

Combining on-foot porters with vans for last-mile parcel deliveries: results of a study in central London

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Maja Piecyk is a Professor in Logistics at the University of Westminster. She is a former Deputy Director of the Centre for Sustainable Road Freight, an EPSRC-funded research centre between Westminster, Heriot-Watt and Cambridge Universities. She had also led a number of research projects focusing on the environmental performance and sustainability of freight transport operations. Much of her current work centres on the optimisation of supply chain networks, GHG auditing of businesses and forecasting of long-term trends in energy demand and environmental impacts of logistics. Maja is a Chartered Member of the Chartered Institute of Logistics and Transport (UK), and a Fellow of the Higher Education Academy.

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Tom Cherrett is a Professor in Logistics and Transport Management within the Transportation Research Group. He teaches transport planning, freight and passenger systems and construction management to Masters and Undergraduate students. His research interests cover: i) Core goods distribution (things that we buy) and how retail logistics can be made more efficient within and between our urban areas but particularly over the last mile. ii) The use of smartphone technology in logistics to enable customers and employees to better share and use data iii) Remote monitoring technology working with optimisation techniques to more effectively manage the collection of waste and recyclables in urban areas. He has over 130 journal and conference papers published and is a Chartered Member of the Institute of Logistics and Transport.

Fraser McLeod is a Research Fellow within the Transportation Research Group with over 30 years' experience of working on transport-related projects. In recent years his research has focussed on evaluation of freight transport. Areas of study have included: the servicing of charity donations banks using remote monitoring technology to improve vehicle collection schedules; joint procurement and goods consolidation for large municipal organisations; parcel delivery operations in urban areas and the scope for using roadside porters.

Andy Oakey graduated from the University of Southampton with a First-Class Honours in Civil Engineering in 2018. His final year dissertation focused on improving the sustainability of last-mile parcel deliveries in London through portering methods and involved a series of real-world measurements and trials for the FTC2050 project; it achieved the CILT award for

Undergraduate Logistics Dissertation of the Year. On graduation, Andy joined Atkins in London as a Rail Planner in the Transport Consultancy and Advisory team where he was nominated for the award of 'best newcomer'. He returned to the University of Southampton as a PhD student in 2019. His research focuses on the development of a shared fleet logistics system, using the NHS same day delivery networks as a case study.

Oliver Bates is Senior Research Associate at Lancaster University looking at the role of people and digital technology in the demand placed on digital and physical infrastructures. He completed his PhD at the School of Computing and Communications at Lancaster University in 2016. His current work looks to leverage digital technology to redesign for environmental and social justice in homes, on campuses, and of urban freight. He uses agile and lean practices and mixed-methods approaches to enable rapid prototyping of data science, user experience and software solutions.

Adrian Friday is a Professor of Computing and Sustainability at Lancaster University. He is interested in the role of computational systems in helping us understand the externalities of socio-technical systems, and in finding more sustainable ways of living that reduce global warming. His current work focuses on the role of energy data in smart cities, smarter and lower energy thermal comfort in the workplace, and improving sustainability of last-mile logistics.

Sarah Wise is a lecturer for the Centre for Advanced Spatial Analysis of University College London. Her research interests lie in exploring and forecasting the development of systems involving people, infrastructure, and information using methodologies including agent-based modelling (ABM), social network analysis (SNA), data mining, statistical analysis, and geographic information systems (GIS). Sarah completed a PhD in the Computational Social Science department of George Mason University in 2014. She graduated from the University of Chicago in 2009 with a double major in Computer Science and East Asian Cultures and Language. She has worked for Argonne National Laboratory, the United States Department of State, and various government contractors.

Kostas Cheliotis is a Research Associate at the Centre for Advanced Spatial Analysis, working on the FTC2050 project. His research interests include computational simulations of spatial systems, spatial behaviour at the architectural scale and the interaction between design and space use, and interactive visualisations as a tool for efficient communication and dissemination of information. His current work focusses on developing agent-based models of last-mile road freight traffic and developing interactive platforms for understanding the impact of urban freight.

Tolga Bektas is Professor of Logistics Management at the University of Liverpool Management School. He has a PhD in Industrial Engineering from Bilkent University and postdoctoral research experience at the University of Montreal in Canada. His research is on mathematical modelling and optimization of problems arising in freight logistics, including network design, vehicle routing and location analysis, with a particular focus on reducing the environmental externalities of road transport. He has been an investigator on a number of externally funded projects in railway timetable optimisation, maintenance planning in sea vessels and last-mile distribution in cities. His publications include peer-reviewed journal papers, and a textbook titled Freight Transport and Distribution printed by CRC Press in 2017.

Abstract

Parcel delivery operations in central London currently consist of drivers using vans. Drivers travel by road, leaving their vehicle parked at the kerbside for up to 60% of the round time while making deliveries on-foot to consignees, walking up to 10 km per day. A trial was carried out in which on-foot porters using wheeled bags made parcel deliveries to consignees, supplied by van. The results of this trial and additional analysis of its wider implementation across London's Central Activities Zone (CAZ) indicate that parcel portering could result in reductions in vehicle parking time at kerbside (of approximately 50-65%), and vehicle driving time and distance travelled (of approximately 25-35%) compared to current parcel operations. These operational outcomes would result in associated improvements in greenhouse gas emissions and local air quality, as well as reductions in the vehicle fleets required by carriers. Related planning considerations for public policy makers including the review of vehicle kerbside stopping regulations to encourage portering, the provision of land for secure storage facilities for goods to be delivered by porters, and rest break facilities for porters are identified and discussed.

Keywords: urban freight; last-mile deliveries; on-foot porters; parcels; central London; planning; sustainability

1 Introduction

This paper reports on a live demonstration and analysis of portering (using humans to carry goods on-foot) for the delivery of parcels in central London. The trial, which was undertaken in association with Gnewt Cargo (a last-mile urban parcel carrier with a fleet of approximately 80 vans delivering in central London; www.gnewt.co.uk) investigated the scope for porters to deliver parcels over the final mile, essentially decoupling the driving and walking elements currently all undertaken by the delivery driver.

