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ABSTRACT

The rise of the on-demand economy has led to a rapid increase in the delivery of meals from restaurants and fast food outlets by delivery drivers (DDs) using bicycles, mopeds and cars, with newly-established platform providers handling order and payment processing and, in many cases, the co-ordination of these deliveries. Little is currently understood about the collective transport impacts of such activity in urban centres and to what extent this poses challenges for transport policymakers. The paper provides an international review of market growth in this sector together with insight into key topics associated with its freight delivery operations in urban areas. Using a substantial database of meal deliveries made in London by a major platform provider, this paper quantifies the operational performance of these deliveries and their transport and environmental impacts. On average, 9.6 deliveries were undertaken by a DD daily, with each taking 25 minutes from pickup to delivery with an average trip length, from restaurant to customer of 2.2km (1.4 miles) a DD travelling 41.3km (25.7 miles) in total per day, The analysis of the case study indicates the relative transport inefficiency of these on-demand meal deliveries compared to other forms of urban road freight (with a meal delivered by car being responsible for approximately 1300 times the distance travelled by an articulated HGV operation per tonne delivered). It also highlights the far greater GHG emissions and transport intensity associated with meals deliveries by cars and petrol mopeds compared to bicycles (emitting 5 and 11 times more GHGs per meal delivered than bicycles, respectively).
The transport and GHG emissions intensity of these meal deliveries raises important policy issues, especially given the rapid growth in the provision of, and demand for, these services internationally, Based on the review and analysis, the paper provides a discussion of the key issues that urban policymakers around the world need to take account of in relation to this fast-growing sector including vehicle fuel sources, road safety, trip generation rates and their impacts on local residents, together with recommended actions.

INTRODUCTION

The rise of the global on-demand e-commerce economy has led to a rapid increase in the numbers of online orders for delivered ready-to-eat meals (referred to as ‘meals’ in the paper), typically provided by restaurants and fast food outlets. This growth has also seen new start-ups, rapid development, expansion, acquisitions and mergers of online platform companies that link customers, restaurants and delivery personnel via internet and smartphone technology. Some of the most popularly used platforms around the world, many operating multi-nationally, include (with headquarter locations shown in parentheses): Meituan Waimai (China), Swiggy (India), Grubhub (USA), Uber Eats (USA), Deliveroo (UK), Takeaway.com (Netherlands), who merged with Just Eat (UK) in 2020, Delivery Hero (Germany), who own Foodpanda (Germany), and Naija Eats (Nigeria). Most of these platform providers utilise crowdsourced self-employed delivery drivers (DDs) who use their own vehicles (e.g. cars, motorcycles or bicycles), creating new logistics networks of people willing to service the demand (McKinnon, 2016).

This fast-growing on-demand meal delivery sector is placing additional pressure on an already congested kerbside infrastructure and is imposing new transport and planning challenges on towns and cities. This new source of urban freight transport has received little attention to date from researchers and policymakers and this paper makes three contributions to research in this topic: firstly, it provides a comprehensive review of the international literature related to the on-demand meal delivery market and its operations and impacts. Secondly, through empirical analysis using an operational dataset from a meal delivery platform provider, it quantifies the transport characteristics and environmental impacts of on-demand meal deliveries in London. As far as the authors are aware this is the first such academic analysis of the delivery operations in this sector, and thereby providing an approach and set of operational metrics that could be adopted and applied by researchers in other cities and countries. Thirdly, it sets these meal deliveries in context with other forms of urban freight in terms of their transport and environmental impacts, and provides a discussion of the planning policy challenges that this new form of urban delivery poses, and the considerations and recommended practical actions that may be required in response by urban policymakers across the world.

METHODOLOGY

Interviews with policy makers, and with managers and DDs working in the meal delivery sector in London were carried out into these delivery operations and related parking strategies. The relevant topics that emerged from these interviews were then used to carry out an international review of existing literature associated with meal deliveries. The topics covered in this review include: the size and growth of the international on-demand meal delivery market, meal delivery operations and their transport impacts, delivery characteristics and driver’s perspectives, health and safety issues, and the impacts of vehicle trip generation at restaurants and fast food outlets. Wherever available literature permits, this review has drawn on internationally sourced material that provides insight into meal deliveries and the issues associated with them. Given how recently the on-demand meal market has emerged, its delivery operations and their impacts have been subject to relatively little academic research, so use was also made of material concerning these topics written by business journalists and trade reporters in order to obtain the greatest insight possible from all these relevant, available sources.

Given the relative lack of previous academic research into on-demand meals and their deliveries, in order to investigate these delivery operations in further detail and to corroborate any findings identified during the review of existing literature, a significant database of operational delivery data was obtained from a major on-demand platform provider serving restaurants in Greater London covering two time periods in 2017. This dataset comprised a total of 40,941 meal deliveries made by 195 DDs over a total of three months. An initial dataset comprising deliveries during the period 10-30 July 2017 was used to develop the methods used, while a larger dataset, covering November-December 2017, provided added robustness and a seasonal comparison. Each data record contained latitude/longitude coordinate pairs for the trip origin (e.g. a restaurant) and destination (delivery address), the date and times of collection and delivery, the vehicle type used (i.e. bicycle, moped or car) and a unique DD identifier number. Trip distances were obtained for all cycling and driving trips using the Google Maps Distance Matrix API. Various data analysis and visualisation techniques (e.g. heat mapping) were used to examine the data and quantify the transport impacts associated with meal delivery in the parts of London studied. Key operational parameters that could be derived from the available dataset and which reflect the patterns and extent of this freight transport activity were identified and calculated. In addition, a second data collection exercise was carried out to graphically represent the origin locations of DD journeys from all ‘on-demand’ delivery platforms used by fast food outlets in three north London high streets.

Using the findings from this analysis of operational data made available by the platform provider, together with data collected during the interviews with operators and DDs regarding transport and parking operations, a spreadsheet-based data analysis was carried out to quantify the greenhouse gas (GHG) emissions (expressed in grams of CO_2 equivalent - CO_2e - comprising CO_2, CH_4 and N_2O) of these vehicle activities and the transport intensity, both in terms of the distance travelled by road and the kerbside parking space occupied associated with meal deliveries in London by vehicle type. Kerbside space and time occupancy were calculated by multiplying the width and length of vehicles by the time vehicles spent at the kerbside, expressed in the unit m^2hrs. GHG emissions were derived from the vehicle activity data analysed together with the use of generalised vehicle emissions factors in order to compare the impacts of different vehicle types used for these meal deliveries (DBEIS and DEFRA, 2017; European Cyclist's Federation, 2017).

