Collaboration in Urban Distribution of Online Grocery Orders

Abstract

Purpose - Population growth, urbanisation, and the increased use of online shopping are some of the key challenges affecting the traditional logistics model. This paper focuses on distribution of grocery products ordered online and the subsequent home delivery and click & collect services offered by online retailers to fulfil these orders. These services are unsustainable due to increased operational costs, carbon emissions, traffic, and noise. The main objective of our research is to propose sustainable logistics models to reduce economic, environmental, and social costs whilst maintaining service levels.

Design/methodology/approach - We have a mixed methodology based on simulation and mathematical modelling to evaluate the proposed shared logistics model using: i) primary data from a major UK retailer, ii) secondary data from online retailers, and iii) primary data from a consumer survey on preferences for receiving groceries purchased online. Integration of these three data sets serves as input to vehicle routing models that reveal the benefits from collaboration by solving individual distribution problems of two retailers first, followed by the joint distribution problem under single decision maker assumption.

Findings - The benefits from collaboration could be more than 10% in the distance travelled and 16% in the time required to deliver the orders when two online grocery retailers collaborate in distribution activities.

Originality/value - The collaborative model developed for the online grocery market incentivises retailers to switch from current unsustainable logistics models to the proposed collaborative models.

Keywords - Food logistics, Urban logistics, Sustainability.
Paper type - Research paper

1. Introduction

Managing urban areas has become one of the most significant challenges of the 21st century. Current projections estimate that the world's urban population will be 66.4% of total population by 2050 (UN, 2015). Figure 1 illustrates the percentage of population living in urban areas and a forecast for USA, Brazil, Western Europe, China, and India (UN, 2014). In Europe, 74% of the population lives in urban areas already and it is estimated to increase to 82% by 2050 (UN, 2014). As more people prefer to live in urban areas, the demand for all kinds of products is going to be higher in cities. Consequently,

more products will be transported to and distributed within cities to satisfy the needs of a growing population.
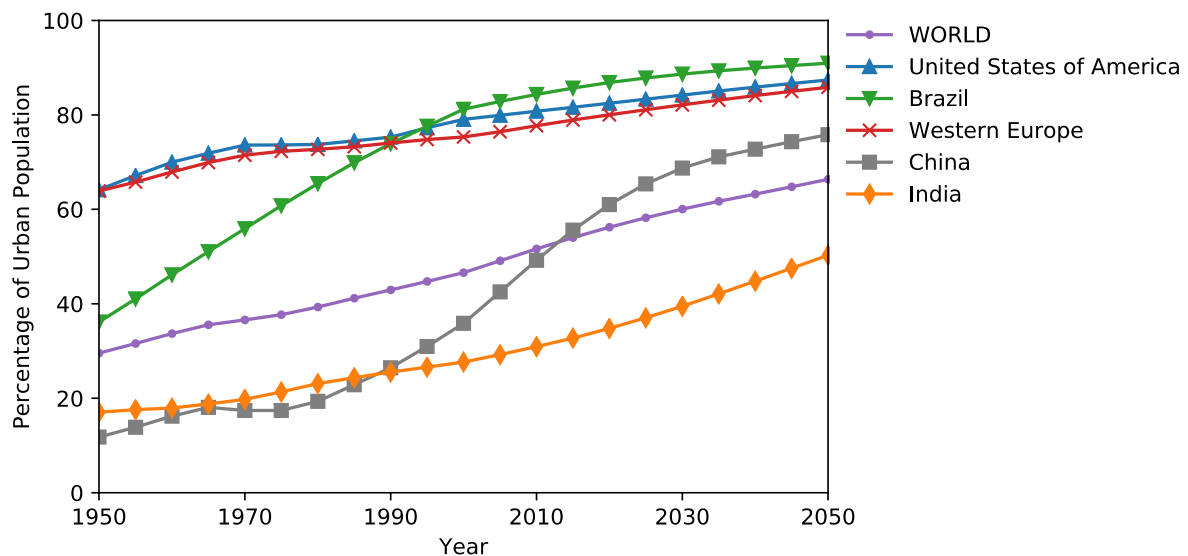
Urban areas represent specific challenges related to economic, environmental, and social aspects of freight transport (Lindholm and Behrends, 2012). Some of the main challenges are: cutting transportation cost, fuel-distance efficiency, lack of traffic infrastructure capacity, redesigning the distribution network, and cities' plans to meet the air quality standards set by the European Commission (Directive 2008/50/EC). The latter is due to the significant effect of urban freight transport on quality of life in urban environments through traffic congestion, vehicle emissions, and noise pollution (Nathanail et al., 2017).

Specifically, transport is the fastest growing sector with the road transport subsector being the largest contributor to total CO_2 emissions (EPA, 2011) whilst pollution and noise are accompanying problems in urban areas. To alleviate these problems, megacities usually have transport-related restrictions such as the size of trucks that can move in city centres, the hours they can supply retail shops, etc. Such restrictions make the distribution of goods more complex and raise the total operational and transportation cost, harming retailer's profitability.

During the past few years, developments in information technologies have enabled retailers to offer new services such as online shopping. Along with books, fashion items, flight tickets, and hotel bookings, people now choose to shop online almost anything, including groceries. It is forecasted that e-retail would dominate the retail sector in the next few years and online shops would harm traditional brick-and-mortar shops (Doherty

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and Ellis-Chadwick, 2010) notwithstanding the distribution challenges posed by this online activity (Ishfaq et al., 2016).

In this paper, we focus on the UK grocery retail sector as it is the second biggest online market in the world in terms of size after the Chinese online grocery market (IGD, 2016). The sales of the UK online grocery retail market accounted for £9.9 billion in 2016 (Mintel, 2017), is estimated to reach £16.7 billion by 2021, and to be around 10% of the whole grocery market (Mintel, 2016). Figure 2 presents the market size from 2011 onwards and forecasted up to 2021. The UK online grocery retail market has seen an annual growth more than 15% (Figure 2), while the total grocery market has grown less than 5% annually in the last 10 years (IGD, 2015). Due to this unprecedented market growth, there is a need for operational models for the distribution of online purchased groceries in cities and this paper is investigating such operational models.
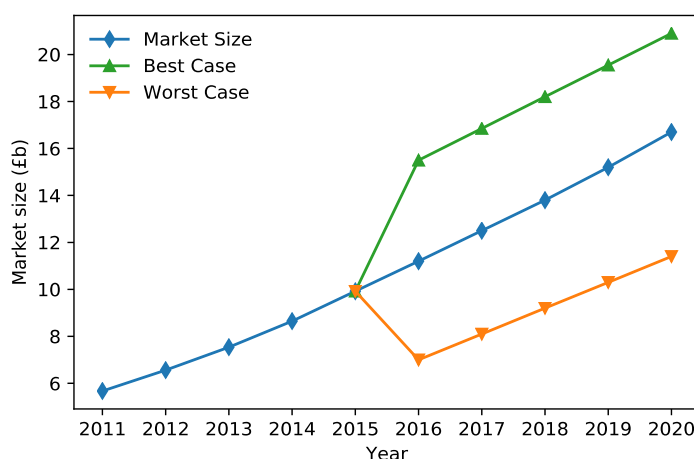