From the earliest times of human settlement until the mid-nineteenth century, the primary means of transporting goods within the City of London was by foot (Stern, 1960). London's walking 'porters' were involved in two main types of supply chain activity, (i) moving goods between an origin and destination (such as between a ship and a store, or between a store and a customer), and (ii) loading and unloading transport vessels including boats and ships (Stern, 1960). Portering was a low-class, often unlicensed occupation, generally carried out by the young and poor (Stern, 1960). In the 18th century, porters started to use barrows and handcarts to aid delivery (Armstrong, 2001) and by 1841, 'stands' (locations where porters could wait to be hired (Stern, 1960; Earle, 1994) and 'pitching places' (porter resting places (Barker, 1998; Cooper, 2016)) had begun to appear all over central London. Portering in London began to diminish from the mid-nineteenth century onwards with the relocation of the docks out of central London, and then the rise of the bicycle and motorized transport.

In recent years the only remaining forms of outdoor freight transport carried out on foot in developed countries are postal services, door-to-door leaflet delivery, and sales people, usually in dense urban areas. On-foot delivery services made a brief reappearance in London during the 2012 Olympic Games when two parcel carriers utilized runners to deliver small, light, time-critical items. DHL worked with Jog-Post (a leaflet delivery company) to put in place a team of approximately 100 joggers, capable of running 8-16 km per day at speeds of 8-13 km per

hour (Post & Parcel, 2017; runABC Scotland, 2012). Meanwhile, CitySprint used twenty joggers and five rollerbladers with the former covering on average 10 km per day (Firstlight, 2012). In 2016, DHL opened a 1200 square foot ‘walking courier’ facility in New York’s lower Manhattan financial district, employing approximately a dozen ‘foot couriers’ who delivered parcels in five ZIP codes (DC Velocity, 2016; DHL, 2016). UPS has used what it described as ‘air walkers’, often operating from a mobile UPS vehicle to pick up and deliver letters, documents and parcels on-foot in central business districts of some American cities (UPS, 2017). In addition to on-foot portering, some researchers have considered the use of electrically-assisted cargo cycles for urban parcel delivery (Melo and Baptiste, 2017).

Portering remains an important means of outdoor goods transport in developing countries, especially in geographically challenging terrains or where mechanized handling systems are not available, (e.g. Nepalese mountain porters, and Indian porters who provide transportation of luggage at railways stations, Bastien et al., 2016; Gaurav and Singhal, 2003).

Transport for London and the central London boroughs have an objective to reduce the intensity of road freight transport, thereby alleviating traffic levels and the associated negative environmental impacts (Mayor of London, 2018; 2019). These organizations also aim to reduce freight demand for kerbside space and time whilst supporting and maintaining freight service levels in central London. These aspirations are shared by many urban authorities in developed countries (Dablanc et al., 2017).

The use of portering for last-mile logistics has the potential to provide traffic and environmental benefits, including reduced kerbside dwell time and space occupation by parcel vans during the working day, as well as the scope to reduce vehicle kilometres travelled and time spent driving on the urban road network. It could also help bring about operational benefits for parcel companies, by helping them to address issues concerned with longer and increasingly unreliable journey times, difficulties in finding kerbside parking space and reducing vehicle fleet requirements. To investigate the viability of portering in last-mile parcel operations, a methodology was applied that involved studying existing parcel operations in central London, and designing and evaluating a live demonstration of portering in the financial district of central London. The operational challenges for parcel carriers and planning issues for policy makers posed by portering are discussed in the penultimate section of the paper.

2 Ascertaining the scope for portering

Survey work and data analysis was carried out in various locations in central London during 2016-2017 using two carriers as case studies. This developed a detailed understanding of multi-drop parcel carrier operations through meetings with company management and planners, the use of GPS equipment to track vehicles and drivers, surveyors accompanying drivers on their rounds, and the detailed analysis of workload manifest data provided by the companies (Allen et al., 2018a).

The analysis found that parcel carriers’ vans typically spend 3.5 – 4.5 hours per vehicle per day parked at the kerbside whilst drivers are making collections and deliveries, representing, on average, 62% of the total time that the vehicles are away from their depot each day. The vast majority (95%) of vehicle stopping locations are on-street at the kerbside, with vehicles being parked on multiple occasions over the course of their working day (typically 25-40 times per day) with short driving distances between vehicle stops. The mean drive time between stopping

locations was 3.7 minutes, with an average 8.1 minutes dwell time at each vehicle stop. Mean driving and parking times per parcel were 1.5 and 2.3 minutes, respectively.

Drivers walk long distances over the course of the day as part of their delivery and collection activity (approximately 8 km on average during the total round, or 72 metres per parcel, not taking account of walking inside buildings, Allen et al., 2018b). Drivers have to take elevators or climb stairs at approximately 15-20% of the addresses they visit resulting in longer vehicle dwell times at kerbside. These findings indicate that there could be potential benefits to carriers, other road users, wider society and the environment if this existing pattern of operation could be changed. The vans are currently used inefficiently with them stationary and only providing secure mobile storage for approximately 60% of their working day. Given that these vehicles are expensive assets changing this situation represents a potential opportunity for cost savings.

One approach to altering these vehicle operations requires helping the driver to make better decisions about where to park and how to group deliveries together in walking tours. This is a highly challenging and little studied optimization challenge (Allen et al., 2018b; Nguyen et al., 2018). However, research indicates that vehicle round time may be reduced by making fewer vehicle stops and a greater number of deliveries and collections on-foot each time the vehicle is parked (Allen et al., 2018b; Nguyen et al., 2018). Such a solution is capable of reducing the total round time by approximately 25% and the total driving time (and distance) in the delivery area by approximately 50% but with a 20% increase in parking time and up to 50% increase in walking time and distance (Allen et al., 2018b; Nguyen et al., 2018).