A comparative analysis was carried out of the GHG emissions and transport intensity for the vehicle types used in the meal deliveries studied with the vehicles used in other London-based freight transport operations including other on-demand sectors of grocery and parcel deliveries, as well as general freight transport operations using rigid and articulated heavy goods vehicles (HGVs). The additional data required on vehicle dwell times, journey lengths and vehicle dimensions for this analysis was gathered from survey work carried out by the authors in the Freight Traffic Control 2050 project (www.ftc2050.com) for on-demand operators in parcel and grocery sectors (Allen et al., 2018a) and freight operators in other sectors using heavier vehicles based on disaggregation of vehicle activity in London from the UK Continuing Survey of Road Goods Transport (Browne et al., 2014) and vehicle dwell time surveys (Cherrett et al., 2012). The generalised vehicle emissions factors already discussed were also used.

Analysis was also carried out into the GHG emissions and transport intensity of having these meals delivered from restaurants and fast food outlets on a same-day basis compared with consumers purchasing food in grocery supermarkets by car as part of their weekly shop and then cooking this food at home. This also made use of the platform provider data of meal deliveries in London, together with consumer shopping data from the UK National Travel Survey (Department for Transport, 2019), the generalised vehicle emissions factors previously described and data on oven cooking from governmental and academic sources (DBEIS and DEFRA, 2017; Calderón, 2018).

Transport and planning policy issues of relevance to on-demand meal deliveries in urban areas internationally were identified from the literature review and data analysis carried out in the London case study. Whilst land use patterns vary between urban areas, these policy issues are of relevance to meal deliveries in other cities and countries beyond London and the UK as they relate to the types of meal delivery vehicles used, the various impacts these delivery operations impose on the road infrastructure and environment, and the treatment, health and safety of those making these deliveries. Many of the platform providers offering these meal ordering and delivery services operate internationally and implement operations based on their learning from their competitors in their industry, leading to similar impacts and policy issues in urban areas across countries.

BACKGROUND

Size and growth of the meal delivery market

Meal delivery has existed for many years, with one of the earliest examples being the 'dabbawalla' service, delivering prepared lunches to office workers and schoolchildren in Mumbai since the 1890s (Bondre, 2013). In western countries, particularly the USA and UK, the sector was, until recently, dominated by fast food outlets, especially pizza chains that took their own orders by telephone and organised deliveries themselves. In recent years, the sector has been revolutionised by internet and smartphone technology enabling the introduction of online platforms that facilitate customer ordering and payment on behalf of restaurants and fast food outlets. Some platforms also arrange the meal delivery with just over 50% of all deliveries worldwide estimated to be managed by the platform provider and just under 50% by the restaurants themselves (Statista, 2019).

These platforms have stimulated both supply and demand for meal delivery services and have greatly expanded the range of meal options, with restaurants joining the more typical fast-food outlets on these platforms: a survey of delivery options in Chicago (USA), Amsterdam (Netherlands) and Melbourne (Australia) indicated a choice of 148 different meal types (Poelman et al, 2020). The proportion of eating establishments using online platforms for meal delivery was reported to be strongly linked to the overall level of funding for the industry and the size of marketing budgets, with the highest proportion (56%) observed in Sweden, among a survey of 16 countries worldwide in 2016 (Hirschberg et al, 2016).

In the UK, it was estimated in 2017 that over one-third (around 35,000) of all eating establishments used online apps to support customer ordering (Just Eat, 2017).

The size of the worldwide online meal delivery market was projected to reach US$136,431 million in 2020, with China contributing the greatest share of this (37.8%), with an annual growth rate of 7.5% (Statista, 2019). In the UK, the food delivery market was estimated to have generated total sales of £8.4 billion from 850 million orders in 2019, with 18% growth in sales on the previous year. Survey work indicates that on average, consumers order a delivery 2.3 times each month (MCA, 2019a). In contrast, the market for eating out in UK restaurants generated sales of £18.8 billion in 2019, which was a fall of 3.1% on the previous year (MCA, 2019b). Periods of peak demand coincide with lunchtime and evening meals, while growth in the delivery of breakfasts has also been reported (NPD, 2017). A customer survey across sixteen countries suggested that 74% of all orders placed via such platforms were between Friday and Sunday with 82% for home delivery and 16% for a workplace (Hirschberg et al., 2016).

Growth in demand for meal delivery has seen rapid expansion of many platform companies, with Liu (2019) noting that GrubHub's stock price tripled in three years and that Uber Eats' service quickly expanded to cover more than 300 cities across 6 continents. During the initial weeks of the Covid-19 epidemic in 2020, meal delivery providers struggled due to the closure of restaurants and fast food outlets in cities around the world and the stockpiling of food by households. However, as restaurants began to re-open and households used up their food supplies, demand for meal deliveries began to grow rapidly again and soon surpassed pre Covid-19 levels (Competition and Markets Authority, 2020). Despite the epidemic, Just Eat Takeaway.com reported an increase in orders of 32% and revenue of 44% in the first six months of 2020 compared to same period in 2019 across its entire international business. Growth in order levels was especially strong in Germany (76%) and Canada (59%) (Just Eat Takeaway.com, 2020).

In the UK, where our study is based, the three main platforms used are Just Eat, Deliveroo and Uber Eats. Just Eat, which merged with Takeaway.com in 2020, is the largest meal platform provider in the UK, working with more than 100,000 restaurants and fast food outlets worldwide, accounting for £4.2 billion total food spend, revenue of £780 million and 221 million orders in 2018 (Just Eat, 2019). It originally only provided an ordering and payment platform for its restaurants but in 2018 announced plans to launch its own delivery fleet, with £50 million planned investment (Monaghan, 2018). Deliveroo launched its meal delivery service in the UK in 2013 and operates in 200 cities globally, working with 35,000 restaurants. It provides delivery services via its network of 30,000 self-employed DDs (Deliveroo, 2020). It reported revenues of £476 million in 2018, an increase of 72% on the previous year. However, losses increased from £199 million in 2017 to £232 million in 2018 (Roofoods Ltd, 2018). Uber (UberEats) entered the UK meal delivery market in 2016 and provides its own delivery services via self-employed DDs (Auchard, 2016). In addition to these online platform providers, the three leading takeaway pizza providers in the UK provide their own delivery services with Domino's Pizza having approximately 1100 outlets, and Pizza Hut and Papa Johns approximately 400 outlets each (Mintel, 2019a).

Delivery characteristics and transport impacts

Meal delivery is offered in urban areas where journey distances from the food outlet to the point of delivery are relatively short (e.g. less than 3 miles) to achieve a rapid delivery response at lowest cost. The short distances involved allow a range of transport options to be used, the main ones seen in practice being motorcycles, bicycles, cars or vans. Online platform providers typically use rapid delivery as a selling point and it has been shown that customer retention is positively correlated with speed of delivery (Mao et al, 2019). It is therefore a point-to-point, 'instant delivery' service typically taking 15-45 minutes from when the order was placed and with little scope in practice for carrying out more than one order at a time (Cant, 2019).

