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Reusing Newspaper Kiosks for Last-Mile Delivery in Urban Areas

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Abstract: The current increase in e-commerce is generating growing problems in urban areas in terms of both traffic flow (increasing traffic, no parking spaces) and environmental issues (noise, atmospheric pollution, etc.). In parallel, an iconic element of historic districts is disappearing: more and more newspaper kiosks are closing their business as their work dwindles. In this scenario, the objective of this paper is to propose a model for last-mile parcel delivery that exploits the current available newspaper kiosk network by using them as parcel lockers. To demonstrate the benefits of this proposal, we map the kiosk network of the city of Valladolid (Spain), and compare the environmental impact of a traditional (door-to-door) delivery and the proposed model which reuses old kiosks as parcel lockers. The necessary steps to carry out simulations are described in detail so that experiments can be replicated in other cities that face the same issues.

Keywords: e-commerce; last-mile delivery; urban logistics; urban areas; newspaper kiosk

1. Introduction

E-commerce sale volumes have grown continuously in the last few years. Although a 20.7% global growth rate was forecast for 2020 [1], the ongoing COVID-19 pandemic is leading to substantial changes in online consumption patterns that have accelerated e-commerce growth beyond any expectations [2]. Consequently, an increasing number of vehicles are needed in downtown areas to deliver this growing volume of goods, which leads to traffic-flow problems, and also to negative health and environmental consequences (e.g., noise pollution, CO_2 emissions) [3–5].

In general, while the logistics associated with freight transport have significantly improved in recent years, this cannot be stated for last-mile distribution, which is considered one of the least efficient, the most polluting and the costliest segments along the entire logistics chain [6]. Last-mile delivery is the process associated with moving goods from a courier's warehouse to their final destination [7]. Figure 1 represents a traditional parcel delivery model. Goods are transported from their place of origin by different transportation means until they reach the courier's local warehouse, which is usually located near the customer's address. From this point with traditional last-mile delivery, goods are loaded on delivery vehicles that travel around the city in order to deliver the corresponding parcels to customer addresses.

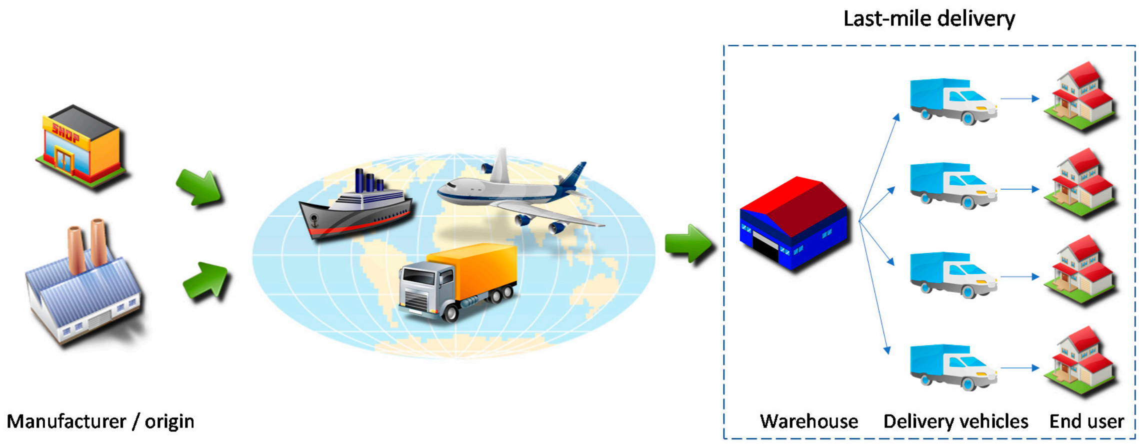
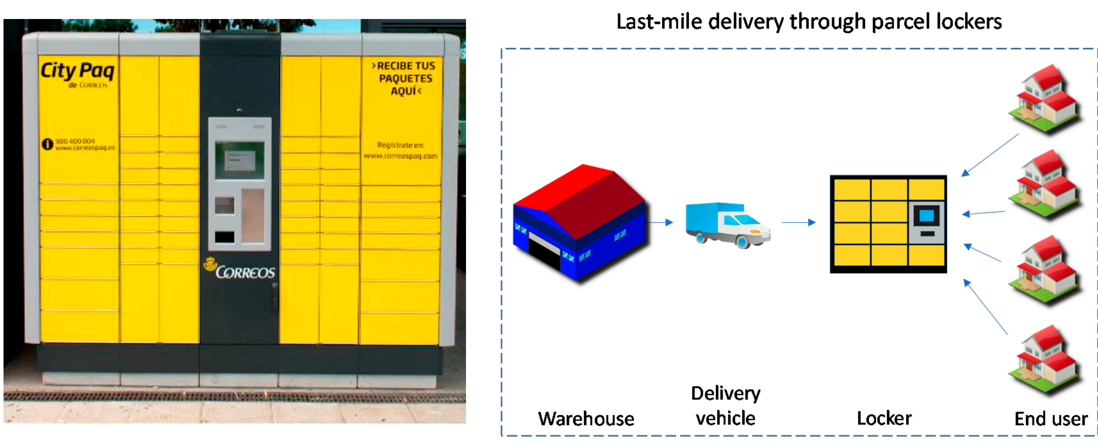


Figure 1. Representation of a delivery model with traditional door-to-door last-mile delivery (right).

The door-to-door delivery service has traditionally been the most frequent mode of delivery for the last mile (Figure 1, right). In this form, the customer simply waits at home for goods to be delivered. Apart from the above-mentioned traffic and environmental issues, this delivery method entails certain drawbacks that make last-mile delivery expensive and inefficient: difficulties in finding the exact client's address, or no-one at home when delivery people arrive, to cite only two examples. In these situations, the customer needs to either go to the courier's depot to pick up goods or wait for the delivery company to make a second delivery attempt.

Last-mile delivery becomes particularly complex in downtown areas given their limited capacity to support increasing traffic demands [8] and parking places for delivery vehicles are often lacking [9]. To mitigate home delivery service problems, a more efficient last-mile distribution alternative has been proposed in recent years: the use of a self-collection delivery service through parcel lockers. Parcel lockers are automated machines for the delivery of goods. They are located in highly frequented areas, usually near customers' homes (Figure 2a). Accordingly when a courier deposits goods in lockers, recipients are notified to come and pick them up (Figure 2b). An integrated terminal allows the identification of the recipient of a package and releases it.



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

Figure 2. Last-mile delivery through parcel lockers: (**a**): parcel locker sample; (**b**): schematic representation of last-mile delivery through parcel lockers.

The use of this automated system for last-mile delivery offers several advantages: it is a simple solution that does not need employees, and it reduces failed deliveries and, thus, subsequent delivery attempts. Consequently, the use of parcel lockers reduces delivery costs and handling times and can also contribute to reduce traffic density and CO_2 emissions. It also reduces the risk of delivering to wrong addresses and avoids having to double-park when no spaces are available, which means a more efficient delivery process. In fact the use of automated lockers has proven especially useful for parcel delivery in large city centers [10], and has received the attention of several studies in recent years as an alternative to traditional door-to-door delivery (please see Section 2 for a literature review).

As previously mentioned, change in consumer habits and subsequent e-commerce growth are driving the need to improve delivery system efficiency in large city centers. At the same time, this change in consumer habits is also responsible for more and more newspaper kiosks currently abandoning their activity due to consumer loss of interest in their traditional activity (Figure 3).

Figure 3. Abandoned newspaper kiosk in the historic district of Valladolid, Spain. Source: Google Maps.