Kerbside space and time are in great demand by multiple uses and, specifically in London, there is an on-going reallocation in favour of bus and cycle lanes, and charging points for electric vehicles (Bastien et al., 2005; Transport for London; 2014). Portering would remove the need for van dwell time at the kerbside by decoupling the driving and walking elements of the round.

3 Developing the portering concept to be used in the live trial

Various methods for portering parcels were considered including dynamic rendezvous between drivers and porters; porters obtaining carrying devices filled with pre-packed parcels from a local storage location and porters travelling on-board the vehicle with the driver. The advantages, disadvantages and practicalities of these various portering approaches were considered in relation to conducting a short-term trial with a limited budget. In addition, the carrier participating in the trial was keen to implement an approach that was as realistic and efficient as possible if it were, in future, to be applied across an entire parcel carriers' operation in central London.

It was decided that in the portering system for the trial, parcels would be loaded into wheeled bags at the carrier's urban depot, with the driver making a rendezvous with the porters on-street at the kerbside using a smartphone-based app (see Figure 1). This portering system was selected based on several factors including: (i) its potential to generate savings in total kerbside parking time; (ii) the low capital costs and rapid implementation time (as it has no land acquisition or vehicle adaptation requirements); (iii) its relatively modest porter requirements for the purposes of the trial and straightforward communication protocol using the carriers existing system; and (iv) its potential to be scaled up across an entire carrier's operation, and/or to be used by several carriers working together.

The live trial was planned to cause as little disruption to the carrier's existing operating model as possible, as customer service levels would need to be maintained. In the portering approach selected, parcels were: (i) delivered overnight from the central hub to the urban depot as normal; (ii) sorted at the urban depot in the early morning into defined portering patches; and (iii) subdivided and placed in portering bags. Heavy or bulky items (over 5 kg or 30 litres (L)) and large consignments to the same address were exempt from portering.

4 Detailed design of the live portering trial

Pre-trial parcel size and weight audits on over 400 parcels indicated that the mean parcel volume was 13.3 L (standard deviation 16.5 L, median 7.5 L) and 73% of individual parcels fell within the size dimensions initially deemed suitable for portering (405 x 405 x 405 mm or smaller. The mean weight of the parcels was 1.3 kg (standard deviation 1.5 kg, median 0.9 kg) (Figure 2).

Evidence suggests that healthy European and North American adults can comfortably carry a backpack weighing one-quarter of their bodyweight over a day-long walk but loads of more than 60% of their body mass cannot be sustained for more than an hour (Bastien et al., 2005; Bastien et al., 2016). Although there is no maximum legal limit on the weights that workers can lift in the UK, Health and Safety Executive guidance suggests a typical upper limit of 25 kg for a man (Health & Safety Executive, 2012). Based on the mean parcel weight determined from the parcel audit and in discussion with the carrier, a suitable limit of 20-25 parcels per porter unit load was derived.

The survey work on the carriers' parcels (primarily Business-to-Consumer transactions) showed a very clear trend towards small and light parcels rather than large and heavy ones, which was ideal for a portering system in which multiple parcels could be conveyed on-foot at the same time in a carrying device, without the overall weight or volume being excessively large (Figure 2).

For a portering system to function efficiently, a durable and easy to use parcel carrying device is needed. A review of potential carrying devices was carried out and the following factors taken into account in selecting the most suitable:

- (i) *Security constraints* - theft and anti-tamper protection of the carrying device and its contents are key. Devices cannot realistically be left outside buildings unattended (locked or otherwise) as this introduces opportunities for theft and interference and could render insurance invalid. The carrying device must therefore remain with the porter at all times, even when ascending floors within buildings.
- (ii) *Weight constraints* – a carrying device needs to be capable of carrying weights in the region of 25 kg. Providing porters with a wheeled device would assist the porter's weight carrying capacity especially when moving on-street between addresses.
- (iii) *Volume constraints* - the larger the carrying device, the greater the number of parcels the porter can handle at once, thereby reducing the number of driver replenishments required, and improving operational efficiency.
- (iv) *Cost constraints* - the device should be suitably priced so as not to have an important bearing on the cost of the portering operation.
- (v) *Other constraints* - Overly-large carrying devices are more difficult to manoeuvre inside buildings. The carrying device must also be weatherproof as it will be exposed to the elements while the porter is on-street and needs to be sealable. It should also be self-

supporting and able to stand on end for manoeuvring in buildings. It needs to be sufficiently robust in order to withstand the wear and tear associated with the activities.

A 200L wheeled bag (primarily designed as a hockey equipment holdall) was selected for use in the live portering trial (Barrington Sports, 2018).

Prior to the live trials, analysis was carried out using historical manifest data to investigate: i) the appropriate apportioning of geographical areas to porters, ii) the number of bags needed, iii) the likely split of delivery workload between porters and driver. Portering areas were referred to as ‘patches’ and various approaches were applied to define and analyse how patches could be determined. A portering system would function as part of a distribution network comprising two levels (‘echelons’) where: i) the lower-level echelon (portering) uses walking as the primary mode of transport, and ii) the higher-level echelon (driving) uses conventional vans and is collectively known as the two-echelon vehicle routing problem (2EVRP) (Crainic et al., 2010). A key issue in portering is that time is arguably a more crucial criterion compared to distance and requires explicit differentiation between walking and driving.

Following dialogue with the carrier and given the time critical nature of the parcel sorting process at the receiving depot, portering patches were defined into fixed areas of postcodes that simplified the parcel-porter allocation task. This required defining workable patches across the trial area (Figure 3) using historic consignee delivery records to determine the density of demand alongside maximum portering loads to quantify the numbers of bags needed per area.

All the postcodes occurring within each defined patch were then identified so that parcels could be allocated to porters. This manual approach was found to give good flexibility, taking into account local knowledge of area and consignee. Due to the variance in parcel volumes, each patch could require either one or two bagloads each day and, to cater for this, a dynamic approach was developed where, as part of the sorting process, parcels could be automatically transferred between patches where they fell along boundary lines, overcoming the problem of patches with fixed boundaries.