Although algorithmic methods have been proposed to improve delivery schedules, some allowing orders to be combined (Reyes et al, 2017; Yildiz and Savelsbergh, 2018; Wang, 2018; Mao et al, 2019;

Liao et al, 2020), the so-called ‘meal delivery problem’ (MDP) is characterised as being highly fragmented and relatively inefficient compared to consolidated parcel delivery services. Heuristic algorithms are generally adopted for scheduling deliveries as optimal solutions cannot be readily derived due to the highly dynamic nature of the work (orders are not known in advance) and the large numbers of customers and restaurants that are typically involved: in China, for example, it was observed that one major logistics provider had up to 1200 lunch orders from forty different suppliers each day in one city (Wang, 2018). In addition, sharp peaks in delivery demand represent a logistical challenge, requiring large numbers of DDs during typical mealtimes but only few required at other times, which might explain why some platform providers do not manage the delivery themselves (Ahmed, 2017). A review and classification of algorithms used by platforms utilising crowdsourced DDs is provided by Alnaggar et al (2019).

There have been very few studies, to our knowledge, that have attempted to measure or estimate the total vehicle activity (e.g. numbers and types of vehicles being used, numbers of trips, vehicle miles) associated specifically with meal deliveries. In China, it was estimated that there were three million DDs in 2017, with the vast majority working wholly within urban areas using mopeds, many of which are electric (Wu and Zheng, 2020). In Paris, France, ‘rather significant activity’ of 100,000 ‘instant deliveries’ per week was estimated, where these comprised all B2C deliveries undertaken within two hours (e.g. meals, express parcels), representing 12% of all B2C deliveries and 2.5% of all deliveries (Dablanc et al, 2017). In principle, city planners may be able to benefit from information about this transport activity, alongside information from other related studies such as those considering grocery deliveries (Gee et al, 2019; Bjørgen et al, 2019).

Driver characteristics and perspectives

DDs tend to be male and relatively young, with surveys in the UK and France indicating that around two-thirds were under the age of 25 and only 5% were female (Warne, 2017; Dablanc, 2019). Some DDs, particularly students, undertake the work on a casual part-time basis while others work full-time. From a survey of around 100 DDs in Paris, 48% worked full-time and 52% part-time (Dablanc, 2019), while a survey by Deliveroo (UK) of 900 of its DDs in June 2017 suggested that 90% of them did not consider the job as their main source of income with 72% delivering at least one order in a particular week and working fewer than 15 hours per week; 19% working between 15 and 29 hours per week; and only 9% working 30 hours or more (Field and Forsey, 2018). Platform providers often promote the delivery work as offering the opportunity to work whenever and wherever you want but anecdotal evidence from worker forums suggests that it can be difficult to obtain enough work due to oversupply of DDs. Having too many DDs for the available work benefits platforms and restaurants in ensuring fast deliveries but is a significant contributory factor to the low effective pay rates typically associated with this work (Field and Forsey, 2018). Platforms typically pay DDs an amount of money per delivery made but it has been reported that it can be difficult to undertake more than two deliveries per hour due to idle time waiting for jobs to be allocated by the platform provider and for restaurants to prepare orders (Cycling Plus and Ainsley, 2016; Fedor, 2016).

Alongside low pay, a key point of contention for DDs is their employment status. Typically, platform providers deny DDs employee status (deeming them to be self-employed contractors) to avoid the associated costs of providing benefits such as paid holiday leave, sick pay, parental leave, protection against unfair dismissal and redundancy pay. Yet platform providers often act as though employers by vetting workers, restricting freedoms such as working for different platforms, determining pay rates and deciding when and how work is performed, and even taking disciplinary action (TUC, 2017). There has been much criticism and negative publicity surrounding the perceived exploitation of DDs and other so-called ‘gig economy’ workers in the UK, France and other countries (Dablanc et al., 2017, 2018; Taylor Review, 2017). This has led to legal challenges and a UK Parliamentary enquiry about poor working conditions, low pay and infringements of rights (Butler, 2018; Wilcock, 2018) and there have been worker strikes in the UK and other countries worldwide (Lomas, 2018; Siddique, 2018; IWW, 2018).

Research into the DD cycling subculture has mostly focused on the parcel delivery sector, as this has been in existence far longer than the meal delivery sector. Sociological studies indicate that for those who feel part of this subculture it is strongly related to the transport mode used as well as the work itself (for example, see Kidder, 2004; 2005; 2009 and Fincham, 2006; 2007, 2008).

Health and safety issues

Cycling as a mode for meal delivery is associated with fewer greenhouse gas emissions and local air pollution compared with other the use of mopeds and cars. However, although manual and electrically-assisted cycles (and cargo-cycles) are emissions-free at the point of use, there are CO_2e emissions associated with electricity generation as well as with the extra food and drink consumption that a cyclist requires compared to a moped, motorbike or car driver. These have been calculated to be approximately 16 g CO_2e / km for a user of a manual bicycle and 6 g CO_2e for an electrically assisted bicycle user (European Cyclist's Federation, 2017). Research has also shown that the manufacture of bicycles is associated with fewer greenhouse gas (GHG) emissions than other vehicles (approximately 5 g CO_2e / km for a bicycle or assisted cycle compared to 42 g CO_2e / km for a car) (European Cyclist's Federation, 2017).

Research has shown that cycling leads to increased overall physical activity, rather than substituting other forms of physical activity and could thereby lead to improved physical health (Donaire-Gonzalez et al., 2015, Rojas-Rueda et al., 2016). While cycling typically leads to an improvement in fitness, it does expose the rider to toxic fumes, and the increased risk of traffic collisions (de Nazelle and Nieuwenhuijsen, 2010).

There are a number of serious safety issues surrounding meal delivery work, which should be of concern to all interested parties (e.g. platform companies, restaurants, city authorities) and to the wider public. Forty-two per cent of respondents in an online survey of UK DDs and taxi drivers using mopeds, motorbikes, bicycles or cars reported that their vehicle had been damaged as a result of a collision while working, with a further 10% reporting that someone had been injured (either themselves or another road user) (Christie and Ward, 2018). A survey of 160 meal DDs in Australia found that 50% had been injured on the job or knew a colleague who had, with many also reporting damage to their bicycles (Zhou, 2018). A study of bicycle DDs in Montreal found that they were six times more likely to be involved in collisions than other cyclists due to the distance the DDs covered and the amount of time spent on the road (Messengerville, 2008). In China it has been estimated that there were three million DDs in 2017, with the vast majority working wholly within urban areas using mopeds, many of which are electric (Wu and Zheng, 2020). In the first six months of 2017, 76 injuries and deaths involving meal DDs were reported in Shanghai while in the city of Nanjing, it was reported that meal DDs were involved in more than 3,000 collisions in the first half of 2017 (Shepherd, 2017).