Figure 2 The past and the future of UK online grocery market sales, Source: Mintel (2017)

To raise their customer base and their market share, retailers offer online services and try to raise their market share without compromising profitability (Murfitt, 2014). Likewise, consumers always ask for more and better services, buy groceries online and expect to receive the groceries at home or at convenient locations and times. Aiming to satisfy these consumers, UK retailers provide them with two options: i) home delivery services and ii) click & collect services. In the first option, consumers select a day and a time slot to receive grocery orders delivered to their houses. In the second choice, retailers transport consumers' orders to a predefined collection point known as the click & collect point where customers must collect their orders during a predefined time interval on the selected day. Depending on their strategy and logistics capabilities, retailers could deliver to various collection points to provide choice to consumers; hence, a collection point could be part of an existing retail store or it could be a locker based in that store or elsewhere (e.g. train station etc.).

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Independent offerings of home delivery and click & collect services lead to logistics inefficiencies as customers located in the same neighbourhoods can be visited by multiple retailers' vehicles around the same time intervals. These vehicles are also likely to be underutilised due to low drop density caused by serving this customer base with multiple service providers. The research question addressed in this paper is: "What is the extent of logistics overlaps between independent deliveries that can be consolidated to improve efficiencies?". For this purpose, the aim of the paper is to investigate logistics collaboration among retailers of varying market shares and establish reductions in distance travelled and the subsequent environmental and social gains owing to collaboration. The objectives set to achieve this aim are as follows:

1. To estimate the market shares of retailers,
2. To simulate home delivery orders,
3. To solve last mile delivery problem with and without collaboration,
4. To establish the distance reduction from collaboration.

Distribution capability has a crucial role in meeting customers' demand because it determines how effectively the supply chain is designed, especially, in grocery distribution where retailers work in an uncertain environment and must cope with fast changing market demands. A typical online grocery order has 60-80 items and customers expect the order to be completed in one delivery, necessitating an efficient order picking and consolidation process (Fernie and Sparks, 2014, p.222). It is possible to use regional distribution centres for picking; however, they are usually not set up for item-level picking, and their local deliveries may be inefficient due to the wide geographic area they are designed to serve (Rushton et al., 2010, p.77). The routing problem is complex due to economic and environmental costs because it is almost impossible to determine the optimal solution in a short period which is less than one day in online grocery order fulfilment.

In this work, we have not considered the use of lockers as a possible collection point as they are not used extensively by UK online grocery retailers; however, they are currently used largely by non-grocery retailers such as clothing and fashion retailers. Both home delivery and click & collect services incur a delivery charge (up to £7) for consumers, but this charge does not cover the additional picking and transportation cost. For example, the operational (picking and transportation) cost per order is £21 for an exclusively online grocery retailer, Ocado (Ocado, 2015).

The UK online grocery market is ultra-competitive, and no logistics collaboration exists between retailers. Retailers decide how to meet the demand and have their own fleet of

trucks using exclusive distribution centres. Therefore, every retailer solves a routing problem of how to visit the orders' locations under the time preferences of customers. Retailers use a dynamic delivery fee policy associated with these services to alleviate the cost of distribution. However, under this approach, the total operational cost is not the optimal one as some neighbourhoods will be visited by many retailers at the same time and because different customers who live nearby will not order from the same retailer. The result is to have overlapping areas during the daily distribution of groceries, increasing transportation cost, decreasing the capacity utilisation of vehicles while negatively affecting the environment and the society through emissions (Koc et al., 2016), traffic congestion, accident fatalities, and noise pollution.

In this work, we examine the benefits that will arise from a potential collaboration among retailers to satisfy the demand for home deliveries. We focus on the gains from collaboration on the distribution of groceries, assuming retailers share their distribution network and capabilities. It would be ideal, if retailers could work as a single entity that makes joint decisions to satisfy the home delivery demand by using a shared logistics model. The latter is the theoretical ideal situation (centralised solution) in terms of cost reduction, but it is almost not possible in a free and competitive market such as the grocery one. Under a shared model, the overlapping routings would be eliminated, increasing vehicle utilisation and maintaining or increasing the existing customer service levels, leading to a win-win situation for the retailers that participate on the shared logistics model.

Our paper makes the following contributions: i) It investigates online grocery orders and the corresponding home delivery demand that follows, developing a novel method to estimate annual home delivery demand for groceries purchased online using primary and secondary data sources. ii) It implements the well-known Capacitated Vehicle Routing Problem (CVRP) in the absence and presence of logistics collaboration in fulfilling home delivery demand to estimate economic and environmental benefits from collaboration. Subsequently, it identifies the circumstances that result in higher benefits from collaboration in terms of distance reduction and measures the impact of a potential collaboration in terms of economic and environmental issues.

The remainder of the paper is organised as follows: Section 2 provides the literature review on e-commerce and distribution activities focusing on grocery markets. Section 3 presents the proposed shared logistics model. Section 4 outlines the methodology followed to generate the home delivery demand in the UK online grocery market. Section 5 presents the findings. Section 6 summarises the conclusions and sets future research avenues.

2. Literature Review

Past studies examined economic, environmental, and social impact of e-commerce. Murphy (2007) considers strategies for online grocery shopping that offset the "killer cost" of e-commerce logistics. If retailers can effectively control the last mile delivery services, then they will be able to extend delivery services to lower margin and more problematic products (Murphy, 2007). Under the existing situation in the grocery market, the delivery model is not sustainable as the cost of delivering products to consumers' homes is higher than the profits from products delivered. Carbon intensity of last mile deliveries should also be considered in assessing the performance of the logistics operation. Edwards et al. (2010) demonstrate that neither home delivery nor conventional shopping has an absolute CO_2 advantage. Both consumers and retailers need to be made aware of environmental implications of their respective purchasing behaviour and distribution methods to make the potential CO_2 savings. In fact, a firm's distribution strategy and subsequent optimal decisions may deviate from the socially optimal decisions under traffic congestion due to the firm's economic incentives leading the whole system to inefficiency (Shao et al., 2016).