A dynamic patching analysis was applied to the proposed portering trial area (Figure 3) using one week of carrier manifest data from February 2018. It was agreed with the carrier that for the trial, the driver would deliver parcels over 5 kg in weight or greater than 30 L in volume, or where over 100 L in combined volume was destined for the same address. Parcels were loaded into 200 L wheeled bags, with each consisting of approximately 20-25 parcels. A desk-based analysis using the historical consignee records suggested that porters could serve approximately 90% of parcels and consignees in the proposed trial area, with the driver carrying out the remaining 10% as well as replenishing porters with portering bags as or when required.

5 Carrying out and analysing the live portering trial

The trial took place on Friday 9 March 2018; discussions with the carrier had identified that all weekdays were equally busy, and a date was selected sufficiently in advance of Easter to ensure the trial date was representative of a normal working day. The trial required merging together parts of two existing vehicle rounds in the EC3 postcode area. This is in the City of London, the heart of London’s financial district and the most densely populated part during working hours (Figure 3). The trial consisted of handling 279 parcels using three porters, all of whom had substantial previous experience of parcel delivery across the EC3 area. The one

driver/vehicle and three porters were monitored using GPS tracking devices (either stand-alone or iPhone-based) so that their routes and timings would be available for subsequent analysis.

The various postcodes within each of the (nine) portering patches (Figure 3) were obtained using an online tool (doogal.co.uk). On the morning of the trial, parcels were sorted at the depot, using the identified postcodes, into the nine defined patches. All three porters, the driver and management team participated in this initial sort. The driver then removed large and heavy items together with multiple items for the same consignee and loaded these directly onto the van. The three porters were then each allocated three adjacent patches and were responsible for sorting their deliveries within each patch into a logical delivery sequence before loading items into 2 or 3 portering bags. These bags were then loaded onto the delivery vehicle along with the items the driver had already loaded for his own delivery. An electrically-powered delivery van with a payload of 600 kg and a volume capacity of 8.4 m³ was used in the trial. However, the vast majority of last-mile delivery operations in London use diesel-powered vehicles so, in these cases, any reductions in the total distance travelled by vehicles would also result in reductions in greenhouse gas emissions and local air pollutants.

The porters then travelled to the EC3 area of the City of London, while the driver drove from the depot. Once there, the driver rendezvoused with the three porters to provide them with their first bag of parcels. The driver and porters then proceeded to deliver their allocated items, with porters communicating with the driver (using WhatsApp) to request bag replenishment. The live trial went successfully from an operational perspective and no problems arose in terms of the delivery of customer's parcels. The porters carried out last-mile logistics for 61% of parcels and 70% of consignees (the driver for 39% of parcels and 30% of consignees). This was due to the driver taking responsibility for all parcels destined for buildings that received more than five parcel deliveries, regardless of their size and weight, which were often multi-tenanted office buildings that were occupied by many companies located on different floors.

The performance of the portering operation was compared with the carrier's surveyed 'business-as-usual' (BAU) operations (i.e. non-portering). Time and distance related performance metrics were calculated on a per parcel and per consignee basis (see Table 1). It should be noted that the total number of parcels handled per consignee was lower in the portering trial than in the 'business-as-usual' (BAU) operation (2.4 compared with 3.3). This ratio fluctuates each day and cannot be held constant for the purposes of a trial. This had the effect of increasing the workload per parcel handled in the portering trial compared with the BAU operation (in terms of more addresses and more walking per parcel), thereby reducing the benefits of portering on a per parcel basis.

Table 1 shows that the actual portering trial resulted in improvements in: vehicle parking time at the kerbside, (52% on a per parcel basis and 65% on a per consignee basis), total vehicle /driver deployment time, (34% on a per parcel basis and 52% on a per consignee basis), and vehicle distance travelled, (by 4% on a per parcel basis and 30% on a per consignee basis). Meanwhile, total vehicle driving time was worse in the trial than the pre-trial operation on a per parcel basis (by 4%) but improved on a per consignee basis (by 24%). The total labour time required (i.e. driver plus porters) was greater in the trial than in the pre-trial operation (by 65% on a per parcel basis and 20% on a per consignee basis).

Further analysis suggested that it would have been possible to achieve a 90% allocation of parcels to porters (with the driver handling the remaining 10%) rather than the 61% achieved in the trial if only parcels destined for the same unique address had been allocated to the driver,

rather than all parcels destined for the same building. The debrief interview with the driver at the end of the trial identified that serving multiple addresses in the same building (i.e. different businesses and residential addresses in multi-tenanted blocks) resulted in substantial total delivery times per building as the driver accessed different floors and negotiated different reception points, which led to considerable vehicle parking time. If the porters had handled 90% of parcels (as the data analysis prior to the trial had suggested was possible) this would be expected to have further reduced vehicle parking time and vehicle driving time per parcel and consignee.

6 Applying portering to the Central Activities Zone in London

Analysis was carried out to gain insight into the potential effects of parcel portering if it was implemented on a larger scale in central London. In order to carry out this analysis, it was first necessary to estimate the annual number of parcels delivered in central London. In 2016 approximately 2.8 billion parcels were handled in the whole of the UK, of which approximately half were sent from business-to-business (B2B) and approximately half from business-to-consumer (B2C) (Allen et al., 2016; Mintel, 2017; Ofcom, 2016, 2017, 2018; Royal Mail, 2013). In addition, forecasts estimate a 33% increase in the volume of parcels handled in the UK between 2016 and 2021, with much of this growth being contributed by ecommerce and online retailing (Mintel, 2017).