Contributory risk factors include poor visibility at night, slippery road surfaces after rain, inadequately maintained vehicles, and being tired, especially for those riding bicycles. DDs using bicycles and mopeds may also ride quickly in their haste to complete work and earn more pay which can involve some risky and/or illegal behaviour such as weaving in and out of the traffic, riding the wrong way along one-way streets and riding on pavements (Marsh and Boswell, 2016; Zhuravlyova, 2018). This riding behaviour of meal DDs is likely to be related to several governance and demographic factors including the young age profile of meal DDs with many having had little experience on the road prior to being engaged as DDs; and the limited amounts of training offered and taken-up. A UK study of self-employed DDs and taxi drivers, involving in-depth interviews and an online survey, found that none of those interviewed were required to have training or were given training other than being informed of online videos, while 63% of survey respondents were not provided with safety training on managing risks on the road (Christie and Ward, 2018). Across both two and four-wheeled DDs, only 25% of respondents agreed that the company cared about their safety whilst working (Christie and Ward, 2018). A survey of 160 DDs delivering meals by cycle in Australia found many reporting that they received little or no training (Zhou, 2018).

Another serious concern is that of physical assault. Meal DDs may be confronted by aggressive or intoxicated customers when working alone after dark, and sometimes handling money, can also make such work dangerous (European Agency for Health and Safety at Work, 2010). Attempts to steal their motorcycles, mopeds and bicycles have led to attacks on some DDs that have resulted in life-changing injuries (McGoogan, 2017).

Trip generation, noise and nuisance at food outlets

Meal deliveries can have positive traffic and social impacts on the localities in which they occur: high street restaurants and fast food outlets can generate substantial vehicle activity and many trips occur within short peak periods of demand, especially in the evening, so can conflict with evening peak road traffic; DD waiting times to collect meals can be considerable and can result in sizeable numbers of DDs and vehicles congregating outside a single food outlet generating noise disturbance for local residents; and many bicycle DDs choose to mount the kerb with their vehicles at collection and delivery points lead to potential conflicts with pedestrians (Allen et al., 2018b; Hexter, 2017).

Deliveroo has introduced approximately 100 stand-alone kitchens in the UK, which they refer to as ‘RooBoxes’ and ‘Deliveroo Editions kitchens’, but which critics refer to as ‘dark kitchens’ (Wearn, 2019; Mintel, 2019b). Each development can comprise several different meal providers. They are located in metal shipping containers, disused carparks and industrial buildings (Pathiaki, 2017). Some of these facilities have been built in close proximity to residential accommodation and can generate up to 200 vehicle trips per hour (Morris, 2018), leading to complaints concerning traffic generation by mopeds, motorbikes and vans; danger of traffic collisions with pedestrians; poor driving behaviour; and vehicle and DD noise during the evening and night (Hexter, 2017). Deliveroo has tried to ensure that deliveries from these kitchens are served by DDs using bicycles instead of mopeds to reduce noise disturbance where that is a particular problem (Butler, 2017). It is also putting in place other mitigation measures to try to ensure that DDs only arrive at the kitchen when meals are ready, the provision of DD waiting areas inside the kitchens, and assembly points in areas as far from any nearby residential properties as possible (Deliveroo, 2018b).

LONDON CASE STUDY

Road traffic and its associated GHG and air quality impacts have been worsening in London. This has led consecutive Mayors of London to implement mitigating policy measures including the Congestion Charging Scheme (in 2003), the Low Emission Zone (in 2008) and the Ultra Low Emission Zone (commencing in 2019). Traffic speeds have fallen and delays increased across London over the last decade (Transport for London, 2016) as demand for kerbside space has increasing, with one central London authority having recently documented 39 different uses of the kerbside, of which deliveries and collections only represented a single entry (Westminster City Council, 2018).

Understanding the transport impacts of meal delivery operations

DD data were supplied by a major platform provider serving restaurants in Greater London, UK. An initial dataset comprising deliveries during the period 10-30 July 2017 (see Figure 1) was used to develop and illustrate the methods used while a larger dataset, covering November-December 2017, provided added robustness and a seasonal comparison. The vast majority of DDs (83%) used a moped, with 10% using a car and 7% using a bicycle. All delivery trips were associated with a single collection and delivery with return trips from a delivery location to the next restaurant collection inferred using the DD ID. Driving distances by moped and car were found to be approximately 10% greater than cycling distances on average.

The DD trips displayed a spatial pattern in which collection points (i.e. restaurants) are concentrated and delivery points are dispersed in the surrounding neighbourhoods, radiated out from the collection points (see Figure 1). This spatial pattern was examined further by overlaying a 500m (1640 foot) grid over the study area, counting the number of collections and deliveries in each cell, and visualising the difference of the two values. The resulting heatmap (see Figure 2) shows a clear relationship, with collection points (i.e. restaurants, shown in red) placed centrally, and delivery locations (in blue) distributed around them. The two figures show the areas of Greater London that were served by this platform provider during this period.

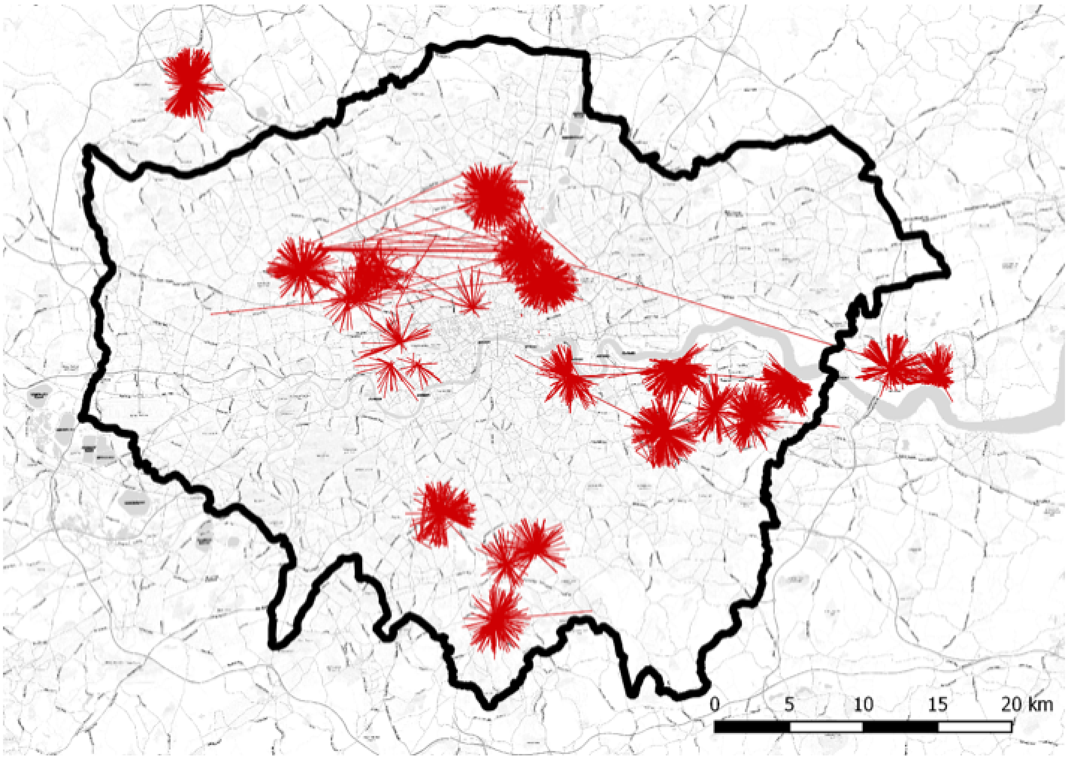


Figure 1. Delivery trips made by DDs working for one platform provider (restaurants to customer) during July 2017 (Greater London area shown).

