THE SCOPE FOR PAVEMENT PORTERS: ADDRESSING THE CHALLENGES OF LAST-MILE PARCEL DELIVERY IN LONDON

Julian Allen
Faculty of Architecture and the Built Environment, University of Westminster, London, NW1 5LS, U.K.
Tel: +44 (0)20 350 66627; Fax: +44(0)20 7911 5839; Email: allenj@westminster.ac.uk

Tolga Bektas *(corresponding author)*
Southampton Business School, University of Southampton, Southampton, SO17 1BJ, U.K.
Tel: +44 (0)23 8059 8969; Fax: +44(0)23 8059 3844; Email: t.bektas@soton.ac.uk

Tom Cherrett
Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, U.K.
Tel: +44 (0)23 8059 4675; Fax: +44 (0)23 8059 3152; Email: t.j.cherrett@soton.ac.uk

Oliver Bates
School of Computing and Communications, Lancaster University, Lancaster, LA1 4WA, U.K.
Tel: +44 (0)1524 510326; Fax: +44 (0)1524 510492; Email: o.bates@lancaster.ac.uk

Adrian Friday
School of Computing and Communications, Lancaster University, Lancaster, LA1 4WA, U.K.
Tel: +44 (0)1524 510326; Fax: +44 (0)1524 510492; Email: a.friday@lancaster.ac.uk

Fraser McLeod
Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, U.K.
Tel: +44 (0)23 80593316; Fax: +44 (0)23 8059 3152; Email: f.n.mcleod@soton.ac.uk

Maja Piecyk
Faculty of Architecture and the Built Environment, University of Westminster, London, NW1 5LS, U.K.
Tel: +44 (0)20 350 65154; Fax: +44(0)20 7911 5839; Email: m.piecyk@westminster.ac.uk

Marzena Piotrowska
Faculty of Architecture and the Built Environment, University of Westminster, London, NW1 5LS, U.K.
Tel: +44 (0)20 350 66626; Fax: +44(0)20 7911 5839; Email: M.Piotrowska@westminster.ac.uk

ThuBa Nguyen
Southampton Business School, University of Southampton, Southampton, SO17 1BJ, U.K.
Tel: +44 (0)23 8059 8969; Fax: +44(0)23 8059 3844; Email: ThuBa.Nguyen@soton.ac.uk

Sarah Wise
Faculty of the Built Environment, University College London, 90 Tottenham Court Road, London, W1T 4TJ, U.K.
Tel: +44 (0)20 3108 3905; Email: s.wise@ucl.ac.uk

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ABSTRACT

The UK parcel sector generated almost £9 billion in revenue in 2015, with growth expected to increase by 15.6% to 2019 and is characterised by many independent players competing in an 'everyone-delivers-everywhere' culture leading to much replication of vehicle activity. With road space in urban centres being increasingly reallocated to pavement widening, bus and cycle lanes, there is growing interest in alternative solutions to the last-mile delivery problem. We make three contributions in this paper: firstly, through empirical analysis using carrier operational datasets, we quantify the characteristics of last-mile parcel operations and demonstrate the reliance placed on walking by vehicle drivers with their vans being parked at the curbside for, on average 60% of the total vehicle round time; secondly we introduce the concept of 'portering' where vans rendezvous with porters who operate within specific geographical 'patches' to service consignees on-foot, potentially saving 86% in driving distance on some rounds and 69% in time; finally, we highlight the wider practical issues and optimisation challenges associated with operating driving and portering rounds in inner urban areas.

INTRODUCTION

The UK parcel sector generated almost £9 billion in revenue in 2015, a 6% increase on the previous year, with growth expected to increase by 15.6% to 2019 (1). With over 1.7 billion parcels being delivered domestically per annum (2), light goods vehicles (LGVs – up to and including 3.5 metric tonnes (3.85 U.S. ton) gross weight) have seen the greatest growth with 3.6 million licenced in the UK (2015), a 23% increase relative to heavy goods vehicles since 1995 (3,4,5). The parcel distribution sector is characterised by many independent players competing in an 'everyone-delivers-everywhere' culture leading to much replication of vehicle activity (6). This in turn negatively impacts on congestion and the need to reduce emissions in cities which is a central requirement of EU legislation (7).

The UK parcels market consists of three sub-sectors where transactions take place between different entities: business-to-business (B2B); business-to-consumer (B2C), and consumer-to-all-parties (C2X). In the UK, B2B accounted for 38%, B2C, 56%, and C2X, 6% of the parcel market in 2012 (8) with forecasts suggesting that volumes in the B2C and C2X sub-sectors will grow at approximately 4.5 to 5.5% per annum in the medium term (9).