The Central Activities Zone (CAZ) which comprises central London is approximately 30 km² in size, which is equivalent to only approximately 2% of the land mass of Greater London and only 0.01% of the land mass of the UK. However, despite its small size, it is responsible for 1.7 million jobs, and is home to approximately 250,000 residents (Mayor of London, 2016). This is equivalent to approximately 5.3% of all jobs in the UK and 0.4% of all entire resident population (Office for National Statistics, 2017). In terms of economic output, the CAZ accounts for approximately 10% of the Gross Value Added of the entire UK (Mayor of London, 2016). For the purposes of the analysis, it was assumed that the CAZ accounted for 7.5% of B2B parcels and 2.5% of B2C parcels in the UK in 2016 (the latter was based on the size of the workforce and the preference of some employees for personal deliveries to their workplace). This provided an estimate of 135 million parcels are handled in the CAZ in 2016.

The current overall annual transport impacts of this parcel delivery and collection activity in the London CAZ (i.e. without portering) was then estimated. This was achieved by using data collected in the larger survey of parcel operations in the CAZ in 2016-17 previously discussed which included 25 drivers' vehicle rounds (Allen et al., 2018a). This was used in preference to simply grossing up the driver data from the City of London pre-trial operation as the driver taking part in the trial was extremely experienced, having worked for more than 20 years in the parcels sector. The larger survey of parcel operations within the London CAZ, was therefore more representative of the performance range of drivers (as it included both novice and experienced individuals, and their performance varies considerably in terms of: vehicle routing decisions, selecting appropriate vehicle stopping locations, deciding how many customers to serve on-foot once the vehicle is parked, optimizing walking routes – from the parked vehicle to the delivery/collection point, and locating the point of entry to the building which may not correspond with the delivery/collection address (Bates et al., 2018). In addition, the City of London is the most densely developed part of the London CAZ, so the larger survey better reflected the diversity of building sizes and delivery density in the wider CAZ. Table 2 shows the difference in the operating performance between the City of London driver in the

trial and the average driver in the wider CAZ survey. The larger survey also reflected various depot locations from which vehicles and drivers were despatched.

It was assumed that the vehicles used for 'business-as usual' (BAU) parcel activity in the London CAZ in 2016 was the same as that used in the City of London (3.5 metric tonne gross weight van with an internal load space of 8 m³). This analysis provided an estimate of BAU total parcel activity in the London CAZ resulting in a total vehicle deployment time on-street (driving and parked) of 9 million hours, with a total driving of 36 million km (see Table 3).

Two portering scenarios were analysed. In these scenarios, it was assumed that the same vans would be used as at present (3.5 tonne vans) but that if portering was implemented across the London CAZ, one fleet of these vans would be used to provide porters with bagloads of parcels at the kerbside and another fleet used to deliver the remaining parcels that are outside the weight/volume limits for porters (5 kg and/or 30 L). It was calculated that when carrying bagloads of these smaller parcels this second fleet was capable of carrying twice as many parcels as in the BAU situation in which the entire range of parcels are carried loose (by excluding the larger parcels and utilising the full volume capacity of the vehicle).

In scenario 1 it was assumed that porters and drivers would handle 61% and 39% of parcels, respectively (as in the City of London trial). In scenario 2 it was assumed that porters and drivers would handle 80% and 20% of parcels, respectively (the difference being that in scenario 1 drivers would handle individuals parcels over 5kg and/or 30L plus multiple parcels with a volume greater than 100 L destined for the same building (as in the City of London trial), whereas in scenario 2 drivers would handle individuals parcels over 5 kg and/or 30 L plus multiple parcels with a volume greater than 100L destined for the same unique address (i.e. parcels for different unique addresses inside the same building would be handled by porters). This was derived from data analysis of the parcels handled in the City of London trial which indicated that 90% of parcels were both under 5 kg and/or 30 L, and less than 100 L when those with the same unique address were grouped together.

In both portering scenarios, based on the City of London trial it was assumed that the vehicle dwell time at kerbside for vehicles providing bagloads to porters (for the driver to park near to the dynamic rendezvous point, find the porter's bag in the back of the vehicle and allocate it to the porter) was 2 minutes on each occasion (a conservative assumption based on the time observed for this activity in the City of London trial). It was also assumed that the van fleet responsible for delivering large/heavy and multiple items for the same building would experience interdrop distances, journey times and parking times per parcel handled that are 25% greater in portering scenario 1 than in the non-portering CAZ survey (i.e. when drivers handle 39% of all parcels), and 50% greater in portering scenario 2 (i.e. when drivers handle 20% of all parcels). Assumptions concerning the delivery performance of porters were derived from the live portering trial in the City of London given that this was the only data available concerning such on-foot delivery operations.

Table 3 shows the results of this analysis, providing the comparison of current, business-as-usual (BAU) parcel activities in the London CAZ (i.e. in which all deliveries are made by drivers) with these two portering scenarios. The analysis indicates that both portering scenarios would be expected to result in reductions in total vehicle kerbside parking time for parcel operations (of 49% in scenario 1 and 67% in scenario 2). Scenario 1 would be expected to reduce total vehicle distance and driving time travelled by approximately 25% (a reduction of 10 million vehicle kilometres and 0.8 million hours per annum, respectively). Meanwhile

scenario 2 would result in vehicle distance and driving time savings of approximately 35% (a reduction of 13 million vehicle kilometres and 1.2 million hours per annum, respectively). The total vehicle deployment time on the roads (i.e. taking into account driving and parking) would be expected to fall by 39% (4.0 million hours per annum) in scenario 1 and 53% (4.7 million hours per annum) in scenario 2. This would have major benefits for both society and carriers who would have substantially reduced vehicle fleet requirements. The vehicle distance and time savings would have further benefits in terms of reductions in greenhouse gases emissions and local air pollutants.