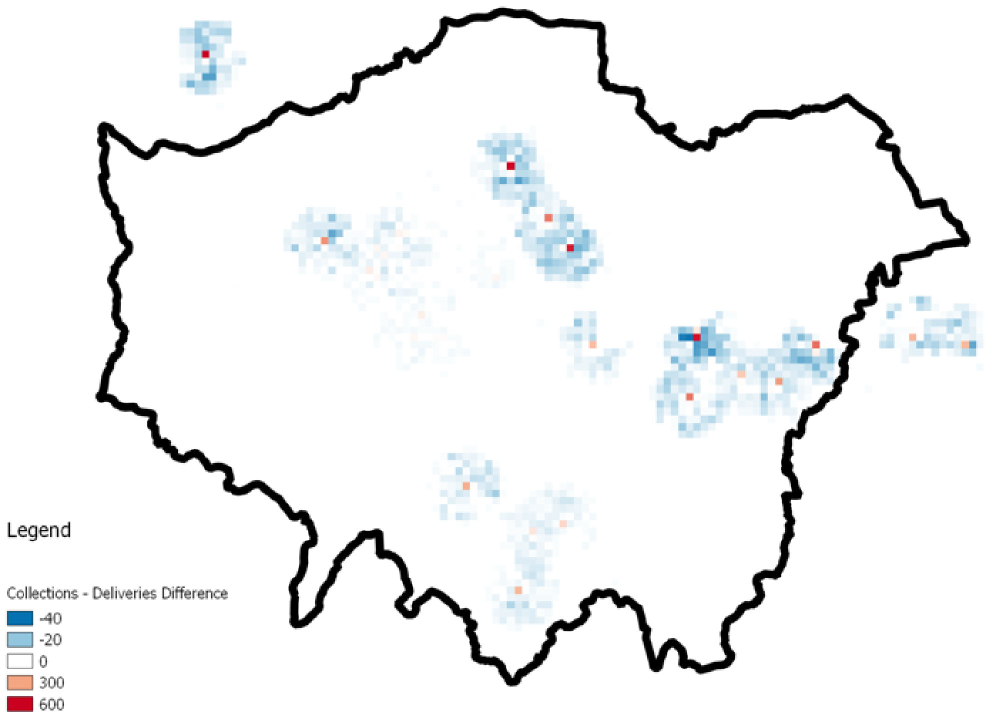


Figure 2. Heatmap of DD activity for one platform provider during July 2017 in which blue hues signify more deliveries, and red hues more collections from restaurants per cell (Greater London area shown).

The July 2017 data contained 7,918 deliveries over 21 days (377 deliveries/day), serviced by 85 DDs, while the November/December dataset had 33,023 deliveries over 60 days (550 deliveries/day), serviced by 110 DDs with individuals being generally busier in November/December than in July (Table 1). Comparing the time spent making deliveries with the total work session length suggested that only 38% of time was productive during July, whereas this increased to 49% in November/December with less time being spent waiting for the next job to be allocated.

During November/December, the average number of jobs worked each day was 9.6, with each job taking 25 minutes on average from pickup to delivery with an average trip length, from restaurant to customer, of 2.2km (1.4 miles). The average distance travelled by a DD in a day was 41.3km (25.7 miles), not including commuting to and from home, of which half the distance was associated with return trips from customers to the next restaurant. The maximum number of deliveries made by a DD on one day was 27. The mean and median delivery speeds, derived from the time and distance data, were both estimated as 5.5km/hr (3.4 miles per hour) although the time used may include some time at the vehicle (e.g. loading food) and at the customer.

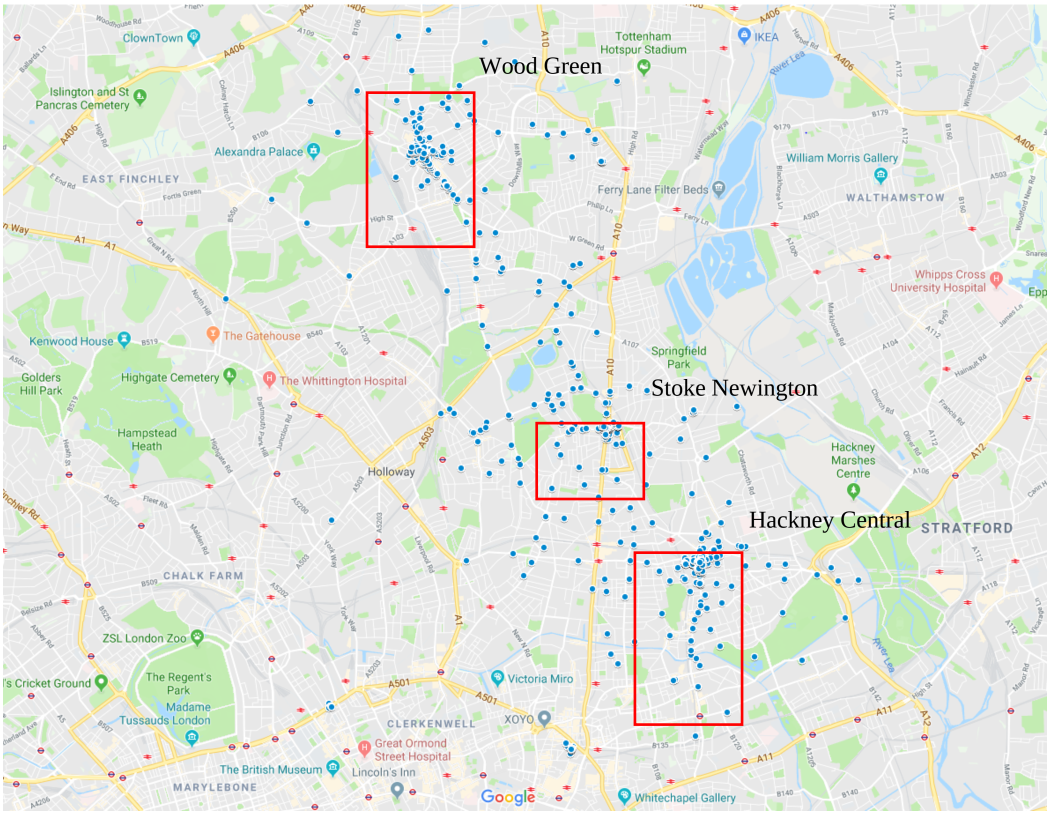
Investigating the number of days worked by each DD revealed a broad spectrum, ranging from 1 day only (3 DDs) to 56 days out of the 60 working days in November/December (2 DDs). Of the 85 DDs studied in July, 25 were no longer working in November/December and 50 new DDs were introduced in the latter dataset, suggesting the relatively high turnover rates associated with this type of work.

