today's customer's mobile and active life and has great advantages as follows:

- Reduces delivery time and costs.
- Eliminates the probability of failed delivery due to customer not being at the address.
- Beneficial in terms of traffic density and CO_2 emission.
- Can reduce the distance travelled by 40% to 65% depending on location flexibility (Reyes et al., 2017).

On the other hand, the fact that concepts such as smart city and smart mobility are becoming increasingly popular by the day to create solutions to urban logistics problems, and that private car ownership in developed countries is being reduced due to environmental and social concerns where common transport vehicles are being crowdsourced can be deemed as a limitation for the future of this model.

3.5. Cargo bike

With the pressure of fast deliveries on LSP, it has become mandatory to resort to alternative remedies that provide delivery flexibility on cramped and/or pedestrianized roads. Within this context, cargo bike delivery appears to be a useful method. Cargo bike delivery notably focuses on the reduction of environmental factors and offers a more sustainable and flexible distribution model. Besides, it aims to prevent dense vehicle traffic in urban areas and causes less environmental impact (Arnold et al., 2018). Figure 10 illustrates last-mile delivery via cargo bike.

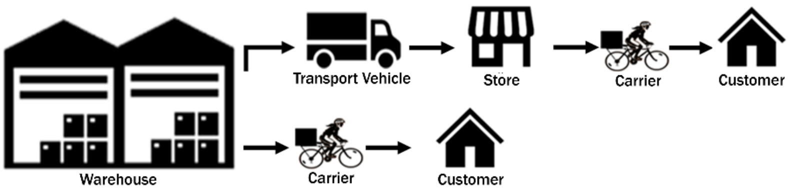

Figure 10. Cargo bike delivery model

Various cargo bike types used in last mile delivery are described in Table 6, whose visuals are presented in Figure 11.

Table 6. Types of cargo bike (Nürnberg, 2019)

Bike Type	Description
Post bike	Two-wheeler bike that the cargo box is mostly in front of the steering wheel or behind the saddle. Maximum transportation weight is usually between 50-75 kg.
Longtail	Two-wheeler bike type with a trunk at the back, which loaded up to 50 kg.
Frontloader	Mostly a two-wheeler in which the cargo box is placed at a low level in front of the bike. The low center of gravity as well as the geometry of the chassis allow for maneuvers even at higher transportation weights.
Trike	Multi-wheeler vehicles with the largest cargo area that can carry up to 500 kg of weight.

(a) **(b)** **(c)** **(d)**

Figure 11. Types of cargo bike (**a.** Post bike (Cargo Cycling, 2021); **b.** Longtail (ECF News, 2011); **c.** Frontloader (Sutton, 2016); **d.** Trike (Manthey, 2018))

Considering the weight of cargo packages loaded on the cargo bike which can already be heavier than a normal bike, electric bikes (e-bikes) are more preferable in cargo deliveries since they are hard to ride by manpower. E-bikes also become prominent since they are faster and consume eco-friendly energy. To reduce emissions and improve sustainability, UPS uses e-bikes which can carry up to 100kg of cargo in Sweden and Denmark. (UPS Stories, 2020). Likewise, aiming to cancel out the emission they cause entirely by the year 2050, DHL are targeting to use eco-friendly collection and delivery solutions such as bikes and electric vehicles for 70% of their first and end customer services (DHL, 2017). Cargo bike delivery model provides significant advantages, notably in terms of sustainability and:

- Remarkably reduces CO_2 emissions as it doesn't consume energy or consumes eco-friendly energy.
- Lowers traffic density and resolves noise problems.
- Enables fast and easy delivery in cramped and pedestrianized areas.

Alongside the foregoing advantages, it also has some limitations such as relatively low transport capacity, lack of bike roads in developing countries, difficulty to ensure the rider's traffic safety and too much effort requirement for non-electric models. Nevertheless, it is expected that this delivery model will become prevalent all around the world in the upcoming years with other LSP following the footsteps of Amazon, DHL and UPS who are the pioneers of cargo bike delivery.

