Transportation Research Part D 63 (2018) 514–532

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

The environmental social cost of urban road freight: Evidence from the Paris region

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ARTICLE INFO

Keywords:
Environmental economics
Urban freight
Air quality
Climate change
Paris region

JEL classification:
Q51
Q53
Q54
R41

ABSTRACT

This paper investigates the environmental impact of urban road freight in the Paris region, focusing on pollutant emissions. We develop a modeling chain including a freight demand model, a multiclass traffic assignment model, and a road emission model. This allows for a detailed representation - spatially and with regard to operations - of urban road freight. We find that while urban road freight represents only 6% of trips and 8% of distances traveled by road in the Paris region, it accounts for 36% of total damages caused by pollutant emissions from road traffic. This is the combined result of light and heavy goods vehicles emitting more than private cars, and of freight traffic being more spatially concentrated (within the city center) than passenger traffic, thereby affecting more population. All in all, the environmental cost of urban road freight is around 2.1 billion € per year. Some policy implications are discussed.

1. Introduction

Urban freight today faces a paradox. On the one hand, picking-up and delivering the right volume of goods to the right place at the right time has become increasingly crucial to the functioning of cities (OECD, 2003; Dablanc, 2009; Macharis and Melo, 2011). On the other hand, economic and technological constraints (Cullinane and Toy, 2000; Holguin-Veras, 2002; Comi et al., 2012) lead freight operators to resort massively to road transport. Urban road freight (URF) is therefore accused of contributing substantially to environmental nuisances in cities, and more generally to degrading urban livability through its impact on congestion, traffic safety, or the use of public space (OECD, 2003; Cui et al., 2015; CIVITAS, 2015), leading public authorities to enforce policies aimed at making URF more sustainable (*e.g.* road pricing, low emission zones, incentive mechanisms to promote off-hour deliveries or the use of electric vehicles; Holguin-Veras et al., 2006; Mirhedayatian and Yan, 2018; Demir et al., 2014; Cui et al., 2015; Russo and Comi, 2016; Ellison et al., 2013).

While data collection efforts have been engaged over the last decade (Toilier et al., 2016; Allen et al., 2010; Holguin-Veras and Jaller, 2014), a fine knowledge of urban road freight is still lacking to corroborate the claims regarding its alleged environmental impact. As opposed to private car (PC) trips - for which information from households travel surveys (and increasingly from big data

Abbreviations: BPR, Bureau of Public Roads; HGVs, Heavy Goods Vehicles; IdF, Île-de-France (the administrative region including Paris); LGVs, Light Goods Vehicles; OD, Origin-Destination; PCs, Private Cars; tkm, ton-kilometers; URF, Urban Road Freight; VDF, Volume-Delay Function; vkm, vehicle-kilometers; VOC, Volume-Over-Capacity

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https://doi.org/10.1016/j.trd.2018.06.002

sources) is available -, authorities are rarely aware of distances traveled by LGVs and HGVs (Light/Heavy Goods Vehicles) and urban freight origins and destinations within their jurisdictions (EC, 2013; CIVITAS, 2015). First, the commercial nature of URF implies information privacy in most countries. Second, traffic sensors usually cover but a small share of the road network and cannot distinguish LGVs from PCs. Last, organizational features of URF (*e.g.* direct or round trips) make its observation complex. Assessing precisely the environmental impact of URF consequently remains a major challenge to date, be it for public stakeholders or the academic community.

This paper aims to bridge the gap between common beliefs about the environmental impact of urban road freight and its empirical measurement, focusing on pollutant emissions.[1]

We develop a modeling chain that enables us to estimate travel demand for URF and the resulting emissions for up to 30 pollutants. This includes greenhouse gas emissions, firstly carbon dioxide (CO_2), which by contributing to global warming lead to several adverse economic effects (Tol, 2009), as well as local pollutants such as nitrogen oxide (NO_x) or fine particulate matter (PM_{10}), which may endanger the health of exposed populations (Kampa and Castanas, 2008; WHO, 2016). Using this modeling chain, we estimate the environmental social cost of URF for a major metropolitan area.[2] Accounting for 18% of the French population and 30% of the national GDP in 2012, the Paris region is one of the wealthiest areas in Europe, but also one of the most heavily congested (Inrix, 2014). Concerns related to air pollution are nowadays of major interest to elected officials (IdF, 2016) and to the population (EC, 2016). As a consequence, it seems relevant to specify the magnitude of environmental social losses caused by urban road freight.