Logistics costs represent a large fraction of operating costs. A solution that can mitigate the negative impact of logistics activities is to pool demand from different retailers. Consolidation of shipments as well as collaboration between firms in various distribution operations has been examined previously in logistics research. For example, focusing on the grocery industry and the Efficient Consumer Response initiative, Frankel et al. (2002) show the major, positive results which emanate from successful coordinated, collaborative activities between various supply chain partners in that sector. Building on this work and by focusing on collaboration, Kotzab and Teller (2003) propose a co-opetition model in the Austrian traditional grocery industry where all parties improve their profitability by sharing information and setting up business with value-adding partnerships. Similarly, Mason et al. (2007) exploit the role of collaboration in the road freight transport industry in the UK and Europe and highlight the importance of combining vertical collaboration (between firms located at different stages/levels of the supply chain) with horizontal collaboration (between firms located at the same stage/level of the supply chain) with innovative solutions being developed in relation to transport optimisation. Subsequently, the issue of horizontal logistics collaboration has attracted further interest over the past few years and researchers examined the major drivers and barriers for its formation in relation to various sectors including the grocery one. Specifically, Hingley et al. (2011) investigate the key benefits and barriers when

employing fourth party logistics management aiming to establish horizontal logistics collaboration between grocery retailers and highlighted the key challenges/deterrents involved including the fierce competition among grocery retail chains and power dynamics between the various supply chain members of that chain. Sanchez Rodrigues et al. (2015) also examine horizontal logistics collaboration in the fast moving consumer goods industry and identified several factors, synergies and enablers to be taken into account in order this collaboration to materialise such as, inter alia, trust among firms involved, reliable logistics companies and a fair benefit sharing. Overall, there are numerous cases of firms illustrating successfully the potential of horizontal logistics collaboration including the cases presented earlier. In addition, Vanovermeire et al. (2014) show the major benefits (e.g. cost decrease) for three companies in Belgium entering a horizontal logistics alliance whilst Soysal et al. (2018) illustrate that horizontal collaboration between suppliers could result in a decrease of total cost and emissions.

Based on the previous discussion, it is evident that as the supply chain concept spreads amongst firms, a few of them start to consider using collaboration to reduce the environmental footprint of their logistics activities. Ballot and Fontane (2010) demonstrate an important benefit from retailers' collaboration that is a potential saving of at least 25% of CO_2 emissions from pooled networks. Furthermore, Lozano et al. (2016) develop a mathematical model based on cooperative game theory and study the cost savings that different firms can achieve when they merge their transportation requirements. The benefits of collaboration are not uniform but depend on the participating partners and are increased as the size of the coalition grows.

Another topic attracting a lot of interest from academics and practitioners is the design of a more cost effective, green network of warehouses and retail stores. Few studies consider the location of warehouses and how a different re-design of the network affects fuel emissions. For example, Cachon (2014) addresses the problem of how each retailer has to design the network in terms of location and size of shops, and how to minimise the sum of retailer's replenishment cost and consumer's travel cost. It is also proved that if the objective is to minimise operational costs, the optimal solution can raise emission by 67% compared to the minimum level of emissions. Koc et al. (2016) address the impact of depot location, fleet composition, and routing decisions on vehicle emissions in urban areas. Their objective is to minimise the total operational cost (i.e. depot, vehicle and routing cost) of deliveries from a depot to customers' location in a city. They show that the preferable solution is to locate the depots outside the city centre, achieving a 34.5% on average cost reduction. Niknamfar and Niaki (2016) develop a mathematical model for hub location and demand allocation in a network of hubs where a holding

company and multiple carriers are interacting. They propose a framework for collaboration which achieves a reduction on both transportation cost and CO_2 emissions, demonstrating the existence of a win-win situation for both parties. Furthermore, Bektas and Laporte (2011) present an extension of the routing problem in which the objective function accounts for both the travel distance and the amount of greenhouse emissions. In a cost-minimised solution, it is possible a reduction of 5–8% in the overall cost compared to solutions obtained by other objectives. Similarly, Sprenger and Monch (2014) propose a decision support system for cooperative transportation planning in the German food industry and show that it is possible to obtain benefits from a centralised model/solution. They also assume that there are outsourcing options, but these are much more expensive.

An interesting study is the one by Belavina et al. (2017) where a model of online grocery market is considered to examine two alternatives to satisfy the demand for home deliveries. The first alternative is when customers pay a delivery fee each time they order groceries, while the second one is to buy a pass for unlimited free deliveries for a year. In addition, a grocery chain's impact on the environment is assessed based on two factors: i) food waste and ii) the emissions associated with transportation. Shopping groceries online not only affects retailers' revenue models, but also carbon emissions in the last mile distribution owing to the increased convenience through pay-per-order and subscription-based service models.

Following the previous discussion, it is evident that there is a pressing need for a logistics model that will eliminate overlapping routings, increase vehicle utilisation, and reduce operating costs whilst adhering to customer service levels. To the best of our knowledge, there is no precedent in the logistics literature that investigates a collaborative model to satisfy the demand for home deliveries of groceries. Our analysis is based on distribution centre and vehicle sharing, excluding external costs.

3. Distribution Model

Overlapping routings can be eliminated when retailers participate in a shared logistics model. This is comparable to the case where the supply chain is coordinated by a single decision maker. In this section, we use a shared logistics model that includes both economic and environmental incentives for grocery retailers to collaborate with their competitors in food distribution. Collaboration of retailers in logistics activities does not mean that competition is over as it continues in other aspects of the business.

Opportunities for mutual benefits cannot be found unless retailers share their private information honestly. It is important for retailers to participate voluntarily and share their information with the rest because it is in their self-interest. As the grocery retail sector is a free market, any proposed model that constrains retailers' freedom is not a realistic one and could never be applied. Therefore, our idea is first to reach a more efficient solution for all the participants and then apportion the additional benefits to retailers in a way that all of them will receive a better pay-off compared to the existing model. This could be possible under the improvement in the shared logistics model.

As mentioned, retailers have to deliver grocery orders placed online to their consumers' preferred locations (either consumers' houses or click & collect points). Delivery distance, that retailers have to cover, could be analysed in two categories: i) drop distance which is the distance travelled once a drop or delivery zone is reached (last mile logistics) and ii) stem distance which is the distance to and from a delivery zone (stem mile logistics). The drop distance remains the same irrespective of the distance from the supplying picking location, but the stem distance varies with the number of picking locations in the system.