Parcel carriers offer consignees a wide range of delivery options from immediate to same day, next day, to a delivery anytime within a set period of days. 'Express' usually refers to services with a specified day of delivery (e.g. next day or two-day) and time of delivery (e.g. before 09:00, before 10:00). 'Courier' services are usually the most time-sensitive, often guaranteeing same day delivery, or delivery before a certain time. The market for courier services is much more fragmented than for express and parcel services comprising many small owner operators. Data has suggested that next day services accounted for 56% of all UK domestic volumes in 2014-15 and 70% of total parcel revenues (10).

In order to meet customer needs, carriers have developed different logistics strategies and networks. Couriers offering immediate and same-day services typically operate a door-to-door service between the consignor and consignee. A parcel carrier based wholly within one city is likely to make use of a single depot from which multi-drop vehicle rounds are performed whereas a national or international carrier will typically make use of a hub-and-spoke network. In the case of the latter, central hubs and regional/local distribution centres may be operated, with large fully-loaded vehicles operating between the hubs and other distribution centres, and smaller vehicles performing multi-drop rounds for last-mile delivery operated from several local depots in the case of large cities. In addition to this, parcel carriers are using 'lifestyle' couriers (self-employed owner-drivers working on a freelance basis) to manage local last-mile deliveries, the handling of failed first-time deliveries and customer returns. With the plethora of different operators and services, it is estimated that the UK parcel market is approximately 20% overcapacity (11). Given that road space in urban centres is being reallocated to pavement widening, bus and cycle lanes (12), and with Transport for London predicting that traffic congestion in central London will increase by 60% by 2031 (13), there is growing interest in alternative solutions to the last-mile problem.

We make three contributions in this paper: firstly, through empirical analysis using carrier operational datasets, we quantify the characteristics of last-mile parcel operations and demonstrate the reliance placed on vehicle curbside parking and walking as an integral component in the last 100m transaction; secondly we introduce the concept of 'portering' as a potentially viable option for improving the efficiency of last-mile van operations using a case study example; finally, we highlight the wider issues and challenges associated with operating and optimising driving and portering rounds in inner urban areas.

CHARACTERISTICS OF MULTI-DROP OPERATIONS AND THEIR ON-STREET IMPACTS

A detailed study of 25 vehicle rounds operated by two parcel carriers making deliveries and collections across three postcodes in the West End of central London (WC1, WC2 and W1) was also undertaken. This was done over three days in October 2016 and involved: i) GPS tracking of both the vehicle and the driver, ii) surveyors accompanying drivers to verify round timings, parking places used, and delivery/collection locations served, and iii) analysis of the daily manifest data for each vehicle round.

All the vehicles used were vans with a carrying capacity of up to 1 metric tonne (1.1 U.S. ton) and up to $6m^3$ (1,320 gallons) in volume. Parcels for delivery and collection were allocated to drivers each day based on pre-determined and largely fixed vehicle round structures. Parcel deliveries accounted for 94% of all activity with the transaction order being left to the driver's discretion. Drivers were responsible for selecting the route, parking locations and the clusters of consignees to service from each stopping point. The vehicle rounds studied took place in the 'West End' of central London in the area of Oxford Street, Regent Street, Covent Garden, Soho, Mayfair and Piccadilly. The area has approximately 2,000 shops, 2,500 restaurants and cafes, 3,000 licensed premises, 40 theatres, 20 cinemas, 30 museums and galleries as well as 40,000 residents, and accounts for 65,000 employees generating 15% of London's total gross value added (GVA), (14)

The rounds emanated from three depots which had stem mileages of: Depot A (2km (1.24 miles)); Depot B (4km (2.5 miles)) and Depot C (11km (6.8 miles)). The average round duration, defined as the difference in time from leaving the depot and returning, excluding time spent in the depot, was 7.3 hours and the average distance driven within the delivery area (excluding stem mileage) was 11.9km (7.4 miles) with a mean speed of 7kph (4.35mph) (and 8.9kph (5.5mph) including stem mileage). Of interest was the fact that 62% of the total round time was spent with the vehicle parked while the driver unloaded and sorted on average 126 parcels and delivered these on-foot to 72 establishments from 37 stopping places. The average distance walked per vehicle round was 7.9km (4.9 miles) which accounted for 28% of the total distance travelled from the depot (i.e. including distance driven), with 95% of vehicle stops taking place on-street at the curbside. On average, the driver delivered/collected 3.8 parcels from 2.1 establishments per vehicle stop, with establishments receiving/dispatching 1.9 parcels per delivery/collection.