3.6. Drone delivery

Both steerable and able to move autonomously, drones provide quite a quick delivery process and can meet high service standards such as same/next-day delivery and even delivery within 2 hours. Drones that are used for last-mile delivery can fly with a weight of up to 18kg on average (Poljak, 2021). The energy drones need to fly is supplied by lithium-ion batteries. Drones can usually deliver for a flight time of maximum one hour. Figure 12 shows drone delivery model.

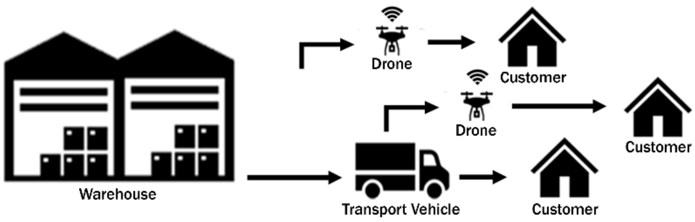

Figure 12. Drone delivery model

Factors such as low transport capacity and short battery life require the drones to frequently turn back to central warehouses. These limitations can be eliminated via drone+truck integrated transport (Figure 13). This model provides to complement the features of drones and trucks. While the truck has a lower speed than the drone, the drone has low weight and single order capacity. Using the model eliminates the inefficiencies of both, so the delivery process will be faster, weight and order capacity increase (Agatz et al., 2018). In this method, the driver loads the package into the cage under the drone and then directs the drone to an address via the previously determined autonomous route. Then, the drone updates its route using GPS technology to reach the truck which is on route for the next delivery (Burns, 2017). The combined use of drone+truck -especially for deliveries to rural areas- aims for the drone to perform quick and low-cost deliveries while the truck continues its trip on the main road.

(a)

(b)

Figure 13. a. UPS drone and delivery truck (Burns, 2017) **b.** Mercedes Vision Van (Muoio, 2017)

One example is the drone-truck integrated delivery model by UPS (Figure 13a), and another one is the vehicle design by Mercedes named "Vision Van" which can deliver via drone as well as having a feature enabling electric and automatic cargo load (Figure 13b). Wing, Amazon Prime Air, UPS Flight Forward, Flytrex, Wingcopter, Zipline, DHL Parcelcopter and Boeing also pioneer and contribute to drone delivery advances (Ueland, 2021). Drone delivery method comes with many advantages listed as follows:

- Especially suitable for the delivery of small packages and fast food in urban areas.
- Reduces noise and traffic density and prevents CO_2 emissions from increasing (Pugliese et al., 2020).
- Saves energy and ensures staff safety as it is an unmanned process.
- Reduces the number of wrong deliveries.
- Presents a solution for orders that require quick delivery.

Even though this method presents a sustainable delivery model thanks to the use of electrical energy and resolves urban logistics problems, it has its own disadvantages: besides the obligation for drone use to be allowed by legislation; other potential problems can be listed as high costs (for both the drone itself and its spare parts), the risk of failed delivery resulting from early consumption of battery due to battery-related faults, the time and effort it takes to gain the necessary experience to operate the drones, failed deliveries due to malfunction and easy theft risk (Grinddrone, 2021).

3.7. Autonomous ground vehicle

One of the most significant contributions of technology to last mile logistics processes is the possibility to deliver using autonomous vehicles. Autonomous vehicles are equipped with various technological features such as radar, lidar, ultrasonic and infrared sensors and video cameras. These features enable autonomous vehicles to perceive the environment, avoid accidents by identifying objects, measure the distance from objects, 3D view and efficient night vision. Furthermore, autonomous vehicles eliminate the need to manually park, hence providing the drivers with benefits such as timesaving, enhanced road safety and collaborative driving (Mounce and Nelson, 2019). Customer picks delivery via an autonomous device whilst ordering, and the delivery is performed once the customer comes and picks up their package from the vehicle parked in front of the customer's house or any other chosen location (Figure 14). Deliveries made via this model make it possible to monitor the process.