In this paper, we propose a model for using shared vehicles in the stem distance. In the proposed model retailers use common trucks to transport the orders from their exclusive picking locations which could be stores, or dedicated distribution centres to shared micro hubs in urban areas, which are the drop zones according to the above definition. The flow of UK grocery orders can be conceptualised in Figure 3 where large flows from retailers' picking locations are transported to shared micro hubs in residential areas, which serve as a cross-docking facility to perform the last mile delivery of grocery orders to consumers' preferable locations.

Figure 3 Conceptualisation of Online Grocery Flows

The mathematical model behind this shared distribution from picking locations to micro hubs is the Capacitated Vehicle Routing Problem (CVRP), since a large truck will collect orders picked at each retailer's picking location and deliver to multiple shared micro hubs, which can then manage the distribution within the drop zone. As mentioned above, distribution within the drop zone is currently out of scope for this paper.

One of the classic combinatorial optimisation problems, vehicle routing, has become a key element of managing distribution operations (Wei et al., 2017). The Vehicle Routing Problem (VRP) (Laporte, 1992) domain is rich with many extensions including but not limited to CVRP, VRP with time windows, or VRP with pickup and deliveries. The origins of the VRP, which is a generalisation of the travelling salesperson problem (TSP), can be traced back to Dantzig and Ramser (1959). The TSP determines the shortest route that passes n locations, only once. When each pair of locations is linked, the total number of routes through n locations is ($n!$)/2; a number that grows very large very fast: for example, the total number of possible routes for 10 locations is 1,814,400. The TSP is generalised to VRP by imposing capacity constraints that are smaller than the total demand of all locations to be visited. In that case, multiple vehicles are needed to satisfy the total demand in the service area.

In this work, a CVRP with pickup and delivery is used to measure the benefits that arise from retailers' collaboration. We assume that every micro hub is served by a single picking location, this means that we use the CVRP with a single depot (in our case depot is the distribution centre). In our problem, customers are the micro hubs that the retailer(s) should visit and supply them and the demand is the number of grocery orders to be delivered at each micro hub. Regarding the mathematical formulation of CVRP, we refer the reader to Toth and Vigo (2002).

The CVRP can be defined as a complete graph $G = (V, A)$, where $V = \{0,1,2,…,n\}$ is the vertex set and A is the arc set. Vertices-i, with $i = \{1,2,…,n\}$ correspond to the customers, where vertex 0 corresponds to the depot. For each customer-i, there is a known, non-negative demand d_i. A nonnegative cost, c_{ij} is associated with each arc (i, j) $\in A$ (i.e., $i, j \in V$) and represents the travel cost from vertex i to vertex j. We assume identical vehicles are available to distribute the orders across micro hubs (in our case there is no constraint for the size of fleet) and each can be loaded at maximum with capacity C (in our case, this is the maximum numbers of online orders that a vehicle can carry). The problem is to determine which arcs will be used to satisfy customers' demand whilst minimising total distance travelled. This is achieved by using binary variables X_{ij} that indicate if arc (I, j) is used ($X_{ij} = 1$) or not ($X_{ij} = 0$) for all $i, j \in V$.

In this work, our objective is to minimise the total distance that the retailer's fleet should cover to supply all micro hubs. The main inputs in our case are: a distribution centre, micro hubs, distances between all locations of distribution centre and micro hubs, daily demand for each micro hub, and vehicle capacity. This information is summarised in Table 1.

Table 1 Notation of CVRP in our study

CVRP	Our study
0 : Depot	Distribution centre
$N=\{1,2,...n\}$: Set of customers	Set of micro hubs
$V = \{0\} \cup N$: Set of possible locations	
d_i : Demand of customer-i, $i \in N$	Number of orders to be delivered to a micro hub
c_{ij} : distance between i and j locations, with $i, j \in V$.	
X_{ij} : binary decision variables	
C : Vehicle capacity	

We define the problem as finding the minimum distance to serve the daily demand from each micro hub. This problem is typically formulated as a binary mixed integer linear programming problem as we presented above and small instances (up to 10 micro hubs to be serviced) are solved optimally using commercial solvers such as CPLEX. Large instances (number of micro hubs to be visited > 10) cannot be solved to optimality within an acceptable period (e.g. less than several hours) due to the NP-Hard nature of the problem. Hence, we run the CPLEX in truncated mode and report the minimum distance obtained. We use the CVRP to show the potential benefits from collaboration, in terms of distance reduction and fleet size needed to serve the demand. The formulation does not change, but the data that is input to the model changes: In the As-Is case where retailers work independently, we input demand data from each retailer separately and solve the routing problem. In the To-Be case, we input aggregate demand data from both retailers and solve the routing problem accordingly to show the effect of collaboration in logistics.

In our model, we calculate 12 Key Performance Indicators (KPIs), first under the base case where retailers work independently (the As-Is situation) and then the proposed case where they collaborate (the To-Be situation). We then compare the KPIs to establish the benefits from collaboration. Through the comparison between the As-Is and the To-Be situations, we evaluate the performance of our model and measure the economic and the environmental impact. The 12 KPIs we examine are:

1.   The total distance that must be covered (optimisation objective),
2.   The average distance per route,
3.   The average distance per order,
4.   The maximum number of routes required to satisfy the demand,
5.   The average number of served micro hubs per route,
6.   The total driving time for the whole fleet,
7.   The average driving time per route,
8.   The total drop-off time for the whole fleet,
9.   The average drop-off time per route,

10. The total time (i.e. driving time plus the drop-off time) for the whole fleet,
11. The average time per route,
12. The utilisation of fleet at the starting point (i.e. at the picking location).

In the next section, we present the data generation methodology for online grocery demand in the UK as it is the critical input to our capacitated vehicle routing models.

4. Demand Estimation Methodology

The grocery retail sector in the UK is known for its severe competition and it is no surprise that major retailers have started investing large sums in the online channel more than a decade ago (Hackney et al., 2006). Four leading retailers (ASDA, Ocado, Sainsbury's, and Tesco) possess around 80% of the total online grocery market. In Table 2 we present the sales for the six leading retailers in the UK during the years 2012-2015.

Table 2 Leading online grocery retailers' sales (in million, including VAT), 2012-15, Source: Mintel (2014-2016)

Retailer	2012	2013	2014	2015
Tesco	£ 2,241	£ 2,635	£ 2,945	£ 3,287
Sainsbury's	£ 1,061	£ 1,180	£ 1,318	£ 1,297
Asda	£ 760	£ 865	£ 1,009	£ 1,038
Waitrose	£ 193	£ 275	£ 377	£ 346
Ocado	£ 732	£ 846	£ 1,009	£ 1,211
Morrisons*	N.A.	N.A.	£ 68	£ 200
Other	£ 686	£ 760	£ 813	£ 1,270
Total	£ 5,673	£ 6,562	£ 7,540	£ 8,649

* Morrisons started its online grocery service in 2014.