The spaces occupied by the kiosk are owned by the City Council. At some point, the City Council made a long-term concession and allowed kiosks to be installed in these spaces. That is, kiosk operators were awarded the concession to operate a kiosk in that space for a long period of time, i.e., several decades, but not actually as a rental. After the space was licensed, operators bought and installed their own kiosks. As this is not a rental, but a concession, if and when the kiosk eventually goes out of business, the operator has two options: to try to sell the kiosk as a whole to somebody else (i.e., space plus structure); or to dismantle the whole structure and return the space in its original condition to the City Council. The second option is generally costly, which is why kiosk owners normally prefer the first option: shutdown and try to sell the kiosk to another operator. This fact explains why there are so many 'abandoned' kiosks throughout the city today (Figure 3). These kiosks are shut and abandoned despite them occupying privileged locations (i.e., they are easily visible and accessible, and are situated in transit areas close to other uses and services in the city, etc.). Several studies suggest that places with such characteristics are desirable as locations for parcel lockers, as choosing the appropriate location is one of the most important success factors for this delivery method [11–13].

In this context, the objective of this paper is to propose a last-mile delivery model that exploits the current available kiosk network by using them as parcel lockers. Our proposal consists in incorporating parcel lockers attached to each currently existing kiosk in the city (whether they are operational, or their business has ceased). To demonstrate the benefits of this proposal, we offer a case study conducted in the city of Valladolid (Spain) in which we simulate and compare the environmental impact of traditional home delivery and the proposed model that reuses old kiosks as parcel lockers. The necessary steps to carry out simulations are described in detail so that experiments can be replicated in other cities that face the same issues.

The rest of the paper is structured as follows. Section 2 provides a literature review. Section 3 describes the process followed to build the model and to design the experiments. Section 4 shows the results of simulations, which we use to compare the environmental impact of the delivery method herein proposed with traditional last-mile delivery methods. Finally, Section 5 provides discussion and conclusions.

2. Literature Review

Studies of the use of automated lockers as an alternative to home delivery have focused mainly on three topics: efficiency from the shipping company's point of view (Table 1); optimal design/location of lockers (Table 2); consumers' intention to use parcel lockers (Table 3).

Table 1. Recent studies that focus on efficiency from the shipping company's point of view.

Study	Methodology	Location	Main Findings
[14]	Agent-based modeling	Belo Horizonte, Brazil	Parcel lockers increase carriers' profits (fewer vehicles required, shorter traveled distance)
[15]	Case study/simulation	Antwerp, Belgium	Stimulating customer self-pick up can reduce delivery companies' operational costs
[16]	Mixed Integer Linear Programming	Toronto, Canada	Selecting optimal numbers, locations, and sizes of parcel lockers to maximize a company's profits
[17]	Mixed Integer Linear Programming/heuristics	-	Logistics costs in last-mile delivery can be reduced by allowing customers to pick up parcels from the parcel lockers near their homes
[18]	Mixed-integer programming/metaheuristics	-	Lower cost/shorter time if customers accept a larger set of lockers for delivery
[19]	Data analysis from the travel diary data of a parcel delivery operator	Jabodetabek, Indonesia	The use of parcel lockers is more efficient in total travel length terms compared to direct delivery service

Table 2. Recent studies on the optimal design/location of lockers.

Study	Methodology	Location	Main Findings
[20]	Mixed-integer linear programming/case study	Singapore	The optimal location of lockers requires considering customers' perceived service quality
[21]	Conceptualization	—	Development of several locker design options for efficient delivery service
[22]	Hierarchical cluster analysis	Brisbane, Australia	Importance of the optimal integration and distribution of parcel lockers across the area to meet city and transport planning objectives
[23]	Mixed-integer programming	—	Minimize the company's fleet size while offering customers a flexible service by using mobile lockers

Table 3. Research focused on consumers' intention to use parcel lockers.

Study	Methodology	Location	Main Findings
[11]	Survey	Belo Horizonte, Brazil	Users' revealed preference shows that delivery lockers have a high potential demand from online shoppers
[12]	Qualitative analysis (focus groups)	Christchurch, New Zealand	Factors affecting the likelihood of customers using lockers: spatial location, parking availability, proximity to home and office, and hours and security of their operation
[13]	Survey	Szczecin, Poland	Importance of the parcel locker location: close location to home, on the way to work and available parking spaces
[24]	Questionnaire	China	Location convenience and innovation positively affect consumer's intention to use delivery lockers
[25]	Questionnaire	China	Factors that affects customer willingness to use lockers: age, value of parcel, and online shopping frequency
[26]	Theoretical study (innovation diffusion theory)	Singapore	Relative advantage, compatibility and trialability positively impact customers' intention to use parcel lockers
[27]	Questionnaires	China	Relation between psychological factors (perceived risk, perceived satisfaction) and online shoppers' intention to use self-service delivery services

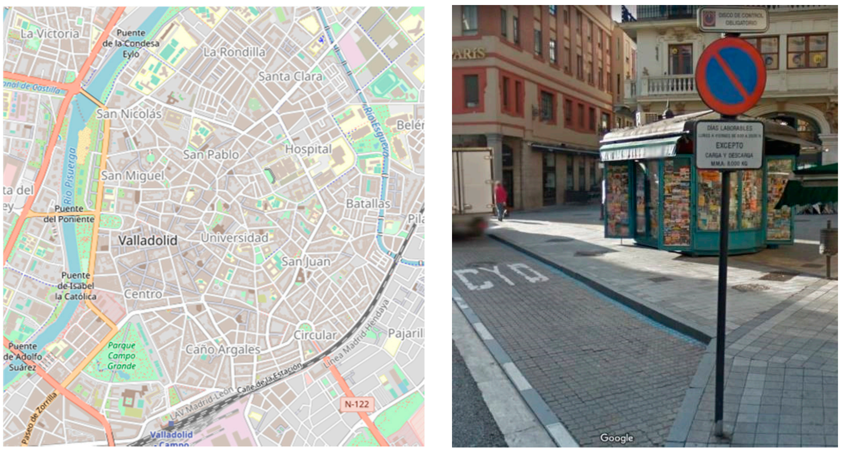
By analyzing recently published related works, we conclude that although the proposal to use lockers for last-mile delivery is not new, it is only in the last few years that it has been paid attention to, for the advantages their use brings to large cities.

The use of lockers as a last mile-delivery method is a current global topic. However, the success of its application eventually depends on local characteristics (e.g., layout of city streets, local e-commerce demand, etc.). Therefore, it may be too early to generalize the conclusions drawn by recent literature on the topic because many of these studies have focused on specific cities. Nonetheless, we consider that complementing previous studies with the results of simulating locker-based last-mile deliveries in other cities is an important opportunity to contribute to general knowledge about the advantages of this delivery type. Hence this paper simulates last-mile delivery by considering the peculiarities of the city of Valladolid (Spain) regarding both the use of parcel lockers and traditional home delivery.

The literature shows that the location of parcel lockers is one of the key factors in their success (Table 3). In fact many studies have focused on finding the optimal locker location (Table 2). These studies propose deploying new infrastructure in the city but, to the best of our knowledge, no previous study has proposed reusing urban infrastructure to facilitate the deployment of parcel lockers. Reusing urban infrastructure is a way to achieve sustainable urban development as it avoids waste generation due to demolition, and allows a better use of embodied energy, which suggests socio-economic benefits [28]. In fact in a recent review on sustainability principles and trends in modern cities, city logistics have been identified as one emerging area of innovation towards a sustainable transportation strategy [29]. For this reason, and from our point of view, these developments need to be accompanied by improvements in last-mile delivery in the interest of urban sustainable development. Moreover, reusing the current network of newspaper kiosks could help to meet this goal.

3. Methodology and Inputs

Valladolid is a medium-sized city in northwest Spain. Its population is almost 300,000. Figure 4a is a map showing the historic district of this city. Like most European cities, the urbanization of the historic city center began in ancient times, and has resulted in characteristic narrow streets with an erratic layout. This area has traditionally suffered intense traffic because most of the city's economic activity takes place in the historic district. In recent years, e-commerce growth has brought an increasing number of delivery vans to these streets. This fact has made the problem worse, not only due to increased traffic burden, but also to the shortage of parking spaces for delivery vehicles. Regardless of the other benefits discussed below, reusing kiosks as parcel lockers can mitigate the traffic blockage problem associated with door-to-door deliveries: double-parking issues will reduce as kiosks currently maintain their parking spaces for press delivery (Figure 4b), which could be reused by parcel delivery vehicles.