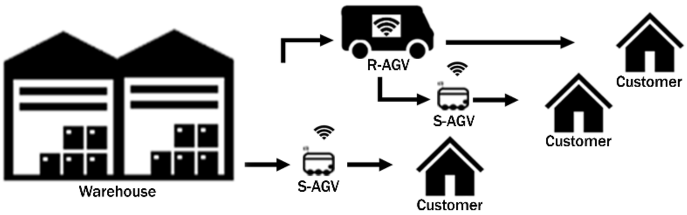

Figure 14. AGV delivery model

Autonomous delivery vehicles used in last mile delivery are categorized into two; as autonomous aerial vehicles and AGV (Barthuly, 2019). While drones, aforementioned in the foregoing section, represent the most common example of autonomous aerial vehicles; AGV come in two fundamental categories as sidewalk AGV (S-AGV) and road AGV (R-AGV). Whereas S-AGVs are robots that can only use sidewalks or pedestrian roads, R-AGVs use the highways used by traditional motor vehicles (Figliozzi and Jennings, 2020). Figure 15 presents examples of S-AGVs (a and b) and R-AGVs (c and d).

(a) **(b)** **(c)** **(d)**

Figure 15. Samples of AGV (**a.** DHL Post Box (internet of business, 2021); **b.** Amazon **Scout (**Scott, 2019); **c.** Udelv (O'Dell, 2018); **d.** NURO **(**Eliport, 2018))

S-AGVs can autonomously move at pedestrian speed on sidewalks and can be remotely controlled in case of any problems. When they reach customer's location, they inform the customer who then can receive the order by opening the lock (Ostermeier et al., 2021). Like drones, S-AGVs can also be integrated into trucks (Boysen et al., 2021). As for R-AGVs, there's no obligation for them to be controlled by a driver, as with the technology available through R-AGVs the driver or operator can take over only when deemed necessary. The use of AGV in last mile delivery provides many advantages such as:

- Reduces parking space problems, especially while using S-AGV.
- Since it is unmanned, it reduces the risk of accidents and hence the financial, environmental and health losses resulting from accidents.
- Shortens delivery times and increases customer satisfaction.
- Eliminates wrong delivery problems.
- Reduces traffic density.
- Reduces fuel consumption and CO_2 emission.

The model also comes with some disadvantages such as the requirement for high capital investment and suitable road infrastructure as well as the dependency on the Wi-Fi network and network reliability.

4. Conclusion

Becoming increasingly complicated and costly by the day with fast urbanization, advances in technology and the rise in e-commerce; last mile logistics practices present a problem in terms of the sustainability of cities. Nowadays, considering the widespread use of internet and the busy work schedule of the urban population; instead of losing time with traditional shopping, customers are prone to fulfill their needs via e-commerce where they demand fast, cheap, and reliable deliveries of their orders. Already under time and cost pressure, LSP operations become harder with customers who are mobile throughout the day and not present at the product delivery address, which reduces the efficiency of last-mile logistics activities which form the last stage of the supply chain.

On the other hand, since a meaningful part of urban logistics activities consist of last mile deliveries; local administrations, practitioners, customers, and researchers alike have been paying more attention to the effects of delivery methods on the quality of life and environment for the urban population within the context of sustainable urban logistics. In order to find solutions to urban problems partially arising from last mile logistics such as traffic density, parking space issues, emissions, noise and air pollution, accident risks and various health issues; there has been a search towards sustainable and efficient delivery models as an alternative to the traditional home delivery model and new generation delivery models have started to be implemented worldwide. It is expected that those LSP and e-retailers who can quickly adapt to these new generation delivery models will have significant advantages over their competitors under the challenging market conditions. Sustainable delivery models also provide other advantages such as correct, quick, and cost-efficient delivery and freedom of mobility for the customers and the elimination of environmental concerns. Therefore, the effective planning and implementation of these new approaches make it possible to retain customer loyalty and assure high customer service quality.