A UK-based food retailer has provided primary data about its distribution of groceries purchased online for home deliveries. Due to the reasons of confidentiality, the data was aggregated over a year and anonymised. The data set contains 346,745 orders from 533 postcode sectors in London from 01/06/2014 to 31/05/2015. We present the distribution of aggregate consumer demand over time in Figure 4. The left panel shows the demand distribution over the days of the week and the right panel shows the demand distribution over the hours of the day. The peaks on Monday and Friday in the left panel and the peaks over 9-10am in the morning and 7-8pm in the evening are evident. These peaks lead to underutilisation of fleets when the retailers invest in fleets to meet the peak demand.
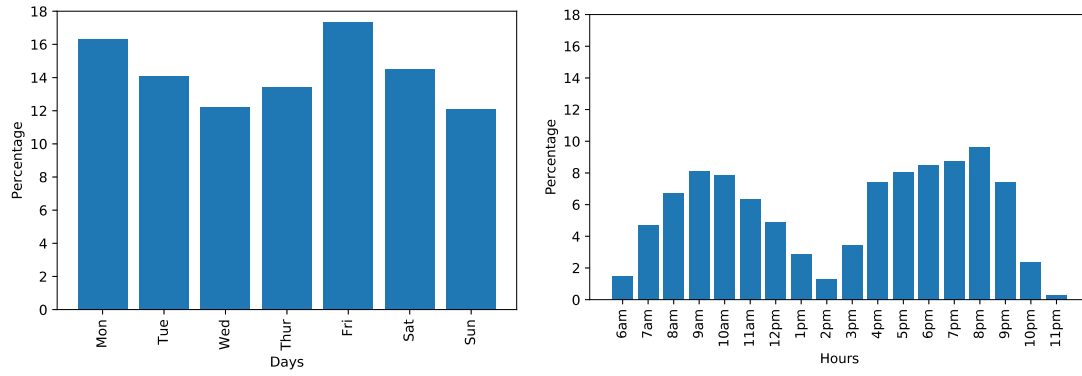
Figure 4 Daily and Hourly Demand Distribution of Groceries Purchased Online

As a remedy to the lack of sufficient primary data we also developed a survey to elicit the consumers' preferences for buying groceries online in the UK and we focused on the following major grocery retailers: Asda, Iceland, Morrisons, Ocado, Poundland, Sainsbury's, Tesco, and Waitrose that provide online services in London. We used Qualtrics to run our survey from 11/11/2016 to 18/11/2016 (six working days) and collected 420 responses without any missing values. It is useful to note that more than 2,800 people participated in our survey but only 420 participants who live in London completed the survey. Our sample size is representative as the ideal size for an 8.7 million population (such as London population) is 384 (Krejcie and Morgan, 1970). Five- and seven- point Likert scale was used to measure respondents' agreement with a variety of statements. The main parts of our survey consist of questions that capture the following facts: online grocery buying habits, consumer satisfaction level with the delivery service, personal characteristics that might affect the aforementioned issues, intention to use click & collect, choice experiment, and demographics. One of the main objectives of this survey is to examine if there is a pattern in consumers' preferences for delivery days and time slots when they select their orders. Based on our survey, it is a realistic assumption to use the demand distribution from primary retailer (Figure 4) for our collaboration scenario.

We generate secondary data to estimate the daily demand for home deliveries of groceries purchased online for the six major UK retailers (Table 2), due to a lack of primary data from these retailers. This method estimates the daily demand per postcode sectors (micro hub's drop zone) based on population of the postcode and the store footprint of the retailers. We use data from secondary sources such as Ocado (2016) and Mintel (2017) to extrapolate daily demand based on market shares of the retailers. We evaluate the accuracy of our approach (i.e. generation of annual demand for home deliveries) based on the primary data set that was obtained (Table 3). We present the main steps of our home delivery demand data generation methodology for the online grocery market as follows:

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1. Establishing the overall UK online grocery market size and individual market shares of the six major retailers (Table 2). Our analysis is based on the sales of 2015.
2. Adjusting online grocery sales according to the geographies served by each retailer and the UK population data.
3. Calculating orders per capita by postcode sector for each retailer.
4. Adjusting the online grocery orders per year by postcode sector by retailer using the retailer's store footprint.
5. Calculating the total number of online grocery orders.
6. Applying a seasonality profile to total online grocery orders per year to derive daily orders (Figure 4).
7. Estimating the demand for six major retailers (Table 4).

Based on the primary data set, we work only with the postcode sectors where the demand is high enough to fit a theoretical probability distribution (at least 30 orders). We also use the latitude and longitude of postcode sectors in our distance calculations. It should be noted that postcodes in the UK are alphanumeric references comprising an outward code of 2-4 characters and an inward code of three characters. The postcode is structured hierarchically, supporting four levels of geographic unit: postcode area (124), postcode district (3,114), postcode sector (12,381), and building postcode (approximately 1.75 million). In this work, it is assumed that each postcode sector is a drop zone served by a single shared micro hub.

There are 266 postcode sectors with at least 30 observations (individual postcodes) for which the aggregated number of orders are reported. This means that we continue with 49.9% of the total postcode sectors in the primary data. Then, we test seven theoretical probability distributions (Cauchy, Exponential, Gamma, Logistic, Lognormal, Normal, and Weibull) and assess the goodness of fit. We choose the distribution and the parameters with the minimum Akaike Information Criterion for each postcode sector. We run all our analyses in `R` using the `fitdistrplus` package. For the 266 postcode sectors, we have estimated the parameters of the theoretical probability distributions. We also run the analyses in `MATLAB` for a sample (25 out of 266 sectors) of sectors to verify the theoretical distributions that have been fit using the `fitdistrplus` package. We found no instances where the parameters fit by `MATLAB` were significantly different from the parameters fit by `R`. The distribution of demand is `Lognormal` in 96% (256 out of 266) of all postcode sectors, while the demand in the remaining 10 sectors follows the `Exponential` distribution. For one of the 266 postcode sectors, the ONS does not provide population data, so we exclude this sector from the analysis (for the sake of

completeness the postcode sector is 'E20 1'). Therefore, the remaining postcode sectors are 265 in London, for which we have primary data. Figure 5 shows the 16 postcode districts that include these 265 postcode sectors.