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

Figure 4. (**a**): map of the historic district in the city of Valladolid. Source: Open Street Map; (**b**): parking facility for newspaper deliveries next to a kiosk. Source: Google Maps.

To demonstrate the environmental benefits of reusing kiosks as parcel lockers, we built a model to simulate parcel delivery in the city of Valladolid, as both traditional door-to-door delivery and by reusing the current existing kiosk networks as parcel lockers. In both scenarios, we compare the total distance traveled by delivery vehicles and subsequent CO_2 emissions. The remainder of this section describes how the model was built and how simulations were designed.

3.1. Generation and Distribution of Consumer Demand

To perform simulations, we first need to estimate the number of parcels that are typically delivered in the city of Valladolid during a 1-day period and the spatial distribution of that demand. However, the actual delivery locations are sensitive information that the companies we contacted are not willing to provide, mainly for legal reasons. Consequently, we needed to find an alternative way to find out how many deliveries are made daily in each city neighborhood.

To do so, our starting point was a dataset from an official report by the Spanish National Commission of Markets and Competence [30]. This report provides statistics on the number of orders placed per person over a 6-month period in Spain as a whole. By assuming that courier companies perform deliveries seven days a week, we divided these figures by 180 and found that the average number of daily deliveries per 1000 people was approximately 15 in the whole country. We then extrapolated this information to the city of Valladolid (with a current population of 287,195) to obtain an estimation of 4321 deliveries per day. This estimate of the number of daily orders matches the information provided by the delivery companies we contacted for this study (note that we cannot make the exact information provided by courier companies public).

The next step was to distribute this demand of 4321 daily deliveries throughout the city. To do so, we hypothesized that the number of deliveries in each neighborhood would be proportional to its population.

Table 4 shows the number of delivery requests per neighborhood that we considered in the simulation. The locations of these neighborhoods are shown in Figure 5.

Table 4. Population of each neighborhood and the considered number of daily delivery requests per neighborhood.

Neighborhood	Population	Number of Delivery Requests per Day
Arturo Eyríes	4584	69
Barrio España	2615	40
La Farola—C. de la Esperanza—Paseo Zorrilla	6369	96
Arco Ladrillo-Pza. Toros-B. G. Civil—P. Zorrilla	26,238	394
Caño Argales—San Andrés	7665	115
Pza. España—Plaza Mayor—S. Martin—S. Juan	8979	135
Cuatro de Marzo	3565	54
Girón-Villa del Prado	8907	134
Hospital	7448	112
Huerta del Rey	15,653	235
La Circular	10,399	156
La Pilarica-Santos Pilarica—Belén	10,441	157
La Rondilla—Santa Clara/XXV Años de Paz	22,246	334
La Rubia-Parque Arturo León	6470	98
La Victoria	14,889	224
Las Batallas	3893	59
Las Delicias	27,538	414
Las Flores	2079	32
Las Villas-P. Alameda-Covaresa-P. Arturo León	22,848	343
Los Vadillos	4335	66

Table 4. *Cont.*

Neighborhood	Population	Number of Delivery Requests per Day
Pajarillos -Páramo San Isidro-Campo de Tiro	21,758	327
Parquesol	26,086	392
Pgno. Argales-Ciudad de la Comunicación	2340	36
San Pablo—San Nicolás—San Miguel	10,181	153
San Pedro Regalado	2730	41
Universidad—La Antigua—Santa Cruz—San Juan	6939	105
Total	287,195	4321

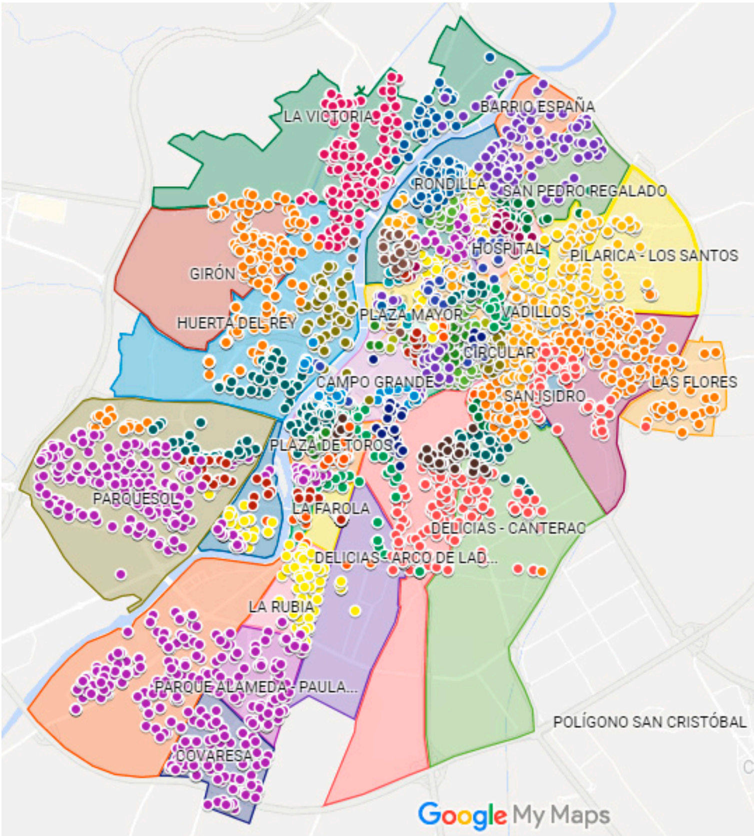


Figure 5. Distribution of the 4321 random delivery locations (i.e., client addresses). Neighborhoods are represented by different colors. Source: Google My Maps.

Having obtained an estimation for the number of deliveries per neighborhood, we used a combination of Microsoft Excel and Google Maps to generate random delivery locations. In each neighborhood, we generated as many random locations (i.e., client addresses) as there were delivery requests (see Table 4). To randomly distribute requests in a neighborhood, we used Google Maps to obtain the coordinates of the square that approximately encompassed that neighborhood. Then we used Microsoft Excel to generate random locations within the coordinates of that square. These random locations represent the customers awaiting a parcel.

Note that some of the points obtained by this procedure were not valid for our study because their geographical coordinates were not appropriate for an address where delivery could be expected (e.g., rivers, parks, etc.). These were discarded.

This procedure allowed the number of delivery requests in a neighborhood to be proportional to its population. Figure 5 shows the location of the random delivery points generated for the simulation. An interactive map with this information is available at: https://www.google.com/maps/d/u/0/viewer?mid=1cLBXHpdGGSUEO5mgPpU3n_5jpcUK0WpF&ll=41.62389025336443%2C-4.653338689314721&z=13.

The number of delivery points per neighborhood corresponds to the figures in Table 4.

Regardless of the neighborhood to which each delivery location belonged, the 4321 daily orders were randomly allocated to one of the five couriers that currently operate in Valladolid. The number of parcels allocated to each company was made proportional to the company's market share (Table 5).

Table 5. Market share of the five courier companies operating in Spain (Source: [30]). Estimation of the number of delivered parcels per day by these companies in Valladolid.

Delivery Company	Market Share	Number of Delivered Parcels per Day
Courier 1	44%	1900
Courier 2	16%	691
Courier 3	11%	478
Courier 4	6%	259
Courier 5	23%	993
Total	100%	4321

3.2. Calculation of Traveled Distance and Emissions

Each company must take a route through the city to allow it to complete the deliveries assigned to it (Table 5). By calculating the total distance that needs to be traveled by all companies in order to complete all deliveries, we obtained an estimate of the total daily CO_2 emission based on a delivery vehicle's typical CO_2/km emission.