7 Planning for parcel portering in urban areas

7.1 Operating cost considerations of the portering system

The total operating costs of the current (i.e. non-portering) parcel operation and the live portering trial in the City of London were estimated (in which porters handled 61% of parcels and the van driver the remaining 39%). Van standing costs (vehicle acquisition, depreciation, vehicle tax, insurance and London Congestion Charge), vehicle running costs (fuel, tyres and maintenance), driver and porter labour costs, and portering bag costs were included in the calculations. Drivers and porters were both assumed to be employed and earning the London Living Wage (currently £10.20 per hour). This calculation took account of the operational costs from the point of despatch from the urban depot to the consignees in carrying out these parcel collections and deliveries. Depot operating costs and administration and management costs were not included in these calculations. These costs calculations indicate that the portering trial was more expensive to operate than the pre-trial operation in the City of London. On a per parcel basis, the cost was 43% higher, whereas on a per consignee basis it was 4% higher with the relative change in cost being different per parcel and per consignment due to the lower number of parcels per consignment in the portering trial compared to pre-trial operation (2.4 compared with 3.3).

The total operating costs of portering in the London CAZ were also calculated for the BAU (i.e. non-portering) parcel operations and the two portering plus van scenarios were also estimated on the same basis as the operating cost calculations for the live trial. Scenarios 1 and 2 (61% of parcels handled by porters and 80% of parcels handled by porters, respectively) were estimated to have 6% and 11% lower total operating cost than the BAU operation. This difference in the operating costs of the live trial and the CAZ-wide analysis are due to: (i) the difference between the number of parcels per consignee in the pre-trial and live trial operations in the City of London (3.3 compared with 2.4) on the days on which these took place, which resulted in the workload required in the portering trial being greater than the pre-trial BAU operation (resulting in the need to visit more unique addresses to deliver/collect the same quantity of parcels in the trial), and (ii) the relative efficiency of the driver in the City of London pre-trial and trial operations (who was very experienced and efficient compared with the average driver in the operating data used in the CAZ-wide analysis). The operational costs calculated in the London CAZ analysis are not subject to these differences in the workload required per parcel that exist in the City of London live trial.

These results indicate that there is uncertainty about the effect that the adoption of portering is likely to have on last-mile logistics operating costs, and that these will depend on the efficiency of the current, non-portering systems that they replace. The transport and sustainability benefits of portering are illustrated in this paper. Given that portering operating costs are likely to be an important factor in the uptake of such a system by parcel carriers, there is an argument that

public policy makers should consider the extent to which they can financially support and incentivise the uptake of sustainable logistics systems such as portering.

7.2 Hub and depot sortation systems

Parcel carriers would ideally need to make changes to their existing hub and depot sortation systems to make portering as efficient as possible. This could include the installation of equipment at the overnight hub to record the size and weight of parcels handled prior to their despatch to the urban depot. The availability of this data could facilitate the sortation of parcels into those to be delivered by porters and those more suited to delivery by vehicle and driver at the hub. This data could also be utilised by parcel carriers to put in place hub sortation by portering bagloads rather than the current approach of sortation by vehicle round. Alternatively, this data could be supplied to the urban depot to permit analysis of the allocation of parcels to portering bags at the urban depot in advance of the arrival of parcels from the hub. This would save time (and potentially costs) in the parcel handling at the urban depot. Conversations with parcel carriers suggest that the technology required to achieve the collection of this parcel size and weight data already exists and could therefore be implemented in a reasonable timescale if parcel carriers wish to engage in portering systems that are as efficiently as possible.

Parcel carriers adopting portering solutions as tested in the live trial would need to develop a suitable communications and work allocation platform to enable the efficient distribution of work to porters both digitally and at the kerbside. This would require the development of suitable algorithms to automatically allocate parcels to portering bags in a logical delivery sequence, as well as the develop of communication platforms already widely in use in the on-demand taxi and meal delivery sectors (by companies such as Uber and Deliveroo).

7.3 Storage facilities for portering bags

Solutions including portering are likely to becoming ever more important as policy makers strive to make central London more pedestrian friendly and reduce the transport intensity and environmental impacts associated with freight. Actions that urban public policy makers could consider taking to support portering include reviewing existing kerbside facilities to support portering (including greater flexibility in where vehicles replenishing porters can stop given the short duration of these stops), and whether portering facilities could be made available at appropriate costs. Such facilities include the provision of suitable, secure storage locations for portering bags. Policy makers could make land available in suitable locations on pavements and in car parks at which locker banks or other similar secure structures (staffed or unstaffed) could be sited at which portering bags full of parcels could be deposited by van drivers. There are already privately-owned networks of locker banks and collection points (Morganti et al., 2014a; 2014b) which policy makers could consider financially supporting the use of for portering bags. Porters could then replenish themselves with additional bagloads of parcels at these facilities rather than having to make dynamic rendezvous with van drivers at the kerbside (as happened in the live trial). This approach to porter replenishment would be expected to lead to even greater reductions in kerbside usage by vehicles in a portering system.

Parcel carriers could seek to acquire private land for the siting of locker banks and other collection points to be used in parcel portering, but given the traffic and environmental benefits of portering, together with the lack of affordable logistics land in many central urban areas, there is a strong case for urban policy makers to assist in the provision of this land at subsidised rates to promote sustainable last-mile logistics operations (Dablanc and Rakotonarivo, 2010;

Dablanc et al., 2014; Piecyk and Allen, 2017). Such facilities could also be used other logistics operations including the collection of parts and tools by service engineers.

Urban policy makers could also seek to make other street facilities including rest areas and toilet facilities available for porters and other workers based on the street. This could be achieved by direct public provision or through putting in place arrangements with private companies (including offices, restaurants and shops) for such workers to use their facilities when required.

7.4 Autonomous vehicles

Once autonomous delivery vehicles are available and have been given permission to operate on urban streets by policy makers, these could be used in conjunction with human porters. These autonomous vehicles would be used to provide porters with parcels either dynamically on-street or via a secure locker bank or collection point in the proximity of where the parcels require delivery. These porters would continue to carry out the final transport leg from the vehicle or secure storage facility to the consignee's delivery locations, crossing roads and dealing with stairs, lifts, doors and doorbells in ways that affordable robots and droids are likely to continue to struggle to cope with for the foreseeable future.