Table 1. Delivery driver statistics related to food delivery activity associated with one platform provider for July 2017 (85 DDs) and November/December 2017 (110 DDs) in London

		July		Nov/Dec	
		mean	median	mean	median
Number of jobs per DD day		7.5	7	9.6	9.0
Percentage of days worked per DD		57%	67%	51%	56%
Duration (hh:mm)	Individual one-way delivery trip	00:19	00:17	00:25	00:25
	Daily one-way delivery trips total	02:27	02:15	03:21	03:42
	Work session (includes time between trips)	06:31	07:06	06:53	07:05
Distance (km)	Individual one-way delivery trip	2.0	2.0	2.2	2.2
	Daily one-way delivery trips total	16.0	14.8	20.9	20.4
	Work session (includes return trips)	29.4	27.3	41.3	38.9
Delivery speed (km per hour)		5.4	5.4	5.6	5.6

Investigating restaurant collection times across the November/December dataset demonstrated an evening peak profile, with 63% of all meals (n=22,100) being collected between 17:00 and 22:00 with lunchtime activity being substantially lower by a factor of 2.75 until 16:00, when the evening peak starts to build. There was minimal activity in the morning and after 23:00.

Research by Juhari (2018) attempted to quantify the likely total number of DD journeys originating from all the 'on-demand' delivery platforms used by three individual fast food outlets (part of a national chain) located in Wood Green, Stoke Newington and Hackney Central. Figure 3 shows the origin points of meals destined for delivery from all outlets in the dataset across these three areas of London (red squares), highlighting the density and number of restaurant and fast food outlets engaged in home delivery. The data from the 10th to the 30th July 2017 suggested that each of the three restaurants generated 26.7 (Wood Green), 24.3 (Stoke Newington) and 24.8 (Hackney Central) delivery orders via the platform per day on average (Wood Green (SD 12.7, Min 8, Max 51); Stoke Newington (SD 12, Min 1, Max 47). Of interest is the number of online orders placed with these restaurants across all the platforms used, in this case, Just Eat, Deliveroo, Uber Eats and Hungry Panda. From a survey of restaurants and fast food outlets in Southampton (n=18), the use of 'on-demand' delivery platforms was made up of Just Eat (24.7% of orders), Deliveroo represents 39.9%, Uber Eats is 8.6%, Hungry Panda is 6.7% and an outlet's own system, 19.4% (Juhari, 2018). Using these figures, the results suggested that the three restaurants, who all took online delivery orders via multiple platforms may have delivered 70.5 (Wood Green), 64.2 (Stoke Newington) and 65.5 (Hackney Central) orders per day on average.



Green, Stoke Newington and Hackney Central areas of London between the 10th and 30th July 2017.

Transport intensity and greenhouse gas emissions from meal deliveries

Using the delivery data provided by the major platform provider together with interviews with managers and DD drivers about their operations and parking strategies and generalised vehicle emissions factors, an analysis was carried out of: i) the GHG emissions per tonne of delivered product, and ii) the transport intensity (expressed in terms of the distance travelled along with the road and kerbside parking space occupied per tonne delivered) associated with meal deliveries in London by vehicle type (Table 2).

The results indicated that although the distance travelled per tonne delivered (4,000 km) is the same for all vehicle types (given that the journey distance and load are the same in each case), mopeds (340kg of CO_{2e}) and cars (716kg of CO_{2e}) have far greater impacts in terms of GHG emissions per tonne delivered compared to bikes (64kg of CO_{2e}). Similarly, road and kerbside occupancy levels were greater for mopeds (1.6m^2 and 323 m^{2}hrs/tonne) and cars (8.1m^2 and 1620 m^{2}hrs/tonne) compared to bikes (1.2m^2 and 0 m^{2}hrs/tonne) with the latter either taken direct to the door or parked on the footway during collection and delivery. The results suggested that mopeds and cars emit, respectively, 5 and 11 times more GHGs per meal delivered than bicycles. The far greater length and width of a car results in it occupying approximately five times greater road space when travelling, and five times greater kerbside occupancy than a moped.

Table 2. GHG emissions and transport intensity of meal deliveries in London studied

Vehicle used	**GHG emissions per tonne of product delivered (kg of CO_2e/tonne)**	**Distance travelled per tonne of product delivered (km)**	**Road space occupied by vehicle (m^2)**	**Kerb occupancy by vehicle while parked per tonne delivered (m^2hrs/tonne)**
Bicycle	64	4,000	1.2	0
Moped	340		1.6	323
Car	716		8.1	1,620

Notes:
All journeys assumed to be point-to-point involving a single meal transported from restaurant to delivery point; assumed average each-way journey distance of 2 km.
Average of collection time of 10 minutes at restaurant which includes waiting between jobs, and average delivery time of 2 minutes at customer address.
Bicycles parked on the footway not kerbside during delivery or collection.
Average meal weight assumed to be 1 kg.
CO_2e generalised vehicle emissions data per km for bicycles, mopeds and cars (DBEIS and DEFRA, 2017; European Cyclist's Federation, 2017). Bicycle g CO_2 e/km based on extra food and drink consumption of a cyclist compared to a moped, car or van driver.

A comparative assessment of the GHG emissions and transport intensity (in terms of distance driven per tonne delivered and kerbside space occupancy of the vehicle) for a selection of vehicle types used in on-demand meal deliveries and various other London-based freight transport operations including other on-demand sectors of grocery and parcel deliveries, as well as general freight transport operations using rigid and articulated heavy goods vehicles (HGVs) was conducted. The results (Table 3) indicate the comparative transport and GHG inefficiency of meal delivery compared with other forms of on-demand deliveries and general freight operations due to the transport activity being dedicated to such a small quantity of goods. Meal deliveries are responsible for far greater distances travelled and GHG emissions per tonne delivered than on-demand delivery of groceries, parcels and general freight operations using HGVs. A meal delivered by car is responsible for approximately 1300 times the distance travelled and 200 times the GHG emissions of an articulated HGV operation per tonne delivered. In addition, the vehicles used for meal delivery emit approximately 7-80 times more GHGs per tonne of product delivered than a rigid HGV. The results indicate that meal deliveries using cars and mopeds also result in far greater kerbside space and time occupancy than the other freight transport operations and vehicle types with which they have been compared.