The mean drive time between stopping locations was 3.7 minutes, with an average 8.1 minutes dwell time observed at each vehicle stop, which was comparable with previous studies (15, 16). Mean driving and parking times per parcel were 1.5 and 2.3 minutes respectively, with associated driving and walking distance of 202m (221 yards) and 72metres (79 yards). The walking distance per establishment served was 105 metres on average. The findings suggest that last-mile parcel operations are characterised by walking with the vehicle left stationary, often conflicting with a curbside infrastructure legislated in favour of passenger transportation (17). In these circumstances, carriers are increasingly facing fines with UPS receiving penalty charge notices totalling over $17m from servicing clients in New York alone during 2016 (18). With the growth in parcel delivery set to continue (19), carriers are becoming increasingly interested in exploring new ways of working.

THE CONCEPT OF 'PORTERING' TO REDUCE LAST-MILE VEHICLE IMPACTS

Human carriage of goods has been an important means of commercial freight transport in our cities for centuries (20, 21). The advent of the railways largely resulted in the demise of the City of London porter and the use of barrows and hand carts for goods movement (22, 23) but this concept could be viable once again for parcel logistics in London and other dense urban areas where curbside parking is problematic. 'Espace de livraison de proximité' (ELP or in English, 'nearby delivery areas') have been operated in several French cities in which consignees goods are offloaded at a reserved, centrally-located unloading space and delivered by ELP staff using trolley, carts, bicycles and electric vans (24, 25, 26). A similar approach was implemented in Paris in which goods were unloaded from motorised vehicles at a 'virtual exchange point' and then delivered locally on-foot using a trolley (27). In Brussels, the parcel carrier TNT experimented with a 'mobile city hub' from which cargo bike deliveries were made (28). Meanwhile, in New York's lower Manhattan financial district, DHL operates a 'walking courier' facility from which deliveries of packages and documents are made on-foot (29). In this paper, we suggest that portering could take two operational forms, both with the specific objective of reducing vehicle stopping times at curbside:

Scenario 1 – In this case the van alights at the curbside in the drivers preferred location, where a pre-notified porter is waiting to receive the parcels from the driver for local delivery on-foot (this could be referred to as 'drop-and-drive'). In this sense, the driver would still be making the same number of stops as if he/she were making the deliveries on foot and the time taken to make the deliveries by the porter would be the same. No porter facilities are required in terms of dedicated curbside space or storage facilities but carriage provision for parcels would be necessary in terms of a hand cart. This scenario is akin to the notions of crowdshipping on a large scale (30, 31, 32) and would be most applicable in locations with extremely dense delivery networks or where substantial vehicle access and curbside parking restrictions exist.

Scenario 2 – In this case, there would be a fixed number of portering reception points (substantially less than the current number of vehicle stopping locations per round) which could be reserved curbside spaces, small permanent facilities/buildings, existing retail stores that already provide ecommerce collection point services or temporary mobile depots which are delivered to the location each day. These portering reception points would cover a greater delivery catchment area compared to Scenario 1, and therefore drivers would drop off a larger number of parcels destined for more consignees at each stop. The porters would make deliveries from these points either on-foot, possibly using handling equipment, or using cargo cycles (depending on the size, weight and number of parcels to be conveyed and the distances involved).

The key benefit to carriers of adopting such portering services is the reduction in vehicle stopping time at the curbside and, in the case of scenario 2, reductions in the overall distance travelled and time taken on vehicle rounds. Portering would have the potential to make rounds more efficient and vehicles more productive in terms of their carrying capacity and utilisation. These gains would be traded against the additional cost of the porters, the carrying equipment and the telematics systems needed to manage the last-100m transaction to the consignee (however, the time that porters take to walk and distribute the parcels should match the current on-foot performance of drivers in scenario 1).

UNDERSTANDING THE ROLE PORTERING MIGHT PLAY IN EXISTING CARRIER ROUND STRUCTURES

Researchers have previously used several approaches in an attempt to gauge the intensity of parcel operations on-street including individual business audits through 'Delivery and Servicing Plans' (33), observational high street surveys (34) and driver activity studies (35). In this research, a new research approach was adopted in which manifest data from two major carriers were used in an attempt to understand the spatial intensity of last-mile delivery and collection activity within central London, and what role portering might play in current operations. Manifest data covering transactions in the WC1, WC2 and EC1-4 postcode areas between 1st October 2016 and 7th February 2017 were used in the analyses.