7.5 Porterage collaboration between parcel carriers

If parcel carriers choose to adopt portering systems, it would be most efficient for them and most sustainable for the urban area and society if they collaborate with each other and use a shared network of porters, rather than each establishing their own dedicated porters and related physical infrastructure for replenishing porters with parcels in the urban environment. However, history suggests that parcel carriers are typically reluctant to work jointly on operational innovation due to their traditional competitiveness and perceived customer brand loyalty. This suggests a further role for public policy makers in helping to foster last-mile logistics operations and infrastructure that generate the greatest transport and environmental benefits for society.

7.6 Parcels for large and multi-tenanted buildings

As previously mentioned, in studying the BAU delivery operations in the City of London prior to the live trial, it was found that drivers have to ascend and descend staircases and lifts to deliver to 15-20% of consignees. This can arise for both commercial consignees, especially those in large office blocks, and residential consignees in blocks of flats which major generators of last-mile parcel flows and related vehicle trips. This results in drivers spending substantial periods of time inside buildings (e.g. waiting for lifts to different floors, climbing and descending stairs), thus increasing vehicle kerbside dwell time and total working time taken.

From the perspective of vehicle kerbside space and time usage (as well as in terms of the operating cost to parcel carriers to make deliveries and collections), this is an inefficient solution. In some such establishments, the building managers have put in place arrangement to obviate this requirement (for example by allowing parcel carriers to deliver items for those in the building to a single mail room, reception desk, locker bank or loading bay). This indicates an important role for policy makers in implementing future land-use and building planning permission approval that require a single ground floor reception facility in such buildings.

8 Conclusions

It was intended that the use of porters would assist parcel carriers who are facing an ever-more challenging urban situation in which to carry out their operations, due to reducing traffic speeds, and increasing competition for kerbside space, which are making their last-mile deliveries more difficult and expensive to carry out. It was also the intention of the trial that the use of portering could help to reduce the transport and environmental impacts of these parcel operations.

The live City of London trial and London CAZ-wide analysis suggest that parcel portering could result in reductions in vehicle parking time at the kerbside (of approximately 50-65%), and vehicle driving time and distance travelled in parcel operations (of approximately 25-35%) in central London based on the analysis carried out. These operational outcomes would result in associated improvements in greenhouse gas emissions and local air quality pollutants, as well as reductions in the vehicle fleets required by carriers. Portering makes it possible to deploy numerous delivery personnel on-street at the same time to achieve parcel delivery service levels without the need for an equivalent number of vehicles.

There are many planning issues for companies and policy makers to consider in relation to portering if it to prove as effective as possible in commercial, transport and environmental sustainability terms. Policy makers should focus especially on the provision of suitable locations for the siting of secure facilities in which parcels can be left for porters, thereby removing the need for dynamic rendezvous between van drivers and porters and further reducing vehicle kerbside dwell times. If portering is implemented by parcel carriers, policy makers could also work to encourage that parcel carriers collaborate to make use of shared networks of porters to avoid proliferation of personnel and infrastructure and the associated impact on operating costs. Policy makers may also have to perform a role in incentivising, subsidising or mandating portering operations given their transport and environmental benefits if such schemes prove marginal for parcel carriers on operating cost grounds.

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Figure 1 The parcel portering delivery operation from senders to recipients.

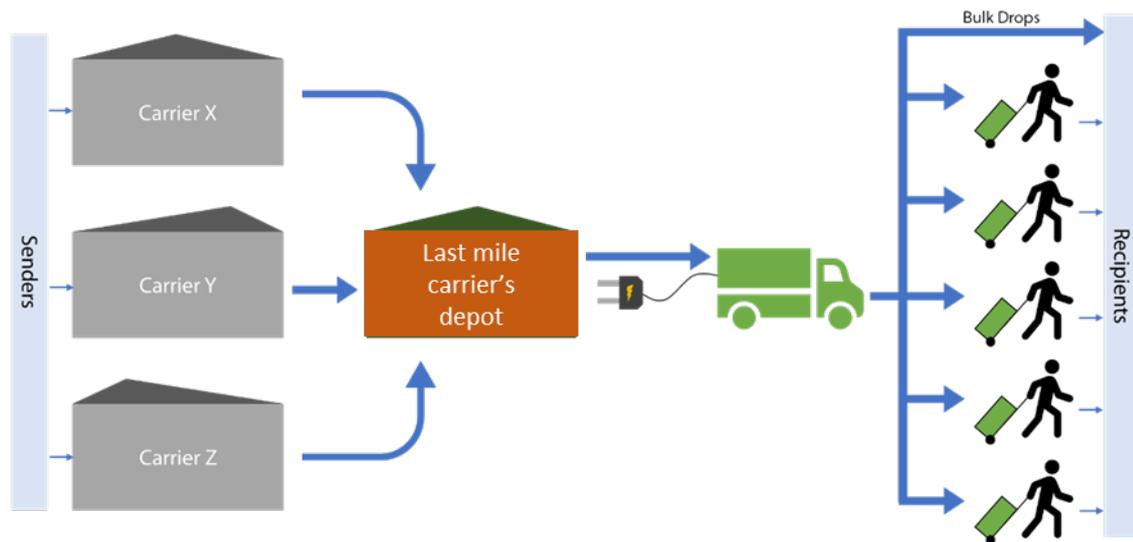


Figure 2 3D probability histogram displaying the relationship between parcel weight and volume based on the January 2018 weight/size survey (plot generated in MATLAB).