In order to shed some light on urban logistics problems; this study looks into the operation, comparison, advantages and disadvantages, integration and example practices of new generation sustainable delivery models used in last mile logistics. To this end; as the most accepted models in literature as well as practice; crowdsourced delivery, C&C, PP, PUDO, locker, RDB, in-car delivery, cargo bike, drones and AGVs have been studied from a sustainable urban logistics point of view where their similarities and differences have been presented. Future researches will aim to use Multiple-Criteria Decision-Making (MCDM) methods for last mile delivery model selection as well as to optimize the economic and environmental purposes of various delivery models under certain limitations based on the example of Turkey.

Contribution of authors

All authors contributed equally to the design and implementation of the research, the interpretation of the results, and the writing of the manuscript.

Conflict of interest

The authors declared that there is no conflict of interest.

References

Agatz, N., Bouman, P. & Schmidt, M. (2018). Optimization approaches for the traveling salesman problem with drone, *Transportation Science, Articles in Advance*, 52 (4), 1–17. doi: https://doi.org/10.1287/trsc.2017.0791

Amaral, R.R., Šemanjski, I., Gautama, S. & Aghezzaf, E.H. (2018). Urban mobility and city logistics – trends and case study, *Promet - Traffic & Transportation*, 30 (5), 613-622. doi: http://dx.doi.org/10.7307/ptt.v30i5.2825

Arnold, F., Cardenas, I., Sörensen, K., Dewulf, W., (2018). Simulation of B2C e-commerce distribution in Antwerp using cargo bikes and delivery points, *European Transport Research Review*, 10 (2), 1-13. doi: https://doi.org/10.1007/s12544-017-0272-6

Barthuly, D., (2019). *Autonomous ground vehicles in urban last-mile delivery – an exploration of the implementation feasibility and consumer's acceptance*, Master Thesis, Universidade Católica Portuguesa, Business and Economics Lisbon. url: https://repositorio.ucp.pt/handle/10400.14/29253

BoxBot. (2019). url: http://www.prweb.com/releases/boxbot_unveils_a_new_system_for_self_driving_parcel_delivery/prweb16361603.htm

Boysen, N., Fedtke, S. & Schwerdfeger, S. (2021). Last-mile delivery concepts: A survey from an operational research perspective, *SpringerLink, OR Spectrum* 43, 1–58. doi: https://doi.org/10.1007/s00291-020-00607-8

Broadhurst, B. (2020). Crowdsourced Delivery Is Here to Stay. url: https://www.supplychainbrain.com/articles/30887-crowdsourced-delivery-is-here-to-stay

Burns, S. (2017). Drone meets delivery truck. url: https://www.ups.com/us/en/services/knowledge-center/article.page?kid=cd18bdc2

Cargo Cycling. (2021). url: https://www.cargocycling.com/cargo-cycles/cargo-courier/

Catalano, F. (2015). Amazon will deliver packages to car trunks, working with Audi and DHL. url: https://www.geekwire.com/2015/deliveries-to-your-car-trunk-amazon-teams-with-audi-and-dhl-in-new-initiative/

Chua, H. (2012). Cardrops Turns Your Car Trunk into a Mailbox for Your Convenience. url: https://technabob.com/blog/2012/11/01/cardrops-mailing-service/

ECF NEWS. (2011). Delivering Goods by Cycle? An Urban Recipe for Success. url: https://ecf.com/news-and-events/news/delivering-goods-cycle-urban-recipe-success

DHL. (2017). url: https://www.dhl.com/global-en/home/about-us/delivered-magazine/articles/2017/issue-2-2017/zero-emissions-by-2050.html

Doddle. (2020). Sustainable delivery. Luxury or necessity in today's consumer climate? url: https://solutions.doddle.com/hubfs/Doddle%20Pulse%20Sustainable%20Delivery-1.pdf

Eliport Editorial Team. (2018). The Top Ten Autonomous Delivery Solutions of 2018. url: https://medium.com/eliport/the-top-ten-autonomous-delivery-solutions-of-2018-5cfe4e0c90a5