Figure 5 Map of London; Study Area Shaded in Grey

We assess the performance of our demand generation methodology based on secondary data using the weighted Mean Absolute Percentage Error (w-MAPE). The advantage of a weighted metric is to give more weight to the sectors with larger demand. Making a large error in a small area is not as important as making a small error in a large area which may inflate the number of orders estimated. In the last stage, we determine the values of the two parameters in demand generation methodology: 'Population' (step 3) and 'Store Mix' (step 4), to minimise the weighted MAPE. We have done this as many shops in a specific area indicate higher demand for online groceries as well. The parameter values tested are given in Table 3. This happens for the equal weight (50% - 50%) between 'Population' and 'Store Mix' where the weighted MAPE is 0.478.

Table 3 Error measures depending on population and store mix

Population	0%	10%	20%	30%	40%	**50%**	60%	70%	80%	90%	100%
Store Mix	100%	90%	80%	70%	60%	**50%**	40%	30%	20%	10%	0%
MAPE	0.478	0.472	0.478	0.493	0.513	**0.54**	0.571	0.609	0.652	0.698	0.747
Weighted MAPE	0.527	0.507	0.493	0.484	0.479	**0.478**	0.482	0.491	0.504	0.52	0.538

Based on these values we generate the annual demand for the online market for Tesco, Sainsbury's, Asda, Waitrose, Ocado, and Morrisons (Table 4) and based on this demand we continue with the analysis. The outcome of our approach is presented in Table 4 for four postcode sectors in London: 'E10 5', 'E10 6', 'E10 7', and 'E1 0'. For example, we estimate 8,299 grocery delivery orders to be placed from postcode sector 'E10 5' by Tesco over a year. Using the daily demand distribution from the online retailer that

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provided us with primary data over a year, we use Monte Carlo simulation to estimate daily demand distribution. As expected, total annual demand does not change with this simulation, but we do estimate daily demand that informs the CVRPs to be solved.

Table 4 Estimated annual online grocery orders per retailer per postcode sector

Postcode Sector	Tesco	Sainsbury's	Asda	Ocado	Waitrose	Morrisons
E10 5	8,299	4,085	2,208	3,593	864	791
E10 6	9,139	4,499	2,432	3,957	951	871
E10 7	6,649	3,273	1,769	2,878	692	634
E1 0	6,182	3,043	1,645	2,676	643	589

We investigate the existing market structure and estimate the following KPIs: Total travelled distance, Distance per route, Distance per order, maximum number of routes, Stops (shared hubs) per route, Driving time, Driving time per route, Drop-off time, Drop-off time per route, Total time, Total time per route, and Vehicle capacity. Then, we estimate the same KPIs under the proposed shared model in which two retailers R1 and R2, with comparable market shares to Morrisons and Ocado collaborate in the stem distance from picking locations to the shared micro hubs in the drop zones. We report the KPIs to quantify the benefits from collaboration.

5. Analysis and Results

In this section, we quantify the benefits that arise form collaboration on the logistics activities under the scenario that two retailers will work together in the proposed model of shared vehicles for the stem distance.

We examine our proposed model under the scenario that two retailers with comparable market share to Morrisons (R1) and Ocado (R2) collaborate on the logistics activities in the large flows (stem mile) to meet their online demand. A rough estimation about the number of annual online orders that both retailers have to satisfy is around 13.3M, possessing 16% of the total online market (in terms of sales in 2015). Both retailers operate two picking locations to serve consumers in London, where our focus is on the 265 postcode sectors. We assume that every sector is served by a single picking location. Under this assumption, Picking Location 1 (North London) serves 198 sectors and Picking Location 2 (West London) serves 67 sectors. We do not propose any major modifications to retailers' distribution network, since it is too costly for retailers to change their existing distribution network to achieve short term cost savings and emission reduction (Cachon, 2014). We assume that the picking locations are a parameter to our problem, not a decision variable.

To calculate the above KPIs, we use the following model parameters: Average speed (km/h), Time to drop/location (min), Time/order (min), Shift length per route (min), and Loading time per route at picking location (min) as presented in Table 5. These parameter estimates were obtained from industry experts.

Table 5 Model parameters

Parameters	Values
Average speed (km/h)	20
Time to drop/location (min)	10
Time/order (min)	2
Shift length per route (min)	480
Loading time per route at picking location (min)	30

We assume that retailers collaborate in the stem distance (To-Be situation) and calculate the same KPIs based on the values of model parameters (Table 5). Thus, we measure the benefits from collaboration making comparisons between the KPIs in the As-Is and the To-Be situations.

We use the design of experiments to derive valid statistical inferences from our experimental observations. In these experiments, we make changes to the input variables and observe their impact on the benefits from logistics collaboration. We follow factorial design where each complete trial of the experiment investigates all possible combinations of the levels of the factors (Montgomery, 2013). We consider picking locations, vehicle capacity, and logistics operation as the factors that affect the distance travelled to fulfil home deliveries of groceries purchased online. As the retailers define a minimum order size (based on the value of the items) and there is a fixed charge (up to £7 depending on the preferred time window) for the delivery service, we consider that the vehicle capacity is directly related to how many orders can be loaded on a vehicle. Furthermore, we are aware that a typical online grocery order has 60-80 items and in the vehicles there are boxes in which the retailers deliver the orders, so the number of boxes is fixed based on the vehicle size. Table 6 shows the levels of each factor.

Table 6 Design of Experiments

Picking Locations	Vehicle Capacity	Logistics Operation
West and North (2)	10, 15, 20, and 25 orders (4)	Independent (2) and Collaborative (1)

We ran the VRP for each picking location (2), for each capacity (4), for each logistics operation (two for independent operation of retailers and one for joint logistics operation), and for each day (364); resulting in 2*4*3*364=8,736 runs. We use the R Language to prepare the input data and AMPL software to run the mathematical model (CVRP) using the CPLEX solver. We limit the run time of CPLEX to 60 seconds across all

instances and record the solution available at the time the solver is interrupted. We read the outputs from AMPL into R to analyse the results.

As an example, Table 7 presents the results of the CVRP solution on a specific day for independent operation of both retailers and collaborative operation for the second picking location in West London (serves 67 sectors) with a vehicle capacity of 15 orders. It should be noted that the routes may be not the optimal ones as the CPLEX solver is run for 60 seconds per problem instance.

Table 7 Results of the CVRP solution on a specific day

KPI	R1	R2	R1 and R2
Demand (orders)	98	389	487
Total travelled distance (km)	264	821	979
Postcode sectors served	51	67	67
Vehicles needed	7	29	34

It can be seen in Table 7 that the second retailer has to serve the whole area (67 postcode sectors out of 67), while the first retailer serves a part of it. This means that synergies of these two retailers could improve significantly their logistics operation, as they both serve the same area. It can be easily observed that a distance saving of 11% is possible when retailers work collaboratively (979 km instead of 1,085 km). Similarly, the total number of vehicles needed to fulfil the demand of both retailers is 6% lower than the independent operation on this day.