We simulated the traveled distance (and the consequent CO_2 emissions) in two scenarios that we later compared. In the first scenario, we simulated traditional door-to-door delivery, in which the delivery person needed to travel to recipient addresses to make deliveries. In the second scenario, we assigned a parcel locker (i.e., newspaper kiosk) to all the recipients, and the delivery person simply needed to visit a number of kiosks where parcels were delivered.

In either scenario, each company must visit a succession of locations all day long to make their deliveries (i.e., home addresses in the first scenario, newspaper kiosks in the second). To do this, for each company we calculated a route that allowed them to travel through that succession of locations in the shortest possible time. We calculated this route by applying a Traveling Salesperson Problem (TSP) [31] for each delivery company. The TSP is a classic combinatorial optimization problem whose goal is to find the lowest-cost route (in our case, the shortest time route) in which a whole succession of nodes (delivery points in our case) is visited.

To apply the TSP, we first needed to calculate the time/distance that it takes for a delivery vehicle to travel from each node (i.e., delivery point) to all the other nodes to be visited by the delivery company. We used Graphhopper for this purpose [32]. By providing Graphhopper with a matrix that contained the location of all the nodes to be visited by each company, it returned two matrices with the time/distance that it takes to travel from each node to all the other nodes that are to be visited.

Having obtained these matrices, we applied the TSP to find the route that each company might have to follow in order to complete the delivery route. To solve this optimization problem, we used the Solver tool embedded in Microsoft Excel 2019. By employing the matrices obtained from Graphhopper as input, the objective function to be minimized was the time it took to travel through all the nodes assigned to a delivery company with a condition: no nodes can be revisited, and the origin and end of the route must be the company's warehouse. We applied this same procedure to find the best route to complete deliveries in both scenarios (i.e., home delivery and delivery with parcel lockers).

To simulate delivery with parcel lockers (i.e., kiosks), we obtained the geographic coordinates of every newspaper kiosk in Valladolid. More specifically, we searched for the exact coordinates of the loading/unloading parking spaces next to kiosks (Figure 4b) to obtain more realistic results. More often than not two kiosks are physically located close to one another, but the time it takes to drive from one to the other is long because of the particular street layout and traffic direction (e.g., two kiosks located in front of one another, but on opposite sidewalks). Therefore, it is important for the study to determine the exact coordinates of the parking space that could be used by delivery vehicles, especially for kiosks standing on corners (the commonest case).

In both scenarios (i.e., regardless of whether the delivery method is door-to-door or using lockers), the initial and end points of delivery routes were set at the entrance of the industrial park where the warehouses of all the delivery companies are located. This point and the location of the 78 newspaper kiosks currently available in Valladolid are shown in Figure 6.

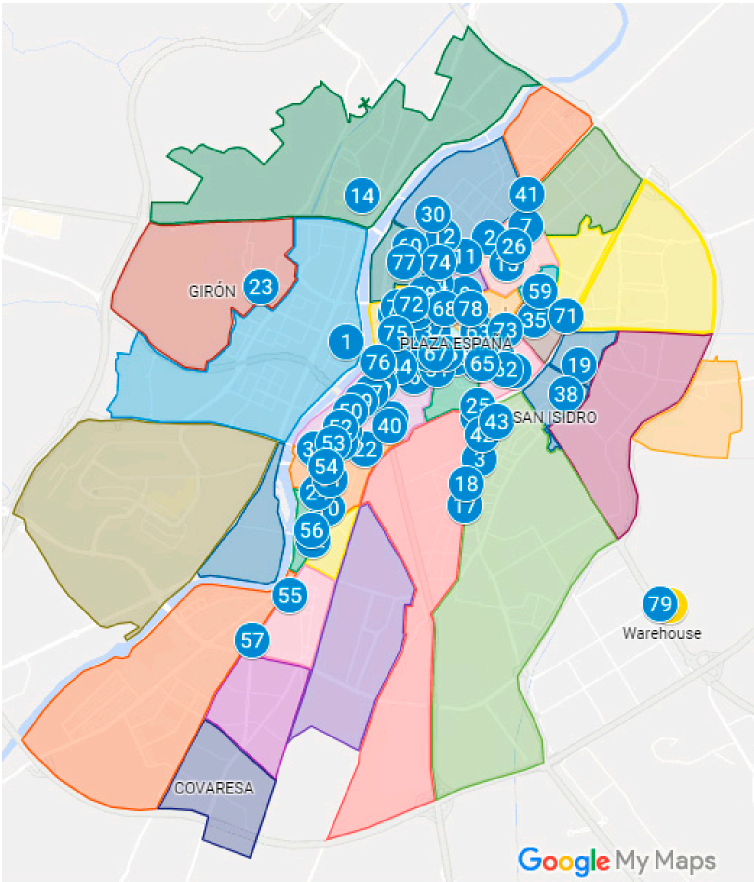


Figure 6. Location of the 78 newspaper kiosks currently present in Valladolid. The item marked as 79 (bottom right in the figure) represents the entrance of the industrial park where the warehouses of the five companies are located. Source: Google My Maps.

For the simulation of deliveries in both scenarios, the following assumptions were made: the maximum capacity of a delivery vehicle is 300 parcels (as also considered by [15]) and delivery persons work an 8-h day. In the first scenario (home delivery), we contemplated that the average time that it takes to deliver a parcel is 5 min (this information came from the local delivery companies that we contacted).

To estimate CO_2 emissions, we took the value of 147 g of CO_2 per kilometer as a reference, which is the European Commission's 2020 target for light commercial vehicles [33]. In both scenarios, once we knew the distance traveled by each company, we estimated the associated CO_2 emissions by multiplying that distance (in km) by 147 g/km.

4. Results

To demonstrate the environmental benefits of reusing kiosks as parcel lockers, this section shows the results of simulating a daily parcel delivery in Valladolid in both traditional door-to-door delivery (Section 4.1) and reusing the current existing kiosk networks as parcel lockers (Section 4.2). With this information, we compared the environmental impact (measured in terms of the total distance traveled by each company and the corresponding CO_2 emissions) in both scenarios.

4.1. Scenario 1: Home Delivery

In this scenario, each delivery company must visit all the random delivery locations that were assigned to them according to Table 5. As these locations are known (Figure 5), we attempted to find the optimal route that would allow each company to cover the succession of delivery locations in the shortest possible time by applying a TSP.

Afterwards, the route obtained for each company was divided into several segments (i.e., trips) by estimating the number of parcels that could be delivered by a single vehicle. Recall that we considered that a delivery person works an 8-h day. By assuming that each delivery took an average time of 5 min, the number of deliveries to be made on a working day was 96. Therefore, our simulations contemplated that the maximum number of deliveries per trip was 96. Consequently, after delivering that number of parcels, we considered that the vehicle would necessarily need to return to the company's warehouse.

For each trip (during which up to 96 parcels are delivered), we calculated the distance it took to drive from the company's warehouse to the first client's address on that trip, plus the distances between the subsequent clients on that trip, plus the distance from the last client's address on that trip to the company's warehouse.

Table 6 shows the number of trips into which each company's route was divided. For each trip, this table provides the number of delivered parcels, the traveled distance and CO_2 emissions. The numbers indicating the trip in the second column of this table include a hyperlink to visualize the trip with OSRM (Open Source Routing Machine).

Table 6. Distance and CO_2 emissions resulting from performing door-to-door delivery in Scenario 1 (door-to-door delivery).