Approximately 90% of Carrier 1's work was business-to-consumer (B2C) related across a mixed land use profile including retail, commerce and domestic customers while Carrier 2 specialised more in business-to-business (B2B) parcel movements. A total of 396 and 112,785 unique consignors were observed in the two carrier datasets respectively, with major fashion, general retailers and on-line ticket companies (C2C) generating the greatest number of records (~110,000 in the case of Carrier 1). The database comprised 894,136 and 394,551 records for carriers 1 and 2 respectively with each record corresponding to a delivery/collection attempt.

To better understand the spatial distribution of deliveries and how portering might operate at the local level, a smaller study area based around Oxford Street was chosen, representing around 2% and 3.2% of the overall datasets from carriers 1 and 2 respectively. The area is approximately 1.3km (0.8 miles) along the topmost edge (Seymour Street, A5204) by 0.4km (0.25 miles) along the rightmost edge (Regent Street) and has a dense land use made up of shops, offices and private addresses containing 1172 distinct postcodes. For spatial analyses, heat maps were generated using GIS software (QGIS) based on latitude and longitudes obtained for each postcode. These enable the numbers of parcels destined for particular postcodes to be displayed, with a radius of 50m (55 yards) being drawn around each point to illustrate where overlap in delivery locations occurs.

Of the 1172 postcodes, 836 received successful deliveries with 336 postcodes recording a failed delivery attempt at some point over the analysis period, (Carrier 1 reported that 38% of failures occurred between 12:00 and 15:00). Aggregate deliveries from Carrier 1 and Carrier 2 were mapped to reveal the distribution and delivery hotspots in the area (Figure 2). The locations receiving the largest number of deliveries are of particular interest as these would be likely best served through direct van deliveries with porters rendezvousing with the van at those locations to then make deliveries to surrounding clusters of smaller consignees on foot (36).

Most of the activity hot spots appeared to be in areas of mixed land use with multi-tenanted offices, shops, restaurants and hotels, including those on Oxford Street, Regent Street and opposite Portman Square (Figure 2). Due to the data anonymization process, it was not possible to determine the extent to which personal deliveries were made to workplaces but this is of interest to employers and transport authorities in London who would like to restrict such activity (37).

In designing portering rounds it would be important to identify the busiest locations in terms of consignee service requests. An analysis of the data suggested that the 'top 8' (0.9%) postcodes, corresponding to the three 'hottest' delivery activity bands identified in Figure 2 (i.e. those with over 522 aggregate deliveries from Carrier 1 and 2 over the period), accounted for 12.3 times the mean activity, or 29.1% of the total activity (Table 1). In addition, the 'top 20' (2.4%) and 'top 45' (5.4%) postcodes accounted for 42.4% and 58% of total activity, highlighting that a relatively small number of locations generate significant package volumes and could be the starting locations for portering rounds. This does however depend on the characteristics of the individual client base (e.g. B2C, B2B), (Figure 1).

INSERT FIGURE 1 HERE

INSERT TABLE 1 HERE

In terms of potential workloads, Mondays and Tuesdays were the busiest days of the week for Carrier 1 and Carrier 2 respectively, with approximately 241 (Monday – Carrier 1) and 290 (Tuesday - Carrier 2) manifest entries per day in the Oxford Street area, 69.8% taking place between 11:00 and 16:00. For Carrier 1, the Monday peak was due to the very high proportion (49%) of failed first-time deliveries experienced on Saturdays that required subsequent redelivery on the Monday, reflecting the number of offices closed on Saturdays. The majority of the activity was related to deliveries which outweighed collections by 18.6 to 1 in the case of Carrier 1. This is an important factor as portering would function best as a delivery-only activity with a one way transaction of packages from the driver to the porter and through to the consignee. Collections would necessitate a porter having to reconvene with a carrier's vehicle at some point to offload packages. This process might also be necessary when dealing with failed first-time deliveries which ranged from 7.4% (Thursdays) to 14% (Mondays) for Carrier 1 and 2.3% (Monday) to 4.4% (Thursday) for Carrier 2, both in line with national averages, IMRG (2014).

Quantifying the potential benefits of a portering service

Using the data collected from the 25 vehicle rounds studied in detail, an attempt was made to understand the likely vehicle time and distance savings from both the drop-and-drive scenario (scenario 1) and the use of a reduced number of vehicle stopping points (scenario 2). For each of the rounds, estimated round times (T_{new}) for the drop-and-drive element were calculated (Table 2) as:

$$T_{new} = T_{actual} - \text{Total parked timed (before)} + (\text{Number of stops x Y minutes per stop})$$

In scenario 1 it was assumed that the same number of stops were made, using a conservative estimate of 3 mins per stop (Y) to unload, scan and transfer parcels from the driver to the porter based on surveyor observations. Replicating the same round orders using mapping software, the results suggested that an average time saving of approximately 4 hours per round (55% of the total round time) could be possible which would have significant implications on driver and vehicle utilisation. The estimated time savings for each of the 25 individual rounds ranged from 2 to 6 hours, which reflected the variability in observed total parking times per round (from 1.9 hours using 14 stopping locations to 6.3 hours using 72 stopping locations). Parking times were mainly influenced by the total workload in different 'hot spot' areas and the individual driver's preference between moving the vehicle frequently to minimise walking or to walk between groups of customers to avoid driving and finding parking places.