Table 8 presents the summary of benefits that arise from collaboration on both picking locations. It is useful to note that the results are based on the values of the parameters that are shown in Table 5. For all examined KPIs (except the Vehicle Capacity Utilisation), retailer's collaboration incurs reduction of them. The arrows in Table 8 indicate the direction of benefits, i.e. the lower the distance, the better it is for the retailers. For example, the 11.5% under C25 for Picking Location 1 (North) means that the joint problem resulted in an average distance reduction of 11.5%.

Table 8 Benefits when two retailers collaborate with shared vehicles for the stem distance

	Picking Location 1 (North)				Picking Location 2 (West)			
Capacity	C10	C15	C20	C25	C10	C15	C20	C25
Distance (↓)	6.4%	8.6%	10.1%	11.5%	5.5%	5.7%	9.4%	11.7%
Distance/route (↓)	4.0%	5.8%	6.5%	8.8%	4.6%	6.9%	8.4%	10.6%
Distance/order (↓)	6.4%	8.6%	10.1%	11.5%	5.5%	5.7%	9.4%	11.7%
Routes (max) (↓)	3.8%	5.0%	2.9%	7.1%	6.2%	3.4%	0.0%	3.0%
Stops/route (↓)	30.6%	38.7%	41.2%	42.5%	32.7%	42.2%	42.5%	42.6%
Driving Time (↓)	6.4%	8.6%	10.1%	11.5%	5.5%	5.7%	9.4%	11.7%

	Picking Location 1 (North)				Picking Location 2 (West)			
Capacity	C10	C15	C20	C25	C10	C15	C20	C25
Driving Time/route (↓)	4.0%	5.8%	6.5%	8.8%	4.6%	6.9%	8.4%	10.6%
Drop-off Time (↓)	16.9%	20.5%	21.8%	22.1%	17.9%	21.6%	22.4%	22.5%
Drop-off Time/route (↓)	14.8%	18.0%	18.6%	19.8%	17.1%	22.6%	21.6%	21.5%
Total Time (↓)	9.5%	12.8%	14.9%	16.2%	9.5%	12.0%	15.3%	17.0%
Total Time/route (↓)	7.1%	9.9%	11.4%	13.5%	8.5%	12.6%	13.9%	15.5%
Vehicle Capacity Utilisation (↑)	2.4%	3.0%	3.8%	2.7%	0.8%	-1.1%	1.1%	1.2%

Moreover, we have prepared boxplots of individual and shared logistics operation for the examined KPIs (Figure 6) to compare the existing with the proposed situation. The first one is the As-Is model (Independent Deliveries); i.e. when retailers work alone (first boxplot) versus the To-Be model (Shared Deliveries); i.e. when retailers collaborate on the food distribution (second boxplot). To provide more details, we explain further an example on the benefits from collaboration. We analyse the improvement about the distance (KPI) for the Picking Location 2 when the vehicle capacity is equal to 10 orders. In Figure 6, the reader could compare easily the examined KPI (i.e. total distance in our example) between the As-Is and the To-Be cases. More specifically, in Figure 6 on the first boxplot at the top, we see the distribution of data (for the whole year) with the five number summary (minimum, first quartile, median, third quartile, and maximum) of the examined KPI when two retailers work independently.
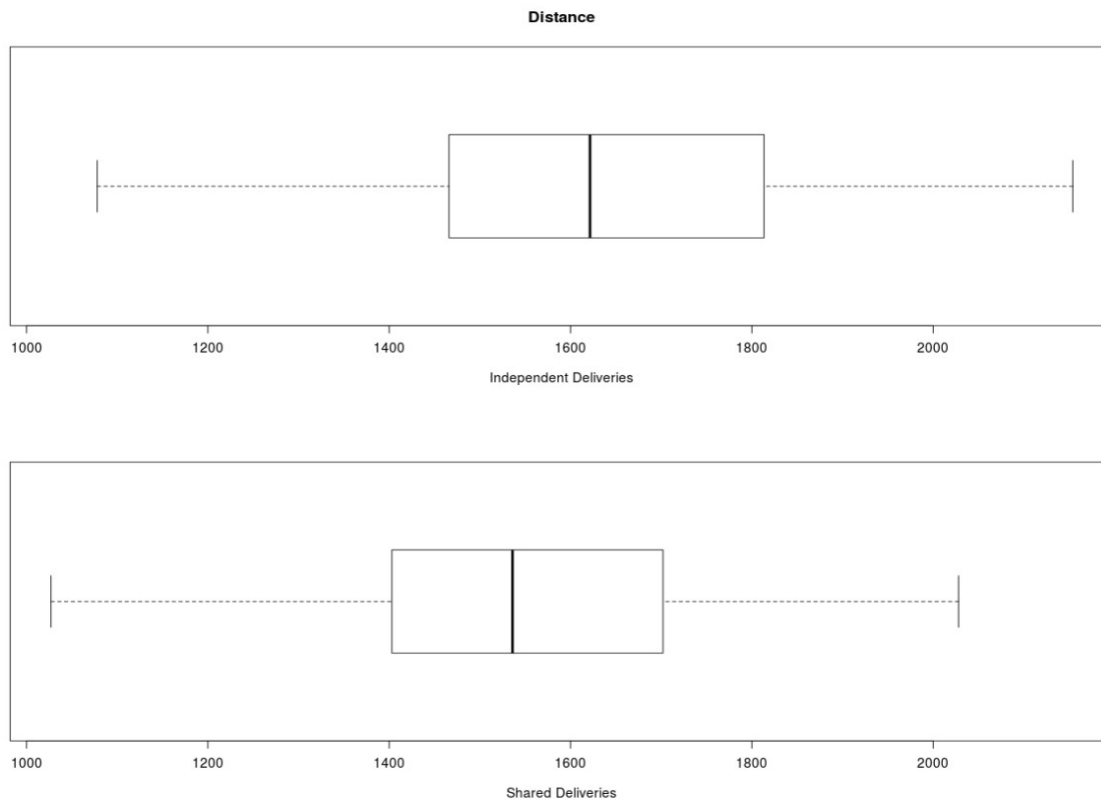

Figure 6 Boxplots of independent and shared deliveries

In this case, retailers need to cover on average 1,640 kilometres (minimum kilometres are 1,070 and maximum kilometres are 2,180) per day to satisfy the demand for home deliveries of groceries purchased online. Under our proposed model (Figure 6, second boxplot), the shared retailers' fleet needs on average 1,550 kilometres (minimum kilometres are 1,020 and maximum kilometres are 2,060) per day to satisfy the demand. 1,550 kilometres are the required distance (on average) if retailers meet their grocery delivery demand when they work collaboratively in distribution. Therefore, the average improvement of 5.5% (i.e. (1550-1640)/1640) is possible under the shared deliveries.