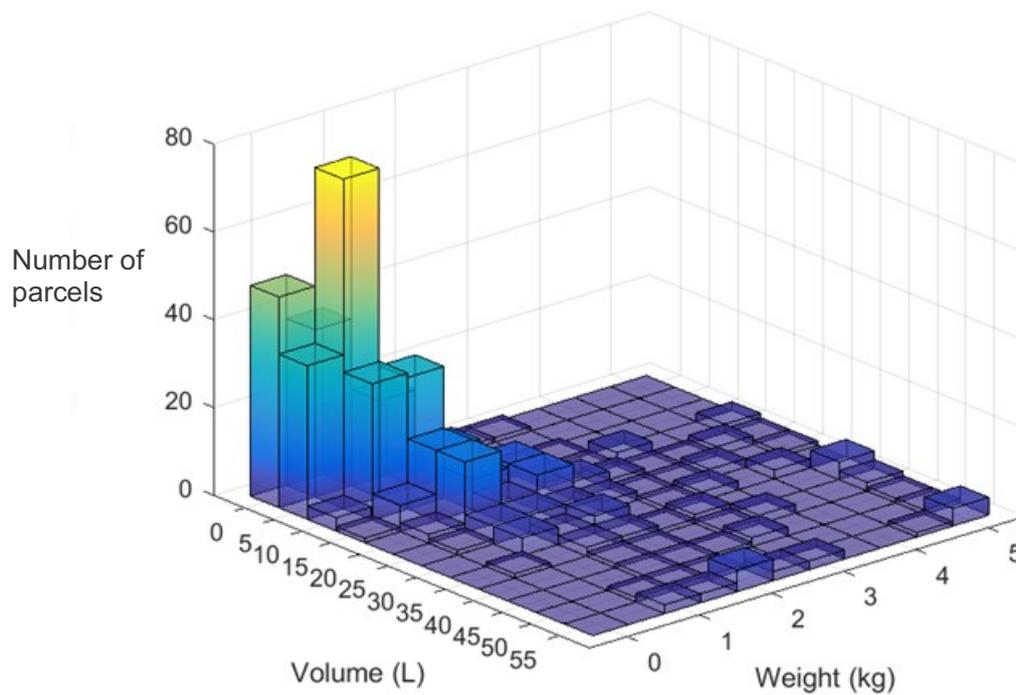


Figure 3 Patches derived based on latitude/longitude coordinates and historical parcel volumes from one week of consignee delivery activity (pins show delivery addresses with different colour used for each patch – map is 1.2 x 1.2 km) (figure generated in Arcmap).

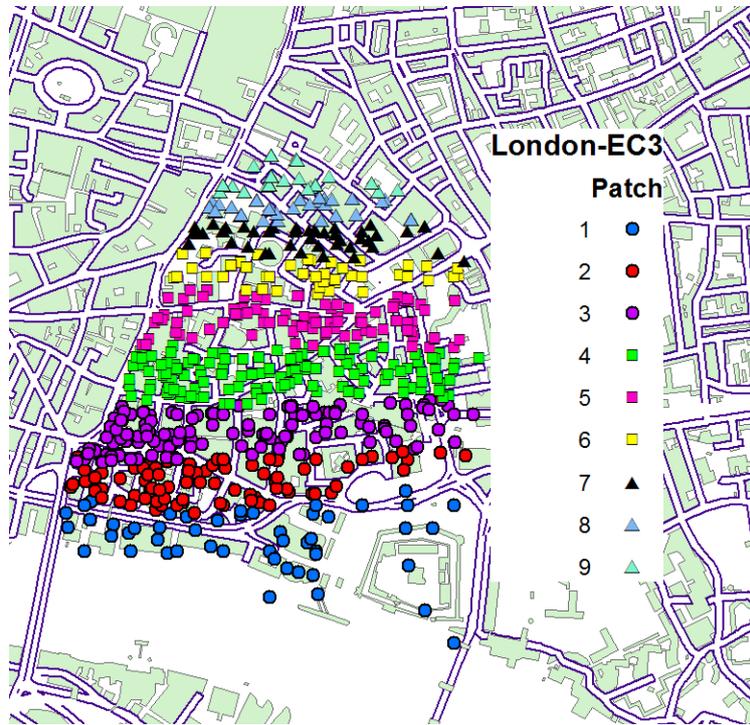


Table 1 Comparison of BAU parcel operation (non-portering) with actual portering trial and simulation in the City of London per parcel and per consignee.

Metric	Per parcel			Per consignee		
	Pre-trial by driver	Portering trial	% diff.	Pre-trial by driver	Portering trial	% diff.
Parking time at kerbside (min:sec)	01:11	00:34	52%	03:55	01:21	65%
Driving time (min:sec)	00:33	00:35	4%	01:50	01:23	24%
Total vehicle / driver deployment time (min:sec)	01:44	01:08	34%	05:44	02:44	52%
Portering time (min:sec)	00:00	01:43	-	00:00	04:09	-
Total labour time (min:sec)	01:44	02:52	65%	05:44	06:53	20%
Vehicle distance travelled (m)	101	97	4%	335	233	30%

Key

Improvement

Worsening

Table 2 Comparison of the operating performance of the City of London driver and the average driver in the larger CAZ survey per parcel (standard BAU delivery operations without portering).

Metric	City of London driver	Drivers in the London CAZ
Parking time at kerbside (min:sec)	01:11	02:20
Driving time (min:sec)	00:33	01:41
Total vehicle / driver deployment time (min:sec)	01:44	04:01
Total driving distance per parcel (metres)	101	267

Table 3 Analysis of total annual BAU parcel operations from depot to customers in the London CAZ compared with portering scenarios in 2016 (absolute values and percentage improvement on BAU operation).

	BAU operation (i.e. drivers make all deliveries)	Estimated performance of each portering scenario compared with current operation	
		Scenario 1 (porters handle 61% of parcels)	Scenario 2 (porters handle 80% of parcels)
Vehicle time taken metrics			
Total driving time (million hours)	3.7	2.9 (-24%)	2.5 (-34%)
Total kerbside parking time (million hours)	5.3	2.2 (-49%)	1.8 (-67%)
Total vehicle deployment time (million hours) (i.e. driving and parking)	9.0	5.0 (-39%)	4.3 (-53%)
Vehicle distance travelled metrics			
Total driving distance (million kilometres)	36.0	26.5 (-26%)	23.1 (-36%)