To demonstrate the likely portering workload that could be involved with scenario 2, one of the surveyed vehicle rounds was studied in detail (Figure 2). This round involved 138 items being delivered to 54 consignees, (including 7 time-guaranteed deliveries and 6 collections) for which the driver used 52 stopping locations across the 1.3km^2 area. The van covered 16.8km over 7.3 hours during the round (excluding stem mileage), recording a mean speed of 8.8 km/hr. Sixty one percent of the round involved the vehicle being parked (5.3 hours, 87% at on-street locations) with the driver making deliveries on foot.

To illustrate how portering 'patches' might be allocated, the 54 consignees were separated into 9 defined delivery patches made up of approximate 350m (383 yard) squares (Figure 2) with two outlying customers to the south East (patch 9). Previous relevant work focussed on where to site 'mini-hubs' in Seville based on 200m (219 yards) radius circles of influence (38). Clearly, the size of the delivery patch has a direct influence on the amount of walking that may be entailed. This has been demonstrated in that the length of the optimal tour over a given patch is proportional to the square root of the size of the area (39), with implications for vehicle routing problems, (40). The geographical scale of walking patches would depend on the package generation characteristics of the surrounding land use and the consequential ability of the porter to physically handle the packages.

Within each delivery patch, a shortest path walking tour between all the customers was devised and approximate walking times and distances quantified using mapping software (Table 2). Handover times in each patch were adjusted to reflect the number of parcels actually delivered. This was achieved by assuming 30s to park the van, access packages for the specific patch and then book them over to the porter (10s per parcel), being consistent with the average of 3 minutes per stop. This produced a range of van-to-porter handover times from 61s to 586s (Table 2) where delivery patch (1) received considerably more parcels (n=54) than the others, mainly due to one customer receiving 32 parcels. The walking and handover times totalled 1.69 hours across all the patches with porter walking distances within each patch ranging between 44m to 1107m (48 to 1211 yards). The major benefit to the carrier is in the time and distance savings from only having to service one handover point in each patch. If in this example, the vehicle traversed patches 7-5-3-1-2-4-6-8-9 in order, stopping in each to drop packages to a porter, the vehicle driving distance within the delivery area (excluding stem distances) could be approximately 2.2 km (1.37 miles), a reduction of 14.6km (9 miles) (86%) over the current system; the time saved would be approximately 6 hours (69%), comprising 5.3 hours spent making deliveries plus around 1 hour driving time savings less around 20 minutes spent with porters. .

Any portering system would have to cater for instances where single consignees were receiving multiple parcels (Figure 1) as it would make logistical sense to service large receivers directly from the van, or situate the drop site as close as possible to them where they featured in a given patch. There would also be the issue of how collections would be managed given the driver-porter transaction is one-way at each rendezvous point. It would be feasible for porters to work across multiple patches and hand back parcels to the driver at another location e.g. moving across after completing the 9 deliveries and picking up 2 collections in patch 5 and then moving to 6 to wait for the driver, hand over the 2 collections and pick up the 3 deliveries for that patch. To operate effectively, this concept would require careful consideration and optimisation of both the driving and walking tours to account for things like dynamic collection requests during the round, failed deliveries and potential redelivery attempts, extended portering time associated with servicing high-rise buildings, carrying capacity limitations of the porters. Carrying capacity is a key issue which will differ between parcel carriers depending on their market specialism (e.g. Amazon states that 86% of its delivered products weigh 2.3kg (5lbs) or less (41) whereas 54% of Carrier 2 parcels weighed less than 5kg (11lbs)).

INSERT TABLE 2 HERE

INSERT FIGURE 2 HERE

THE OPTIMISATION CHALLENGE ASSOCIATED WITH PORTERING

Last-mile parcel delivery problems are generally studied under city logistics systems (42), where the corresponding optimisation problems are modelled using two-tier distribution structures. The first tier usually involves vehicles with relatively large carrying capacities off-loading goods at rendezvous points, for the second-tier to undertake the last-mile transactions.