Courier	Trip Number	Delivered Parcels	Distance	Total Parcels	Total Distance	Total CO_2 Emissions
Courier 1	1	96	103.1 km	1900	1804.1 km	265.2 kg
	2	96	77.7 km			
	3	96	78.9 km			
	4	96	82.4 km			
	5	96	117.4 km			
	6	96	83.9 km			
	7	96	88.2 km			
	8	96	104.6 km			
	9	96	113.8 km			
	10	96	63.3 km			
	11	96	50.2 km			
	12	96	80.2 km			
	13	96	83.7 km			
	14	96	82.4 km			
	15	96	80.5 km			
	16	96	150.2 km			
	17	96	90.0 km			
	18	96	74.7 km			
	19	96	115.2 km			
	20	76	83.7 km			

Table 6. *Cont.*

Courier	Trip Number	Delivered Parcels	Distance	Total Parcels	Total Distance	Total CO_2 Emissions
Courier 2	1	96	81.7 km	691	692.3 km	101.8 kg
	2	96	86.0 km			
	3	96	103.1 km			
	4	96	74.0 km			
	5	96	91.4 km			
	6	96	119.6 km			
	7	96	107.8 km			
	8	19	28.7 km			
Courier 3	1	96	98.5 km	478	459.1 km	67.5 kg
	2	96	89.0 km			
	3	96	77.3 km			
	4	96	94.1 km			
	5	94	100.2 km			
Courier 4	1	96	94.5 km	259	261.2 km	38.4 kg
	2	96	82.1 km			
	3	67	84.6 km			
Courier 5	1	96	101.5 km	993	920.5 km	135.3 kg
	2	96	83.0 km			
	3	96	108.8 km			
	4	96	87.7 km			
	5	96	61.8 km			
	6	96	51.7 km			
	7	96	85.2 km			
	8	96	96.3 km			
	9	96	119.5 km			
	10	96	88.7 km			
	11	33	36.3 km			
Total		4321	4137.2 km	4321	4137.2 km	608.2 kg

In this door-to-door delivery scenario, the simulation showed that the total distance to be covered by all five companies was 4137.2 km, which means CO_2 emissions of 608.2 kg per day.

4.2. Scenario 2: Reusing Newspaper Kiosks as Parcel Lockers

By taking the same random delivery locations for the recipients generated in Scenario 1 (Figure 5), we calculated the newspaper kiosks (i.e., lockers) that were more closely located to each customer. For this purpose, we used Microsoft Excel to compute the geometric distance between each random delivery address and the 78 kiosks in the city. In this way, we allocated the closest kiosk to each costumer. Details of this allocation process are shown in Figure 7. An interactive map with this information is available at: https://www.google.com/maps/d/u/0/viewer?mid=1cLBXHpdGGSUEO5mgPpU3n_5jpcUK0WpF&ll=41.649005383764745%2C-4.692187330961466&z=13.

Note that each order was assigned to the same delivery company that it was assigned to in Scenario 1 (according to its market share; Table 5). With this client-to-kiosk allocation, and by considering the company to which each order was assigned, we obtained the list of kiosks (i.e., lockers) that each delivery company must visit and the number of parcels that have to be delivered to each locker. For each company, we performed a TSP to obtain the order in which kiosks should be visited to complete the delivery route in the shortest possible time.

Given the limited capacity of delivery vehicles, it is likely that a company cannot complete all the deliveries that were assigned to it during a single trip. Recall that we assumed that a standard delivery van can carry up to 300 parcels. Therefore, during our simulations, we considered that the maximum number of deliveries per trip was 300. Consequently, after delivering that number of parcels, we contemplated that the vehicle would necessarily need to return from the last kiosk visited to the company's warehouse to load more parcels. From this point, the vehicle would then go to either the next kiosk on the list or the last kiosk visited during the previous trip, depending on whether all the deliveries assigned to the last visited kiosk were completed during a previous trip or not. This process continues until the company completes all the deliveries that were allocated to it.

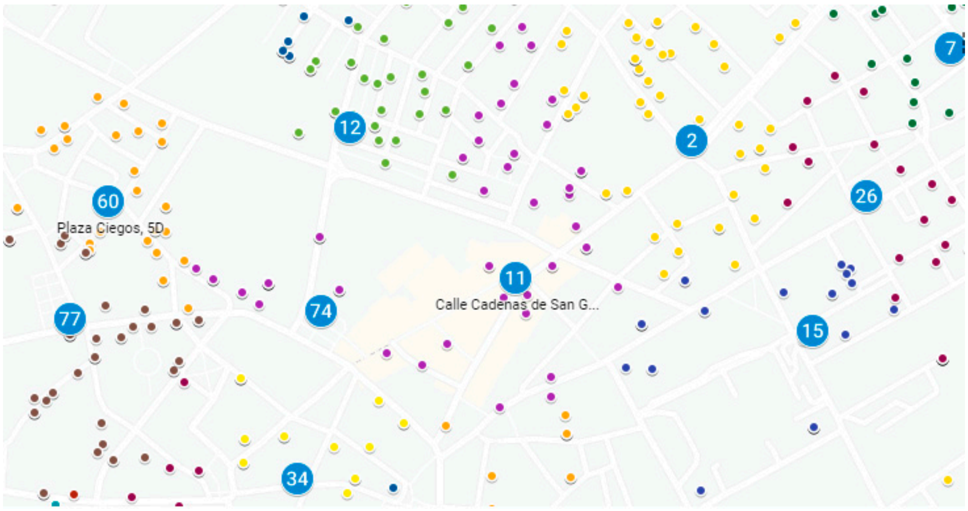


Figure 7. Detail of the allocation of the closest parcel locker (kiosk, blue-numbered circles) to each client (colored marks) according to the random delivery locations shown in Figure 5. The marks with the same color represent the customers who have been assigned the same kiosk. Source: Google My Maps.

For each trip (during which up to 300 parcels are delivered), we calculated the distance that it takes to drive from the company's warehouse to the first kiosk on that trip, plus the distances between each kiosk and the next kiosk on the trip, plus the distance from the last kiosk on the list to the company's warehouse. Note that it is not necessary to assume the number of vehicles owned by each company as we computed the total distance traveled by each company (and the associated emissions) based on the number of trips required to complete the deliveries allocated to each company. Therefore if, for example, a company needs to perform three trips to cover its route, we assumed that the following two situations were equivalent in terms of traveled distance and emissions, including the fact that the company deploys three vans that operate at the same, and each one covers one of the three segments of the route; and the fact that the company deploys one single van for the whole route to operate successions of three delivery trips (returning to the warehouse whenever necessary).

Table 7 shows the number of trips into which each company's route was divided. For each trip, this table indicates the number of delivered parcels, the traveled distance and the associated CO_2 emissions. The numbers indicating the trip number in the second column in this table include a hyperlink to visualize the trip by OSRM (Open Source Routing Machine). More detailed information on the route followed by the delivery vehicles on each trip is included in Appendix A.

Table 7. Summary of the results of the Scenario 2 simulation, which reuses newspaper kiosks as parcel lockers.

Courier	Trip Number	Delivered Parcels	Distance	Total Parcels	Total Distance	Total CO_2 Emissions
Courier 1	1	300	9.20 km	1900	117.27 km	17.2 kg
	2	300	19.36 km			
	3	300	21.97 km			
	4	300	21.89 km			
	5	300	14.46 km			
	6	300	21.88 km			
	7	100	8.53 km			

Table 7. *Cont.*

Courier	Trip Number	Delivered Parcels	Distance	Total Parcels	Total Distance	Total CO_2 Emissions
Courier 2	1	300	29.66 km	691	79.3 km	11.7 kg
	2	300	28.60 km			
	3	91	21.04 km			
Courier 3	1	300	42.1 km	478	66.52 km	9.8 kg
	2	178	24.42 km			
Courier 4	1	259	55.3 km	259	55.30 km	8.1 kg
Courier 5	1	300	22.51 km	993	86.59 km	12.7 kg
	2	300	32.87 km			
	3	300	21.01 km			
	4	93	10.20 km			
Total		4321	406.36 km	4321	406.36 km	59.5 kg

In this delivery scenario, which reuses kiosks as parcel lockers, the total distance to be covered by all five companies was 406.36 km, which means CO_2 emissions of 59.5 kg.