Table 3. GHG emissions and transport intensity of journeys taking place wholly within London

Freight sector	Vehicle type	Km travelled per tonne of product delivered	GHG emissions per tonne of product delivered (kg CO_2/tonne)	Kerb occupancy by vehicle while parked per tonne delivered (m^2hrs/tonne)
Hot meal on-demand same-day delivery	Bicycle	4,000	64	0
	Moped		340	323
	Car		716	1,620
Grocery on-demand same-day delivery	Moped	1,600	136	22
Grocery next-day delivery	Van	100	33	48
Parcel next-day delivery	Van	44	12	127
General freight operations	Rigid HGV	11	9	6
	Articulated HGV	4	3	2

Notes:
Vehicle dwell times and journey lengths for meal deliveries and other on-demand deliveries (i.e. grocery and parcel) gathered from survey work carried out in the FTC2050 project (Allen et al., 2018b).
HGV data sources: vehicle kms and trip lengths in London disaggregated from DfT Continuing Survey of Road Goods Transport (CSRGT) (Browne et al., 2014), and vehicle dwell times (Cherrett et al., 2012).
Assumed vehicle load weights at start of journey based on company interviews and CSRGT data: Meal delivery – 1 kg; next-day grocery delivery – 200 kg; next –day parcel delivery – 450 kg; rigid HGV - 4 tonnes; articulated HGV - 15 tonnes.
CO_2e generalised vehicle emissions data for bicycles, mopeds, cars, vans, HGVs (DBEIS and DEFRA, 2017; European Cyclist's Federation, 2017).

Analysis into the GHG emissions and transport intensity of having meals delivered from restaurants and fast food outlets compared with consumers purchasing food in grocery supermarkets by car as part of their weekly shop and then cooking this food at home (Table 4) indicated that the combined transport and cooking energy for a meal delivery by moped or car is far greater than if a consumer purchases the ingredients themselves by car and cooks them at home (approximately 2-3 times greater in the case of a chicken meal and 2.5-4.5 times greater in the case of pizza for the specific cases studied). Meal delivery by bicycle and car-based weekly shopping and home cooking were estimated to produce similar GHG emissions. Meal delivery options are also worse than personal shopping by car in terms of distance travelled by road by a factor of 20, and in the case of deliveries by car or moped result in additional demand for kerbside space.

Table 4. Comparison of GHG emissions and transport intensity of meal delivery with food purchased from shop by car and cooked at home

Meal type	Method of deriving meal	Vehicle Type	Cooking (kg CO_2e per meal)	Transport (kg CO_2e per meal)	Cooking plus transport (kg CO_2e per meal)	Vehicle km travelled per tonne delivered	Kerbside parking required at delivery point?
Pizza	Meal delivery from restaurant / fast food outlet	Car	0.15	0.72	0.87	4,000	Yes
		Moped	0.15	0.34	0.49	4,000	Yes
		Bicycle	0.15	0.06	0.22	4,000	No
	Personal supermarket weekly trip and cook at home in oven	Car	0.15	0.04	0.19	200	No
Chicken	Meal delivery from restaurant / fast food outlet	Car	0.31	0.72	1.02	4,000	Yes
		Moped	0.31	0.34	0.65	4,000	Yes
		Bicycle	0.31	0.06	0.37	4,000	No
	Personal supermarket weekly trip and cook at home in oven	Car	0.31	0.04	0.34	200	No

Notes:
Vehicle trip distances: restaurant to home and supermarket to home – both assumed to be 2km each-way trip based on analysis of platform provider meal delivery data and consumer shopping data (Department for Transport, 2019).
Weight of goods purchased: supermarket shop by car – assumed 20kg of goods purchased, 1kg of which is the meal. Meal delivery assumed to weigh 1kg.
CO_2e generalised vehicle emissions factors (DBEIS and DEFRA, 2017; European Cyclist's Federation, 2017).
Oven cooking time assumptions: pizza – 10 minutes; chicken 20 minutes. Home electric oven of 2400 kWh assumed; cooking CO_2e emissions factors (DBEIS and DEFRA, 2017). Research indicates that home cooking and restaurant/fast food outlet cooking have same energy requirements as although restaurants may cook more meals at a time, ovens are left on between cooking of meals (Calderón et al., 2018).

DISCUSSION OF PLANNING POLICY ISSUES AND IMPLICATIONS

The analysis carried out indicates that meal deliveries are extremely intensive in terms of road traffic and GHG emissions per tonne of product carried compared with other, more traditional forms of urban road freight transport. Considering the three vehicle types used for meal deliveries, namely bicycle, moped and car, bicycles are more efficient in terms of road space occupied, GHG emissions emitted, and kerbside space and time occupancy per tonne of product delivered compared to mopeds and cars. The latter is due to the fact that DDs do not leave their bicycles at the kerbside when making the delivery to the door. However, given the levels of pedestrian demand for pavement space in dense urban areas, and the fact that some national chain restaurants can have in excess of 70 home delivery transactions per day on average, the wheeling or leaving of bicycles on the pavement while collecting or making the final delivery could result in negative implications for pedestrians.

The analysis also indicates that the combined transport and cooking energy for a meal delivery by moped or car is far greater than a consumer purchasing ingredients in person at a shop using a car and then cooking them at home. Meal delivery by bicycle compared with car-based weekly shopping and home cooking were calculated to produce similar GHG emissions. The analysis suggests that urban policymakers should encourage and promote the use of bicycles over other vehicle modes for meal deliveries. This can be achieved through the provision of dedicated cycle lanes and restrictions and charging regimes for other vehicles. However, careful policy consideration needs to be given to locations in which these bicycles can be safely left while deliveries to customer's properties and collections from restaurants are made so as not to negatively impact pedestrians, especially those who are mobility- or sight-impaired. In cases in which DDs are found to be riding bicycles on the pavement whilst accessing customer's properties it may also be necessary for policy makers to consider whether existing traffic regulations prohibit such activity, as well as suitable methods of prevention. This may include working with platform providers to ensure adequate training is provided to DDs together with approaches to traffic regulation enforcement that can be adopted. Such enforcement can be difficult to implement in the case of cyclists given the typical lack of vehicle and driver registration and suggests a reconsideration of the need for such registration if cyclist deliveries continue to grow rapidly and result in such difficulties for pedestrians.