European Comission-1. (2021). Clean transport, Urban transport Urban mobility. url: https://ec.europa.eu/transport/themes/urban/urban_mobility_en

European Comission-2. (2021). Clean transport, Urban transport Sustainable Urban Mobility Plans. url: https://ec.europa.eu/transport/themes/urban/urban-mobility/urban-mobility-actions/sustainable-urban_en

Figliozzi, M. & Jennings, D. (2020). Autonomous delivery robots and their potential impacts on urban freight energy consumption and emissions, *Transportation Research Procedia*, 46, 21–28. doi: https://doi.org/10.1016/j.trpro.2020.03.159

Fintechtime. (2016). Türkiye'de Click & Collect Dönemi Başlıyor. url: https://fintechtime.com/tr/2016/07/turkiyede-click-collect-donemi-basliyor/

Gielens, K., Gijsbrechts, E. & Geyskens, I. (2020). Navigating the last mile: The demand effects of click-and-collect order fulfillment, *Journal of Marketing*, 1-21. doi: https://doi.org/10.1177/0022242920960430

González-Varona, JM., Villafáñez, F., Acebes, F., Redondo, A. & Poza, D. (2020). Reusing newspaper kiosks for last-mile delivery in urban areas, *Sustainability*., 12 (22), 1-27. doi: http://dx.doi.org/10.3390/su12229770

Grinddrone. (2021). Pros and Cons of Delivery Drones. url: https://grinddrone.com/info/pros-cons-delivery-drones

Halldórsson Á. & Wehner J. (2020). Last-mile logistics fulfilment: A framework for energy efficiency. *Research in Transportation Business & Management*, 37, 1-11. doi: https://doi.org/10.1016/j.rtbm.2020.100481

International Post Corporation. (2020). Oct 2020: The battle for the last mile - analysis of key markets and players in the PUDO space. url: https://www.ipc.be/services/markets-and-regulations/e-commerce-market-insights/e-commerce-articles/2020-10-pudo-overview

Internet of business. (2021). DHL US trials robots, AI, AR & crowdsourcing to beat Amazon. url: https://internetofbusiness.com/dhl-trials-robots-ai-ar-and-crowdsourcing-to-beat-amazon/

Iwan, S., Kijewska, K. & Lemke, J. (2016). Analysis of parcel lockers' efficiency as the last mile delivery solution– the results of the research in Poland, *Transportation Research Procedia* ,12, 644–655. doi: https://doi.org/10.1016/j.trpro.2016.02.018

Jara, M., Vyt, D., Mevel, O., Morvan, T. & Morvan, N. (2018). Measuring customers benefits of click and collect, *Journal of Services Marketing, Emerald,* 32 (4), pp.430-442. url: https://halshs.archives-ouvertes.fr/halshs-01806403

Kämäräinen, V., Saranen, J. & Holmström, J. (2001). The reception box impact on home delivery efficiency in the e-grocery business, *International Journal of Physical Distribution & Logistics Management,* 31 (6), 414-426. doi: https://doi.org/10.1108/09600030110399414

Kargopark. (2021). url: https://kargopark.com/

Kawa, A. (2019). Last mile logistics. in technological revolution. directions in the development of the transport-forwarding-logistics sector, url: https://pitd.org.pl/wp-content/uploads/2020/01/PITD-Report-technological-revolution-directions-in-the-development-of-the-transport-forwarding-logistics-sector.pdf

Kawa, A. (2020). Out-of-home delivery as a solution of the last mile problem in e-commerce, smart and sustainable supply chain and logistics – trends, challenges, methods and best practices. *EcoProduction (Environmental Issues in Logistics and Manufacturing), Springer, Chapter* 2, 25-40. doi: https://doi.org/10.1007/978-3-030-61947-3_2

Koiwanıt, J. (2018). Analysis of environmental impacts of drone delivery on an online shopping system, *Advences in Climate Change Research,* 9 (3), 201-207. doi: https://doi.org/10.1016/j.accre.2018.09.001