5. Discussion and Conclusions

E-commerce growth is leading to increasing courier company activity. The current COVID-19 pandemic is also leading to substantial changes in online consumption patterns. Recent studies show growing purchases of goods that have been traditionally acquired from local stores, but are now being purchased from online businesses, e.g., food and groceries [34–37]. It might be too soon to tell whether online consumption will return to pre-pandemic volumes or if these changes in consumer behavior are irreversible [38]. However, it seems clear that the ongoing pandemic is accelerating e-commerce growth [2]. Furthermore, with the ongoing COVID-19 pandemic, organizations need to identify new ways to deliver their products safely with minimal physical contact [39], which provides an opportunity to rethink traditional delivery channels and mechanisms [40].

As far as last-mile delivery is concerned (i.e., transporting goods from the courier's warehouse to end user addresses), traditional door-to-door delivery leads to traffic-flow problems and health and environmental issues such as noise pollution and CO_2 emissions. Furthermore, many of these deliveries fail because the recipient is not home, so they must be repeated.

This paper proposes a last-mile delivery model that uses the current network of newspaper kiosks as parcel lockers. Our proposal consists in incorporating parcel lockers attached to each currently existing kiosk in the city (whether they are operational or their business has ceased). These lockers will be shared by the different logistics companies operating in the city to perform last-mile delivery. In this model, companies simply need to use their vehicles to perform a route through a set of kiosks in a city to complete parcel deliveries.

This approach will allow kiosk operators to combine their traditional business (sale of newspapers, magazines, snacks etc.) and parcel delivery. As kiosks are already have electric supply, there is no need for work to be done in streets to provide this supply. Furthermore, the marginal electricity use required to operate the locker will be negligible compared to the total use in a newspaper kiosk.

To demonstrate the benefits of our proposal, we compared the total traveled distance and the total CO_2 emissions generated during a last-mile delivery that uses kiosks as lockers to those generated by traditional door-to-door delivery. For this purpose, we mapped the current network of kiosks in Valladolid (Spain) and simulated a random daily demand of orders through this city based on each neighborhood's population density.

When parcels were delivered to kiosks, the simulation showed that the total traveled distance by the five transport companies operating in the city was 406.36 km per day, which means daily CO_2 emissions of 59.5 kg. However, the traditional door-to-door delivery simulation required a total traveled distance of 4137.2 km, which generated 608.2 kg of CO_2 emissions.

The simulations herein performed revealed that if we only considered the benefits from an environmental point of view, the proposed model would involve a reduction of about 90% in the daily CO_2 emissions associated with last-mile delivery in the city.

The chosen scenarios for these simulations (i.e., pure door-to-door delivery versus pure delivery through kiosks) are opposite in environmental impact terms (traveled distance and CO_2 emissions). Of course, when the project is implemented, some deliveries will be made through kiosks and some will continue to be made on a door-to-door basis. Therefore, the environmental benefits after implementing the project will lie between the figures shown in Table 7 (i.e., strictly home delivery) and those shown in Table 7 (i.e., strictly delivery to kiosks).

Even so, we consider that our approach offers more environmental advantages than the solutions that are individually adopted by some delivery companies: installing their own parcel lockers in places like gas stations or shopping malls. These places are usually located far from customers' homes, and thus often require using private cars to go to a locker and collect a parcel, which entails additional CO_2 emissions. Our approach, however, proposes installing shared locker stations attached to currently existing newspaper kiosks. Given the distribution of newspaper kiosks in the central area of cities, there is a good chance that a newspaper kiosk is located at walking distance from customers' homes. For example, in Table 8 we show the average distance/time (on foot) from customers' homes (based on randomly generated delivery locations, Figure 5) to the closest kiosk (Figure 6). These figures were calculated by using OSRM (Open Source Routing Machine).

Table 8. Average distance/time on foot from customers' homes (i.e., randomly generated delivery locations) to the closest kiosk.

N/Hood ID	Neighborhood	Avg. Distance (on Foot)	Average Time (on Foot)
1	Arturo Eyríes	527 m	20 min 42 s
2	Barrio España	638 m	8 min 45 s
3	La Farola—C. de la Esperanza—Paseo Zorrilla	335 m	4 min 35 s
4	Arco Ladrillo-Pza. Toros-B. G. Civil—P. Zorrilla	199 m	2 min 40 s
5	Caño Argales—San Andrés	251 m	3 min 25 s
6	Pza. España—Plaza Mayor—S. Martin—S. Juan	172 m	2 min 18 s
7	Cuatro de Marzo	173 m	2 min 18 s
8	Girón-Villa del Prado	479 m	6 min 30 s
9	Hospital	210 m	2 min 51 s
10	Huerta del Rey	915 m	12 min 26 s
11	La Circular	185 m	2 min 31 s
12	La Pilarica-Santos Pilarica—Belén	702 m	9 min 33 s
13	La Rondilla—Santa Clara/XXV Años de Paz	343 m	4 min 41 s
14	La Rubia-Parque Arturo León	514 m	7 min 8 s
15	La Victoria	835 m	11 min 22 s
16	Las Batallas	250 m	3 min 22 s
17	Las Delicias	576 m	7 min 50 s
18	Las Flores	3207 m	42 min 51 s
19	Las Villas-P. Alameda-Covaresa-P. Arturo León	1442 m	19 min 29 s
20	Los Vadillos	282 m	3 min 51 s
21	Pajarillos -Páramo San Isidro-Campo de Tiro	545 m	7 min 27 s
22	Parquesol	3179 m	33 min 25 s
23	Pgno. Argales-Ciudad de la Comunicación	1362 m	18 min 17 s
24	San Pablo—San Nicolás—San Miguel	170 m	2 min 17 s
25	San Pedro Regalado	771 m	10 min 29 s
26	Universidad—La Antigua—S. Cruz—San Juan	171 m	2 min 18 s

Using a private car to collect parcels at a kiosk is not convenient in the central city areas (i.e., most of the neighbors in Table 8) because of traffic burden, and especially due to the lack of parking places near kiosks. In suburbs, where finding a parking place is not an issue, and also in those places where kiosks are not as abundant (e.g., neighborhoods with IDs 1, 2, 10, 12, 15, 18 19, 22 or 23 in Table 8), it is reasonable to assume that some customers would decide to use their cars to collect parcels. However, according to some recent studies on customers' usage of parcel lockers ([41,42]), many locker users would decide to collect their parcels on their way to work or while running other errands. Consequently, using a car to drive to a kiosk does not always mean increasing traffic or CO_2 emissions. Table 8 can also help to determine the city areas where more kiosks/lockers should be installed to facilitate implementing parcel delivery through lockers.

Apart from the environmental advantages discussed above, reusing kiosks for last-mile delivery also offers advantages for other stakeholders:

- Users: they will be able to pick up their packages at their convenience as the kiosk network is well distributed in their city. The need to leave their home to pick up a parcel can be an inconvenience for some users. However, this can also spell some advantages: no need to worry about the time when parcel deliverers arrive (normally without warning, etc.). In some cases, users will not have to go to the locker expressly because they can pick up the package on their way to work or while running other errands.
- Logistics operators: they will reduce the number of trips. In an ideal case, if 100% deliveries were made through lockers, there would be no movements other than from warehouses to the locker network and back. The practice of driving around the city searching for an address, which has an impact on company costs, would be no longer necessary. Performing second delivery attempts as the recipient is not home would no longer be required.
- Citizens: CO_2 emissions will lower thanks to the shorter traveled distances required to complete parcel delivery. Consequently, noise pollution will also lower. This will also mean a positive contribution to traffic flow in urban areas as fewer delivery vehicles mean faster moving traffic and less improper parking for deliveries.
- The municipality: it will recover an iconic element of urban equipment, which is currently in disuse, which it does not need to maintain, and currently offers a poor image for the city. The concessions and appreciations of this equipment would be reactivated with the new uses for kiosks.
- Kiosk owners (either working or shut kiosks): these assets will generate income as they will be used as parcel lockers. Note that our model contemplates the possibility of complete or partial use, which would facilitate those kiosks that still distribute press and other reading material to extend their services as a parcel delivery point.
- Local companies in the city of Valladolid: they could act as suppliers for conditioning and rehabilitating kiosks.
- Non e-commerce stores: the proposed delivery model can also be extended to incorporate the delivery of local stores (i.e., without logistics operators intervening).