The optimization of plans involves deciding on the routing and scheduling of vehicles across both tiers, the demand locations to be served, the locations of the van-porter rendezvous points, and the capacities of any reception facilities to be used. In our context, we envisage two cases: i) fixed cluster case, where the delivery patches have been identified (as in the case of the nine patches shown in Figure 2) prior to the routing and scheduling; ii) unknown clusters where the delivery or collection points have not been grouped into patches. In either case, vans would operate in the first-tier and porters in the second. We discuss two cases below in further detail:

Fixed Cluster: The first case gives way to generalised vehicle routing problems where the aim is to route vehicles over a given set of clusters that correspond to the delivery patches. Although this class of optimisation problems have been studied at a sufficient level of detail (43), the generalised vehicle routing problem and its variants do not explicitly consider the way in which intra-cluster deliveries are performed. Assuming Scenario 1, where there is no need for a reception facility for handing-over of parcels, there are at least two ways in which deliveries within clusters can be done. Depending on the total weight and size of parcels handed over, the porters would perform direct deliveries in a socalled 'hotelling' mode, back and forth from the van, or, assuming they have sufficient carrying capacity, would operate a smaller tour from consignee to consignee using consolidation. The combined use of hotelling and consolidation within a cluster is another possibility.

Deciding on the location of the hand-over point will be a key part of the optimisation problem, which may be limited to one of the delivery points. In addition, the consolidation poses an additional challenge of finding an optimal tour over the delivery points within a cluster. If there are no additional constraints present in the problem, then the optimal assignments for both the hotelling and the consolidation options can simply be pre-computed for each possible selection of the rendezvous point without forming an integral part of the optimisation problem. Such pre-processing will reduce the solution complexity, assuming that each cluster is feasible with respect to the porters being able to carry the parcels. However, if there are additional constraints on the time-sensitive nature of the parcels, then this pre-processing is no longer possible.

Unknown clusters: If the delivery patches were not pre-defined, then the optimisation problem would have to involve decisions pertaining to the formation of clusters along with the routing and scheduling decisions. The interdependent nature of both sets of decisions means that they will have to be taken in conjunction. In the case of Scenario 1 where a porter is available to receive the parcels, the corresponding optimisation problem would be akin to the truck and trailer routing problem (44) where, in our context, the trailer would correspond to the van performing first-tier deliveries and the porters would act as the trucks in the second-tier for the last-mile deliveries. The problem will also involve additional constraints for time-sensitive deliveries as well as the capacity of the porter in terms of the total weight and size of the parcels they are able to carry. An additional set of constraints will also be needed to synchronise the timing between the van(s) and the porter(s) for a timely hand-over such that neither will stay idle waiting for the other at the rendezvous points.

ISSUES TO CONSIDER WHEN DEVISING AND IMPLEMENTING PORTERING SYSTEMS

In devising and implementing a portering system for central urban areas, there are a range of issues that would require further consideration. These issues have emerged from a combination of reviewing the literature available on portering and related freight concepts (such as Urban Consolidation Centers) and original concepts about portering systems developed through dialogue between the authors, parcel carriers and policy makers as part of the research.

Geographical coverage and the influence of major consignees:
The larger the catchment area for portering, the more likely the need for handling equipment such as trolleys or cargo cycles in addition to porters manually carrying parcels and packages. Understanding the major origins of demand across an area in terms of the number of deliveries, first-time delivery failures, returns and collections is very important when devising the scale and applicability of portering patches and where the most optimal drop locations for vans would be.

The location and type of portering infrastructure necessary:
This will depend on the geographical area served, the variability in weight and size of packages handled, the portering infrastructure requirements associated with the land use needs and the availability of space. Such infrastructure could include a reception facility with or without storage space for incoming and outgoing parcels, overnight storage for handling and transport equipment used by porters, scanning and computing equipment to track and trace goods, recharging facilities for any electric equipment such as cargo cycles, and off-street parking space for vehicles/drivers delivering to or making collections from the portering facility. Autonomous vehicles of varying types might be used in portering operations of the future (45) but given the complexity of crossing roads, climbing stairs, using lifts, and communicating with consignees, it is likely to remain far more efficient and cost-effective to use humans to carry out this last leg of the supply chain in the short-term.

Financing and operating the portering service:
Financing could be led by the private sector given the efficiency savings that parcel carriers would enjoy associated with vehicle and fuel use reduction. Reduced driver and vehicle costs are likely to offset the cost of porter labour but there are potential additional costs associated with portering equipment and the development of apps to support work allocation to porters. Consignees and consignors would benefit from having an improved customer environment at their premises as a result of reduced vehicle operations. Financial contributions by the public sector (i.e. city authorities) could also be justified on the basis of the traffic, environmental and safety benefits associated with the portering approach. Aligning the costs and benefits of the portering scheme with the financial contributions is likely to be important in its success, as is the case with Urban Consolidation Centers (UCCs), public sector financial support may well be necessary in terms of meeting the capital costs of any buildings and other infrastructure required (46).