Köydedurmaz, F. (2017). Click and Collect nedir? url: https://www.nmdijital.com/click-collect-nedir/

Manthey, N. (2018). UK: Funding boost for last-mile cargo e-bikes. url: https://www.electrive.com/2018/09/10/uk-funding-boost-for-last-mile-cargo-e-bikes/

McLeod, F., Cherrett, T. & Song, L. (2006). Transport impacts of local collection/delivery points, *International Journal of Logistics Research and Applications,* 9 (3), 307-317. doi: https://doi.org/10.1080/13675560600859565

Morganti, E., Dablanc, L. & Fortin, F. (2014). Final deliveries for online shopping: the deployment of pickup point networks in urban and suburban areas, *Research in Transportation Business and Management, Elsevier,* 11, 23-31. doi: http://dx.doi.org/10.1016/j.rtbm.2014.03.002

Moroz, M. & Polkowski, Z. (2016). The last mile issue and urban logistics: choosing parcel machines in the context of the ecological attitudes of the Y generation consumers purchasing online, *Transportation Research Procedia,* (16), 378-393. doi: https://doi.org/10.1016/j.trpro.2016.11.036

Mounce, R. & Nelson, J.D. (2019). On the potential for one-way electric vehicle car-sharing in future mobility systems, *Transportation Research Part A Policy and Practice*, 120, 17–30. doi: https://doi.org/10.1016/j.tra.2018.12.003

Muoio, D. (2017). Mercedes is reportedly pouring $562 million into delivery van drones — here's a glimpse of what's to come. url: https://www.businessinsider.com/mercedes-electric-vision-van-drone-delivery-service-photos-2017-3

Nürnberg, M. (2019). Analysis of using cargo bikes in urban logistics on the example of Stargard, *Transportation Research Procedia*, 39, 360–369. doi: https://doi.org/10.1016/j.trpro.2019.06.038

O'Dell, J. (2018). Udelv Demos Autonomous Delivery Van. Launches On-Road Testing. url: https://www.trucks.com/2018/01/31/udelv-autonomous-delivery-van-testing/

Olivo. (2021). La Graine Locale ("The Local Seed"). url: https://www.olivo-logistics.com/en/2019/06/27/la-graine-locale/

Ostermeier, M., Heimfarth, A. & Hübner, A. (2021). Cost-optimal truck-and-robot routing for last-mile delivery, *Networks. 2021,* 1–26. doi: http://dx.doi.org/10.1002/net.22030

ParcelHive. (2021). url: https://parcelhive.net/refrigerated-locker/

Perboli, G., Rosano, M., Saint-Guillain, M. & Rizzo, P. (2018). A simulation-optimization framework for city logistics. An application on multimodal last-mile delivery, *IET Intelligent Transport Systems, pp. 1–8, January 2018*. doi: 10.1049/iet-its.2017.0357

Pinpod. (2021). Who is the PinPod outdoor parcel delivery box for? url: http://www.pinpod.com/who

Poljak, M. (2021). How Much Weight Can a Drone Carry? url: https://www.dronetechplanet.com/how-much-weight-can-a-drone-carry/

Pronello, C., Camusso, C. & Valentina, R. (2017). Last mile freight distribution and transport operators' needs: Which targets and challenges? *Transportation Research Procedia*, *25*, 888–899. doi: https://doi.org/10.1016/j.trpro.2017.05.464

Pugliese, L.D., Guerriero, F. & Macrina, G. (2020). Using drones for parcels delivery process, *Procedia Manufacturing,* 42 (2020), 488–497. doi: https://doi.org/10.1016/j.promfg.2020.02.043

Punakivi, M. & Tanskanen, K. (2002). Increasing the cost efficiency of e-fulfilment using shared reception boxes, *International Journal of Retail & Distribution Management,* 30 (10), 498-507. doi: http://dx.doi.org/10.1108/09590550210445362

Punakivi, M., Yrjölä, H. & Holmström, J. (2001). Solving the last mile issue: reception box or delivery box? *International Journal of Physical Distribution & Logistics Management*, 31 (6), 427-439. doi: https://doi.org/10.1108/09600030110399423