Our study, however, has its limitations. The number of daily delivery requests and their distribution throughout the city are based mainly on each neighborhood's population. This means that the simulated experiments assumed that the most populated neighborhoods would demand more deliveries, which is not necessarily true because other factors affect e-commerce demand (e.g., culture, gender, age, etc.). This study also assumes a uniform distribution of delivery requests in each neighborhood (i.e., it does not take into account which areas in each neighborhood are more likely to demand more deliveries due to, for example, more income). Although we wished to perform simulations with real data obtained from delivery companies, we found that these companies were unwilling to provide this information for legal reasons. The availability of the actual number of delivery requests per neighborhood would have allowed us to obtain more precise results about the number of required trips, total traveled distance or CO_2 emissions. However, more precision in these estimations would not make much difference to the advantages of the proposed model, which have been discussed above. As the two delivery types (i.e., that proposed and based on delivery to kiosks and the traditional one based on door-to-door deliveries) were simulated and compared to the same data according to the same hypothesis, the obtained results help to illustrate the benefits of the proposed model. In any case, if this model is applied in other cities, the availability of real data for delivery demand could mean more precise results for the city to which it is applied.

We also considered an unlimited capacity for locker stations. Although the dimensions of lockers is beyond the scope of this study, we would like to highlight one aspect that should be taken into account when sizing parcel lockers: it cannot be assumed that all parcels will be collected on the same day that they are delivered to lockers by couriers. This fact reduces the locker's practical capacity. One way of handling these issues while implementing the project is to estimate the number of consumers who will not collect their parcels within 24 h and subtract that number from the locker's real capacity. This would give us an idea of the actual number of parcels that can be deposited daily in each locker if we assume that this proportion of customers who do not collect their parcels on the same delivery day remains constant over time.

Some results of our simulations depend on the actual values of certain parameters. For example, with home delivery, we considered an 8-h working day and an average delivery time of 5 min. We decided to use these values based on informal conversations held with local courier companies. Considering an average delivery time of 5 min means that a delivery person can handle 96 parcels, i.e., the vehicle needs to return to the warehouse after completing 96 deliveries; (Table 7). On the other hand, in the case of delivery through lockers, we assumed that the maximum capacity of a delivery vehicle is 300 parcels (as assumed also by other studies, which is also consistent with the information provided by local couriers). This means that when deliveries are made on a locker basis, the vehicles need to return to the warehouse after completing 300 deliveries (Table 7). Choosing different values for these parameters would change the results of simulations slightly (in terms of traveled distance and, consequently, CO_2 emissions). For example, contemplating a shorter working day or a longer delivery time would mean that the number of parcels to be delivered on each trip would be lower than 96 in the case of home delivery (Table 7); and considering a vehicle with a smaller capacity would mean that the parcels to be delivered on each trip would be lower than 300 when kiosks are used as lockers (Table 7). Consequently, each courier would need to run more trips from the warehouse to downtown and back to complete its daily deliveries. These extra trips, however, would not mean a significant increase in traveled distance and, consequently in CO_2 emissions, as the highest contribution to distance (and emissions) is due to driving around the city performing door-to-door delivery rather than driving to and from the warehouse. Nevertheless, based on the results of our study, we can easily obtain a rough estimate of the additional traveled distance/emissions associated with other values of the parameters. A longer average delivery time per parcel or a smaller vehicle size would result in additional trips for each courier. One round trip from the warehouse to downtown entails an average distance of 8 km. Consequently, each extra trip would mean an additional distance of 8 km (i.e., 1.2 kg CO_2), which is reasonably negligible compared to the total traveled distance and CO_2 emissions obtained in the results of our study.

Given the ongoing COVID-19 pandemic, a non face-to-face last-mile delivery based on lockers is probably safer than the traditional home-to-home delivery as it facilitates social distancing. Although locker stations would be accessed by many people, the City Council would be responible for cleaning (and also disinfecting) the surroundings of lockers (as they currently clean these surroundings), whereas kiosk operators would be responsible for cleaning inside lockers. Some logistic operators are currently performing an alternative last-mile delivery in which parcels are not directly delivered to final customers, but are left in stores/businesses located near customers' homes. The approach that we herein present is safer from a health point of view because it does not require an employee handing out parcels to customers, which thus facilitates social distancing. Furthermore, the lockers installed and attached to kiosks would be available 24/7 and no particular security-related issues are expected because newspaper kiosks are located in transited city areas.

Currently, some logistics operators and e-commerce companies have their own developments for the last-mile delivery of goods through lockers. However, the existing newspaper kiosks network can serve several operators and take advantage of synergies. From the circular economy paradigm, the aim is to provide an integrated solution in several stages that is optimal for users (companies and customers) and Public Administrations. Given the scalability of this proposal, it can be easily replicated and applied in other cities.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The following five tables show the details of the trips to be followed by the five delivery companies considered herein when newspaper kiosks are reused as delivery lockers.

The numbers indicating the trip number in the first column of these tables include a hyperlink to visualize the trip by OSRM (Open Source Routing Machine). The second and third columns display the ID of the node (i.e., the 78 kiosks currently available in the city) to be visited. Note that node number 79 represents the location of the courier's warehouse and is, consequently, the node from which each trip starts and ends. The fourth and fifth columns respectively show the distance traveled from the source node to the destination node, and the number of delivered parcels at the destination node.

For each trip, we show the sequence of visited kiosks (nodes). Please bear in mind that each vehicle has a limited space for 300 parcels. When all 300 parcels are delivered, the vehicle must return to the company's warehouse (i.e., node 79) to load more parcels. From this point, the vehicle will then go to either the next kiosk on the list or the last visited kiosk during the previous trip, depending on whether all the deliveries assigned to the last visited kiosk were completed during the previous trip or not. This process continues until the company completes all the deliveries allocated to it. A summary of the total traveled distance and the number of delivered parcels per trip is also calculated for each trip.

Table A1. Sequence of newspaper kiosks visited by Courier 1.

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
1	79	43	2862	33
	43	42	188	1
	42	18	582	28
	18	17	219	91
	17	3	554	10
	3	38	1239	54
	38	19	468	83
	19	79	3091	-
TOTAL			9203	300

Table A1. *Cont.*

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
2	79	19	2957	21
	19	69	3332	2
	69	70	399	5
	70	77	839	32
	77	14	886	89
	14	30	2202	68
	30	60	506	15
	60	74	402	12
	74	12	251	18
	12	72	1084	4
	72	20	224	2
	20	68	185	9
	68	34	405	13
	34	11	1079	10
	11	79	4604	-
TOTAL			19,355	300
3	79	11	4469	9
	11	15	487	10
	15	26	256	9
	26	41	973	72
	41	7	376	20
	7	2	772	47
	2	73	1027	16
	73	27	695	17
	27	5	1012	2
	5	6	111	7
	6	36	543	4
	36	37	190	1
	37	13	31	2
	13	21	82	2
	21	9	668	14
	9	8	257	3
	8	35	998	28
	35	16	508	8
	16	63	321	8
	63	78	246	11
	78	66	508	4
	66	67	165	2
	67	76	1152	1
	76	1	483	3
	1	79	5636	-
TOTAL			21,966	300

Table A1. *Cont.*

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
4	79	1	4900	33
	1	23	1617	98
	23	58	1897	4
	58	75	853	3
	75	29	156	2
	29	22	1826	22
	22	24	996	21
	24	10	516	53
	10	51	398	19
	51	45	1478	1
	45	50	1504	6
	50	52	524	23
	52	53	171	12
	53	46	230	3
	46	79	4821	-
TOTAL			21,887	300
5	79	46	5051	6
	46	48	214	11
	48	33	256	64
	33	54	409	12
	54	56	805	16
	56	32	488	25
	32	57	1645	166
	57	79	5587	-
TOTAL			14,455	300
6	79	57	6207	109
	57	55	966	63
	55	44	2590	1
	44	31	1570	25
	31	40	1739	13
	40	39	123	6
	39	25	1473	11
	25	4	101	2
	4	28	1149	11
	28	65	263	4
	65	61	449	50
	61	59	1298	5
	59	79	3954	-
TOTAL			21,882	300
7	79	59	4077	19
	59	71	614	68
	71	62	935	13
	62	79	2900	-
TOTAL			8526	100

Table A2. Sequence of newspaper kiosks visited by Courier 2.