In terms of running the portering system, the day-to-day operations may be best served by a private operator, selected through a tendering process. If the portering scheme is a private sector-led initiative, this could be achieved through a single company (either a market entrant/start-up company specializing in providing this service or an established freight operator diversifying into this service) or it could be a joint venture formed by several collaborating parcel carriers who will each use and benefit from the scheme. One could envisage a last-mile crowd-sourced operator such as Deliveroo (www.deliveroo.co.uk) providing a porter smartphone-based interface to integrate with the carriers where they would in essence, become a 'freight traffic controller' over the last 100m on behalf of a number of separate carriers. One concern is the potential security issue associated with handing over parcels to a 3rd party but given the tracking and proof-of-delivery functionality embedded in the existing systems used in last-mile fast food delivery, this may not be such a problem in reality.

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AUTHOR CONTRIBUTION

The authors confirm contribution to the paper as follows: study conception and design: All Authors; data collection: Cherrett T.J., Allen,J., McLeod,M.,; analysis and interpretation of results: All Authors; draft manuscript preparation: All Authors. All authors reviewed the results and approved the final version of the manuscript.

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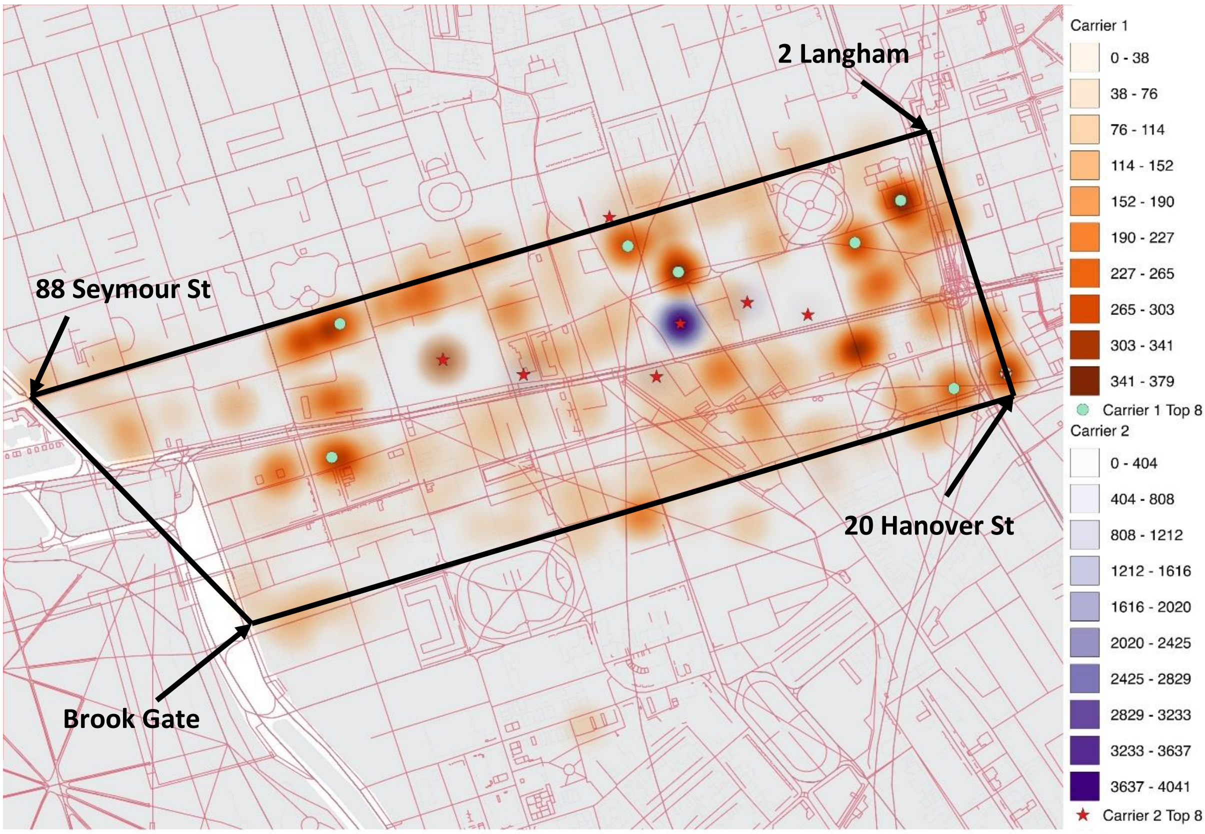

Figure 1. Total number of deliveries (Carrier 1 and Carrier 2) by location around Oxford Street between 1st October 2016 – 7th February 2017 (129 days) and Carrier 2 (Primarily B2B) covers 28th August 2016 – 5th November 2016 (69 days).