Rai, H.B., Cetinkaya, A., Verlinde, S. & Macharis, C. (2020). How are consumers using collection points? Evidence from Brussels, *Transportation Research Procedia*, 46 (2020), 53–60. doi: https://doi.org/10.1016/j.trpro.2020.03.163

Reyes, D., Savelsbergh, M. & Toriello, A. (2017). Vehicle routing with roaming delivery locations, *Transportation Research Part C Emerging Technol,* 80, 71–91. doi: http://dx.doi.org/10.1016/j.trc.2017.04.003

Rovenma. (2021). url: https://www.rovenma.com/tr/smart-parcel-locker/

Różyckı, M., Gral, M. & Anson J. (2021). Out-of-home delivery in Europe 2021 PUDO and parcel lockers, *(*Last Mile Experts, UPIDO), 1-87. url: http://www.lastmileexperts.com/news-case-studies/195-out-of-home-delivery-in-europe-2021

Schwerdfeger, S. & Boysen, N. (2020). Optimizing the changing locations of mobile parcel lockers in last-mile distribution, *European Journal of Operational Research*, 285, 1077–1094. doi: https://doi.org/10.1016/j.ejor.2020.02.033

Scott, S. (2019). Meet Scout. url: https://www.aboutamazon.com/news/transportation/meet-scout

Silva, J.V.S.D., Magalhães, D.J.A.V.D. & Medrado, L. (2019). Demand analysis for pick-up sites as an alternative solution for home delivery in the Brazilian context, *Transportation Research Procedia*, 39, 462–470. doi: https://doi.org/10.1016/j.trpro.2019.06.048

Song, L., Cherrett, T., McLeod, F. & Guan, W. (2009). Addressing the last mile problem transport impacts of collection and delivery points, *Transportation Research Record, Journal of the Transportation Research Board*, 2097, 9–18. doi: https://doi.org/10.3141/2097-02

Sutton, M. (2016). Cycling Industry News. url: https://cyclingindustry.news/larry-vs-harry-starts-global-cargobike-partnership-with-dhl/

Tepebaşı Municipality. (2021). Tepebaşı'ndan Örnek Bir Proje Daha. url: http://www.tepebasi.bel.tr/hd.asp?hid=10039

Ueland, S. (2021). 8 Commercial Drone Delivery Companies. url: https://www.practicalecommerce.com/8-commercial-drone-delivery-companies

UNCTAD-1. (2020). url: https://stats.unctad.org/handbook/Population/Total.html

UNCTAD-2. (2020). url: https://unctad.org/press-material/global-e-commerce-hits-256-trillion-latest-unctad-estimates

UPS Stories. (2020). UPS reduces emissions & congestion in Denmark & Sweden with new zero emission ebikes. url: https://stories.ups.com/upsstories/us/en/newsroom/press-releases/sustainable-solutions/ups-reduces-emissions-congestion-in-denmark-sweden-with-new-zero-emission-ebikes.html

Wang, X., Zhan, L., Ruan, J. & Zhang, J. (2014). How to choose ‘‘last mile’’ delivery modes for e-fulfillment, *Hindawi Publishing Corporation, Mathematical Problems in Engineering.*, Volume 2014, 1-11. doi: http://dx.doi.org/10.1155/2014/417129

Weltevreden, J.W.J. (2008). "B2C e-commerce logistics: the rise of collection-and-delivery points in The Netherlands", *International Journal of Retail & Distribution Management*, 36 (8), 638-660. doi: http://dx.doi.org/10.1108/09590550810883487

World Bank. (2021). url: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

Zenezini, G., Lagorio, A., Pinto, R., Marco, A.D. & Golini, R. (2018). The collection-and-delivery points implementation process from the courier, express and parcel operator’s perspective, *Ifac-papersonline,* 51 (11), 594–599. doi: https://doi.org/10.1016/j.ifacol.2018.08.383