Given the vehicle types involved and the type of delivery, meal orders are not typically considered part of freight transportation by urban policymakers. However, as this paper has demonstrated, this particular sector is growing rapidly in cities internationally and is forecast to continue. Drawing on the findings presented, policymakers should discourage the use of fossil fuel-powered mopeds and cars for these meal delivery journeys. Even in suburban settings, where journey distances may be longer compared to those in a city centre, or in cities with substantial gradients, use of electrically-assisted bicycles and electric mopeds should be encouraged by policymakers in preference to fossil fuel-powered vehicles. Greater capital costs, recharging and overnight storage requirements may hinder the affordability and uptake of electrically-assisted bicycles and electric mopeds but policymakers should consider ways in which they can help support and encourage their use through the use of vehicle grants and the provision of charging infrastructure and vehicle storage facilities. Such an approach would align with current policies to promote active travel (i.e. the use of walking and cycling), which are usually directed at passenger transport, but in this case could also be promoted in terms of freight transport.

The research has indicated the greater risks that meal DDs using bicycles and mopeds face in the course of their work compared to delivery workers using cars, vans and lorries. Policymakers should consider the cycling and moped training schemes and road safety promotion campaigns they already have in place and whether these can be supplemented and tailored to include meal DDs. Thought should also be given by policymakers to ways in which they could work more closely with the meal platform providers that provide work to these DDs to encourage their greater involvement in such training schemes and the promotion of safe practices and traffic awareness while making deliveries.

Meal deliveries can be responsible for substantial vehicle trips at the restaurants and fast food outlets at which these journeys originate. Policymakers need to carefully review complaints received from residents living in close proximity to such businesses in terms of vehicle trip generation rates and related problems such as noise disturbance and vehicle parking. This can involve reviewing whether the provision of delivery services from these locations is in breach of existing planning conditions that the business is already subject to. If such problems become more commonplace and escalate as meal delivery services grow, it may well become necessary for policymakers to include further consideration of meal deliveries in their strategic reviews of planning conditions. This may include specific requirements concerning the provision of suitable facilities including on-site toilets, litter bins, and quiet waiting areas away from residential properties for DDs to use in order to decrease noise and kerbside waiting. It may also require greater scrutiny of planning and change of use applications that are liable to result in restaurant facilities likely to generate substantial DD activity in unsuitable locations close to residential accommodation.

The employment status of meal DDs has an important bearing on their rights in terms of holiday pay and entitlement, sickness pay and pensions. Current scrutiny of these issues in the meal delivery sector and more widely in the gig-economy in several countries by policymakers responsible for employment legislation has the potential to have an important bearing on improving the working conditions and road safety and behaviour in this field of freight transport. Such action, in terms of ensuring that DDs have worker or employed status rather than being self-employed, would also be likely to improve their access to company training schemes.

Although the findings of this paper indicate that meal deliveries are relatively inefficient compared to other forms of urban freight transport, as well as to consumers purchasing food in shops and cooking it in their own homes, national and local government has so far not chosen to single out particular lifestyle choices concerning consumption and delivery behaviours and subjecting these to specific regulations or taxes. This remains a future option for policymakers in the form of additional taxation imposed on operators or consumers of delivery services that are deemed harmful to wider society. Examples exist in the form of taxation on cigarettes, alcohol, sugary foods and plastic bags imposed at a national level in various countries.

Policymakers also need to monitor the use of pavement droids for urban meal deliveries, which some operators have been experimenting. The use of such droids raises important questions for policymakers in terms of their safety to other footway users, especially in busy locations. Droid use also raises issues concerning the potential for vandalism and theft for operators, so are likely to remain uneconomic compared with using human low-wage labour for some time. Urban policymakers also need to keep a watching brief on the potential use of aerial drones for meal and other deliveries. Aerial drones offer potential for savings in journey times, road traffic levels and emissions over conventional road vehicles for meal deliveries (Orda, 2017; Slide, 2016), however, there are substantial security and safety barriers to their use for such a purpose in urban areas. Given these difficulties it seems unlikely that such delivery technologies will enter mainstream use for meal delivery in the near future.

CONCLUSIONS

Meal deliveries to homes and workplaces in cities are growing rapidly and are forecast to continue to do so. Given the relatively small numbers of such freight transport trips in the past, and the extensive use of unconventional vehicles, namely mopeds and bicycles, in delivering these goods, policymakers have not traditionally paid attention to this component of urban freight transport.

Using a substantial database of 40,941 meal deliveries made by 195 DDs by a platform provider over a three-month period in Greater London, this paper quantifies these impacts and discusses the transport and environmental implications of such activity along with the policy options for mitigating the negative impacts. The results suggested that the vast majority of DDs (83%) used a moped, with 10% and 7% using a car and bicycle respectively. On average, 9.6 deliveries were undertaken by a DD daily, with each taking 25 minutes from pickup to delivery with an average trip length, from restaurant to customer of 2.2km (1.4 miles) and a DD travelling 41.3km (25.7 miles) in total per day. Around 49% of the DDs' time was found to be productive (making deliveries) during a typical day in November/December.

The case study findings suggested that mopeds (340kg of CO_2e/tonne) and cars (716kg of CO_2e/tonne) emit, respectively, 5 and 11 times more GHGs per meal delivered than bicycles (64kg of CO_2e/tonne) and, with some national fast-food outlets generating on average 70 deliveries per day, there are growing concerns around the transport intensity of these activities. With a meal delivered by car being responsible for approximately 1300 times the distance travelled and 200 times the GHG emissions of an articulated HGV operation per tonne delivered in the case study, there is a need for policy makers to promote the use of electric modes in this sector.

This paper has demonstrated that this urban freight transport sector is growing rapidly and is inefficient in terms of distance travelled, GHG emissions and kerbside space and time occupancy per tonne of product delivered when carried out using mopeds and cars. The results indicate that the delivery of meals using bicycles is far less transport intensive (in terms of road and kerbside space occupancy) and should be encouraged over these other vehicle types.

Policymakers should take meal deliveries into account in their future urban freight transport strategies and policy planning. Interventions should aim to discourage the use of fossil fuel-powered mopeds and cars for these journeys, and instead promote the use of conventional and electrically-assisted bicycles and electric mopeds. Policy makers have an important role to play in terms of ensuring adequate provision of road safety training, especially for moped and bicycle meal DDs, as well as in taking actions to help minimise the negative impacts of trip generation associated with the restaurants and fast food outlets from which these trips are generated.

The analysis carried out in this paper into the delivery operations and transport and GHG impacts of meal deliveries in London are, as far as the authors are aware, the first time such work has been carried out. Despite the scale of meal deliveries included in the dataset, the case study has the obvious limitations that the operational analysis was based on one meal delivery platform working in a single city. Research into this topic would benefit from other similar studies being carried out among other companies in other cities and countries to provide evidence of similarities and differences in these operations and their transport and environmental impacts. It would also be helpful to be able to track the evolution of these operations over time to understand the extent to which they remain the same or change as meal demand and related delivery activity levels grow.

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