6. Conclusions and Discussion

In this work, we considered how the UK online grocery retailers could improve their operational efficiency in logistics if they work collaboratively to satisfy delivery demand. We proposed a shared logistics model, where grocery retailers work as a single entity making the optimal joint decisions about the home deliveries. Our main aim is to investigate the benefits that can arise from a potential collaboration of UK retailers and measure also the impact of the proposed collaboration in terms of economic and environmental issues.

Currently, major retailers in the UK online grocery market make operational decisions individually to maximise their profits without collaborating with each other. This means that each retailer invests in its own fleet of trucks as well as in distribution centres, solving its own routing problem daily. This independent logistics operation results in inefficiencies in terms of multiple visits to the same area from different retailers around the same time of the day. The delivery operation can improve if the barriers to collaboration can be overcome. This is the motivation of our work, to examine the collaborative gains that will arise when retailers collaborate in the distribution of groceries.

Our findings suggest that collaboration gains depend on the nature of the last mile delivery problem to be solved; depending on the distances between customers served on a day and the corresponding number of orders, there could be little or large reductions in distance travelled. The latter presents our major contribution and we anticipate that these gains and efficiencies could incentivise retailers to consider these collaborative models. More specifically, drop density is an important factor affecting profitability of the home delivery operation; therefore, there is a strong case for collaborating in logistics of online grocery orders where the areas served have a low drop density. Collaboration could help retailers to achieve higher reductions in distance and total operation time in

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postcode sectors with higher daily orders through combining the orders of the same postcode sector in fewer vehicles. We investigate a new physical network design for the online grocery retail where micro hubs located in postcode sectors are proposed to fulfil the online grocery last mile distribution. Our analyses of the distance from picking locations to these micro hubs reveal improvements of up to 18% in total distance when two retailers collaborate. Savings in total delivery time reach up to 21% across the simulated period. In line with that, the average reduction in distance travelled is 10% and the average reduction in the time required to complete the last mile distribution is 16%. The reduction in distance is a precursor of the reduction in carbon emissions due to the strong correlation between the distance travelled and the carbon emissions (Zissis et al., 2018). Therefore, it is plausible to estimate a comparable rate of reduction in carbon emissions.

Relevant research has highlighted the strong potential for horizontal logistics collaboration involving various members of the supply chain including suppliers and third-party logistics companies (Soysal et al., 2018; Vanovermeire et al., 2014). Past research has also shown the potential for horizontal collaboration involving grocery retailers (see for example, Hingley et al., 2011; Sanchez Rodrigues et al., 2015) and Mason et al. (2007) showed similar potential for both vertical and horizontal collaboration in the supply chain focusing on transport optimisation. Despite the above, due to the fierce and cut-throat competition of the retail market, retailers avoid to collaborate in general and in their logistics operations in particular. Our paper has illustrated the major, sustainable benefits (economic, social, and environmental) in urban logistics operations emanating from the collaboration between online grocery retailers. In that way, it has addressed a major gap in the literature as, to our knowledge, no past work has shown these sustainability-related benefits in relation to the collaboration of online retailers. Equally, this paper has stressed a prime opportunity for retailers to pursue as these benefits are worth considering. We are confident that horizontal logistics collaboration could materialise in the grocery retail chain especially when retailers are under increased pressure to improve their sustainability targets (Spence and Bourlakis, 2009). Therefore, retailers which will be proactive and will collaborate with other retailers in their logistics operations will have much to gain in terms of, inter alia, improving their sustainability and corporate social responsibility credentials. Our work has suggested specific logistics solutions aiming to address contemporary societal challenges including the urbanisation one. Considering that the majority of the world population will be living in urban environments by 2050 (UN, 2015), our research has identified possible logistics options to be considered by retail managers, supply chain practitioners and policy makers.

We also propose several suggestions for future research including: i) To identify the best locations for the shared facilities, and what is the catchment area of micro hubs to make them economically viable. ii) To further examine the impact of the application of a Collaborative Planning, Forecasting and Replenishment system in their operations.

Several limitations of this work should be recognised. The most important one is that the online demand is based on ballpark figures without a chance to validate the apportioning results. We use data captured from the delivery system of an online retailer in order to check the accuracy of demand apportioning methodology which is based on published data from the Office of National Statistics, retailers' Annual Reports, and our own survey. We understand the MAPE is high and, therefore, our results should be treated with caution. Nevertheless, our approach is informed by data provided by reputable sources and it does not have subjective decisions. Our methodology and results are transparent and reproducible. Any method is as reliable as the data informed it and we are confident the data sources that we used are trustworthy. Another limitation is that we use symmetric distances approximated from the longitude and latitude of postcode sectors as input calculations for the CVRP. In reality, the distances between two points in urban areas are likely to be asymmetrical and our distance estimations can be improved by incorporating actual road distances into the distance matrix. Furthermore, we ran the CPLEX solver for each CVRP for 60 seconds for each problem instance owing to the higher number of instances that must be solved (8,736). Longer runs may show that the benefits from collaboration could be higher than what we report. We also acknowledge that this work is focused on the UK online grocery market and collaboration approaches analysing an urban logistics problem based on the demand, drop density, operating conditions, and associated costs. We recognise that different results could be expected from other national markets due to different input parameters. Despite this, we are confident that this market can be an ideal testbed to illustrate positive benefits emanating from these collaborative activities as retailers based on other geographical areas of the world develop nowadays similar online grocery offerings. The UK online grocery market is very dynamic and it is one of the most competitive online markets in the world. Therefore, there are many lessons to be learned for online grocery retailers operating in other national markets including the ones from developed and developing economies focusing on retail firms which aspire to become more sustainable in their logistics systems; our work could pave the way for UK online retailers (and retailers in other national markets) to start exploiting and implementing collaborative ventures in logistics operations with other retailers. Some of those logistics operations could involve shared warehouses, joint primary distribution activities and transport planning. However, we are aware that it may be challenging for retailers to collaborate for the transportation

of products during home deliveries as these deliveries constitute a key element of retailers' brand and customer service strategy.

Despite these limitations, we still conclude that the benefits presented are valuable to retailers operating their own fleets to satisfy home delivery demand and to policy makers devising plans to improve the sustainability of urban freight transport.

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