Table 1. Comparison of 'top 8' and all postcode areas in terms of delivered items. Data for Carrier 1 (Primarily B2C) covers 1st October 2016 – 7th February 2017 (129 days) and Carrier 2 (Primarily B2B) covers 28th August 2016 – 5th November 2016 (69 days).

	Number of deliveries - All 836 postcodes *(Top 8 Postcodes)*			
Activity *(days)*	Total	Average per postcode	Standard Deviation	Maximum
Carrier 1 *(129)*	14009 *(2348)*	16.8 *(293.5)*	40 (56)	379
Carrier 2 *(69)*	19218 *(8637)*	23 *(197.5)*	158 (140)	4041
All Deliveries	33227 *(9684)*	39.8 *(491)*	169 (163)	4041

Table 2. Estimated workload for porters with reduced vehicle stopping locations (scenario 2, Figure 2)

Delivery patch (no. consignees)	Parcels	Walking time (seconds)	Walking distance (m (yards))	Handover Time for driver to porter (seconds)	Collections (no. consignors)
1 (6)	54	602	849 (928)	586	0
2 (8)	10	527	741 (810)	133	0
3 (6)	15	559	790 (864)	185	0
4 (4)	4	475	662 (724)	71	3
5 (9)	15	792	1107 (1211)	185	2
6 (3)	6	445	627 (686)	92	0
7 (5)	13	458	647 (708)	164	0
8 (9)	11	565	791 (865)	143	1
9 (2)	3	31	44 (48)	61	0
Total (52)	**131**	**4454**	**6.26km (3.89 miles)**	**1620**	**6**

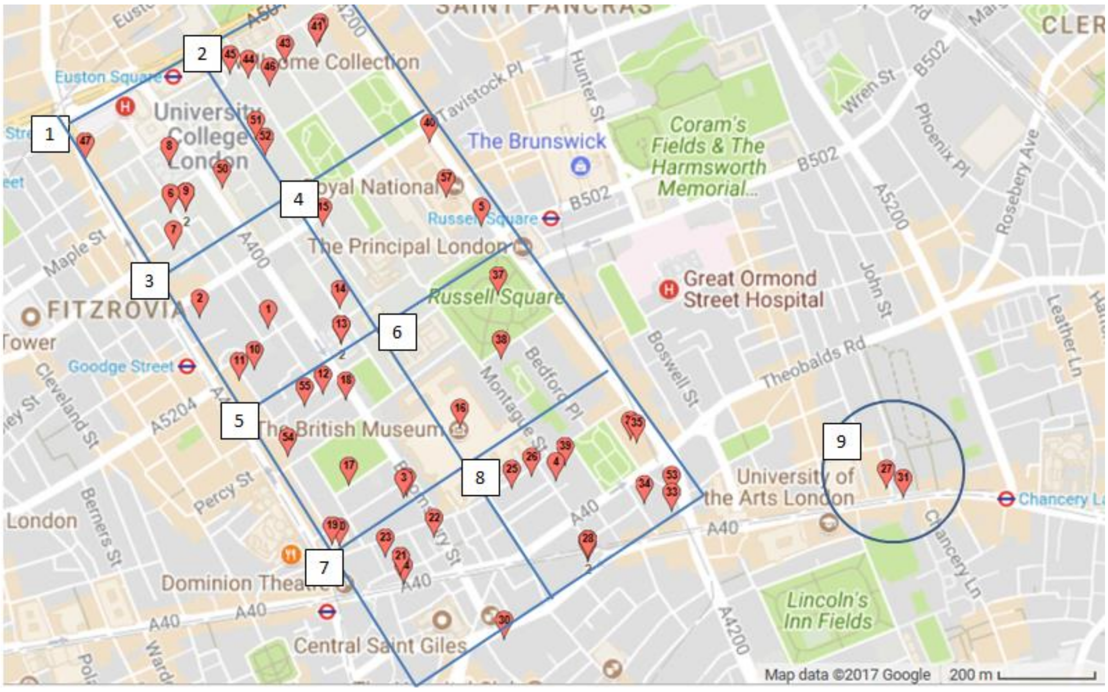

Figure 2. Customer locations on example round and proposed ‘drop-and-drive’ delivery patches