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
1	79	43	2862	10
	43	42	188	1
	42	18	582	8
	18	17	219	30
	17	3	554	4
	3	38	1239	19
	38	19	468	40
	19	69	3332	1
	69	77	780	8
	77	14	886	35
	14	30	2202	21
	30	60	506	9
	60	74	402	3
	74	12	251	6
	12	72	1084	2
	72	68	410	2
	68	34	405	5
	34	11	1079	6
	11	15	487	4
	15	26	256	3
	26	41	973	22
	41	7	376	8
	7	2	772	27
	2	73	1027	7
	73	27	695	4
	27	5	1012	1
	5	36	654	1
	36	37	190	1
	37	9	781	2
	9	8	257	1
	8	35	998	7
	35	16	508	2
	16	79	3225	-
TOTAL			29,660	300
2	79	16	3256	4
	16	63	321	4
	63	78	246	5
	78	66	508	1
	66	1	1242	18
	1	23	1617	30
	23	58	1897	2
	58	75	853	1
	75	29	156	2
	29	22	1826	12
	22	24	996	11
	24	10	516	16
	10	51	398	12
	51	49	1484	2
	49	50	1242	2
	50	52	524	4
	52	53	171	5

Table A2. *Cont.*

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
	53	46	230	1
	46	48	214	2
	48	33	256	21
	33	54	409	3
	54	56	805	14
	56	32	488	9
	32	57	1645	101
	57	55	966	18
	55	79	6329	-
TOTAL			28,595	300
3	79	55	6041	4
	55	44	2590	1
	44	31	1570	9
	31	40	1739	5
	40	39	123	3
	39	25	1473	3
	25	28	1048	7
	28	65	263	5
	65	61	449	19
	61	59	1298	8
	59	71	614	24
	71	62	935	3
	62	79	2900	-
TOTAL			21,043	91

Table A3. Sequence of newspaper kiosks visited by Courier 3.

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
1	79	43	2862	5
	43	18	770	6
	18	17	219	19
	17	3	554	9
	3	38	1239	17
	38	19	468	26
	19	69	3332	3
	69	70	399	1
	70	77	839	10
	77	14	886	13
	14	30	2202	12
	30	60	506	4
	60	74	402	2
	74	12	251	7
	12	72	1084	1
	72	34	492	2
	34	11	1079	1
	11	15	487	3
	15	26	256	4
	26	41	973	18
	41	7	376	6
	7	2	772	17
	2	73	1027	3
	73	27	695	7

Table A3. *Cont.*

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
	27	6	1124	1
	6	37	733	1
	37	13	31	1
	13	35	1476	4
	35	16	508	5
	16	63	321	1
	63	78	246	8
	78	76	1543	2
	76	1	483	11
	1	23	1617	34
	23	22	2591	5
	22	24	996	6
	24	10	516	9
	10	51	398	4
	51	52	1543	3
	52	53	171	1
	53	48	314	6
	48	33	256	2
	33	79	5066	-
TOTAL			42,103	300
2	79	33	5100	13
	33	54	409	6
	54	56	805	7
	56	32	488	7
	32	57	1645	71
	57	55	966	18
	55	44	2590	1
	44	31	1570	4
	31	40	1739	4
	40	39	123	2
	39	25	1473	3
	25	28	1048	6
	28	61	712	11
	61	59	1298	9
	59	71	614	13
	71	62	935	3
	62	79	2900	-
TOTAL			24,415	178

Table A4. Sequence of newspaper kiosks visited by Courier 4.

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
1	**79**	43	2862	3
	43	42	188	2
	42	18	582	1
	18	17	219	11
	17	3	554	3
	3	38	1239	10
	38	19	468	14

Table A4. *Cont.*

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
	19	77	3754	8
	77	14	886	8
	14	30	2202	12
	30	60	506	1
	60	12	654	2
	12	20	1308	1
	20	68	185	2
	68	15	1208	2
	15	26	256	3
	26	41	973	5
	41	7	376	4
	7	2	772	8
	2	73	1027	1
	73	27	695	1
	27	36	753	1
	36	37	190	1
	37	21	113	1
	21	9	668	1
	9	35	1059	4
	35	16	508	2
	16	63	321	2
	63	78	246	1
	78	66	508	2
	66	23	2823	13
	23	75	1818	1
	75	22	1982	1
	22	24	996	2
	24	10	516	7
	10	51	398	2
	51	50	1858	2
	50	52	524	2
	52	48	485	3
	48	33	256	22
	33	54	409	3
	54	56	805	4
	56	32	488	4
	32	57	1645	35
	57	55	966	10
	55	31	3211	4
	31	40	1739	2
	40	39	123	1
	39	25	1473	1
	25	28	1048	3
	28	65	263	1
	65	61	449	3
	61	59	1298	4
	59	71	614	8
	71	62	935	4
	62	79	2900	-
TOTAL			55,302	259

Table A5. Sequence of newspaper kiosks visited by Courier 5.

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
1	79	43	2862	11
	43	42	188	2
	42	18	582	10
	18	17	219	49
	17	3	554	9
	3	38	1239	35
	38	19	468	48
	19	69	3332	1
	69	70	399	4
	70	77	839	12
	77	14	886	36
	14	30	2202	28
	30	60	506	13
	60	74	402	5
	74	12	251	16
	12	72	1084	1
	72	20	224	1
	20	34	590	6
	34	11	1079	13
	11	79	4604	-
TOTAL			22,510	300
2	79	11	4469	1
	11	15	487	13
	15	26	256	3
	26	41	973	31
	41	7	376	4
	7	2	772	27
	2	73	1027	13
	73	27	695	9
	27	6	1124	3
	6	36	543	2
	36	37	190	2
	37	13	31	1
	13	9	750	3
	9	35	1059	16
	35	16	508	9
	16	63	321	6
	63	78	246	3
	78	66	508	1
	66	67	165	1
	67	76	1152	2
	76	1	483	1
	1	23	1617	65
	23	58	1897	2
	58	75	853	2
	75	22	1982	11
	22	24	996	13
	24	10	516	23
	10	51	398	6
	51	49	1484	1
	49	50	1242	6
	50	52	524	13
	52	53	171	6
	53	46	230	1
	46	79	4821	-
TOTAL			32,866	300

Table A5. *Cont.*

Trip Number	Source Node	Destination Node	Distance (m)	Delivered Parcels
3	79	46	5051	1
	46	48	214	2
	48	33	256	55
	33	54	409	10
	54	56	805	13
	56	32	488	16
	32	57	1645	145
	57	55	966	31
	55	31	3211	5
	31	40	1739	7
	40	39	123	1
	39	25	1473	10
	25	4	101	2
	4	28	1149	2
	28	79	3382	-
TOTAL			21,012	300
4	79	28	3739	8
	28	65	263	3
	65	61	449	25
	61	59	1298	14
	59	71	614	36
	71	62	935	7
	62	79	2900	-
TOTAL			10,198	93

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