This paper extends the vast body of literature on the environmental impact of road traffic (see the survey by Shorshani et al. (2015), or specific case studies by Xia and Shao, 2005; Tirumalachetty et al., 2013) by specifying the contribution of URF. This is especially relevant inasmuch as freight transport and passenger transport are typically subject to distinct transport policies considering economic, technological and organizational differences between the two. From a methodological point of view, our modeling chain represents URF with a great level of detail regarding operations as well as the spatial resolution. While freight trip generation is now well addressed, from delivery models to commodity flow based models (Boerkamps and van Bisbergen, 1999; Munuzuri et al., 2009; Nuzzolo et al., 2012), trip distribution has seldom been addressed as, unlike for passenger travel, it cannot be treated using gravity models: one product can travel through several warehouses, in various vehicles and packaging types (Ogden, 1992). An original method such as provided by the Freturb model (Routhier and Toilier, 2007) is therefore needed. The proposed modeling chain allows to estimate freight travel demand for an entire metropolitan area (and not for a single economic site as in Aditjandra et al., 2016), while taking into account the main specificities of URF, such as the distinction between direct and round trips or between own-account and third party operations (unlike Kanarogou and Buliung, 2008). In contrast to previous environmental economics studies carried out at a national scale (*e.g.* Muller and Mendelsohn, 2007), the fine spatial resolution at the municipality level allows accounting for the greater damages of air pollution in dense areas where more population is exposed, as established by the “Impact Pathway Approach” developed in the frame of the European ExternE research project (Friedrich and Bickel, 2001). This proves especially important in the case of urban road freight, as we find it to be more spatially concentrated than passenger private transport, combined with the fact that density levels strongly vary within the Paris metropolitan area.

The rest of this paper proceeds as follows. Section 2 describes the methodology, and Section 3 the data. Section 4 presents the main results which are discussed in Section 5. Section 6 concludes.

2. Methods

The methodology involves two main steps (Fig. 1)[3]: estimating first pollutant emissions, then the environmental social cost of road traffic. Four classes of vehicles are distinguished throughout computations - PCs, LGVs, and HGVs (rigid and articulated)[4] -, allowing us to isolate at each step the contribution of URF.

We start by estimating travel demand related to URF. Based on the characteristics (industry sector, size, premises, etc.) and the spatial distribution of firms within the Paris region, the Freturb-Simetab models (Routhier and Toilier, 2007; Gardrat et al., 2014) estimate generation coefficients (number of weekly deliveries and pick-ups) for all firms, then the resulting travel demand. The corresponding outputs are Origin-Destination (OD) matrices, disaggregated according to the three freight vehicle classes (LGVs and rigid/articulated HGVs). Next, combining the OD matrices for URF and PCs,[5] with transport costs parameters and the road network characteristics, we compute the multi-class traffic equilibrium (Dafermos, 1972) using the TransCAD software. Reflecting strategic interactions among drivers during route choice, it is essentially similar to a Nash equilibrium (Correa and Stier-Moses, 2011). This gives us for each road link the traffic flow, its composition by vehicle class, and the average vehicle speed. These data are finally fed to the Copcete model (Demeules and Larose, 2012). Taking into account the vehicle type, the traffic speed, the technological composition of the vehicle fleet, and so on, Copcete provides estimates of pollutants emitted by each vehicle class, again at the road

[1] French official guidelines (CGSP, 2013) suggest that in the case of road traffic, losses linked to climate change and air pollution largely prevail over other environmental nuisances (*e.g.* noise). Accordingly, the latter are not considered in this paper; neither are social losses linked to traffic safety or to the use of public space.

[2] In this paper, we use the term “environmental social cost” to refer to the specific part of the social cost (of road traffic) related to pollutant emissions (CO_2, NO_x and $PM_{2.5}$).

[3] The detailed methodology is described in Appendix A.

[4] The distinction between LGVs and HGVs is based on the UE definition, i.e. whether the gross combination mass is below or over 3.5 t.

[5] Considering the focus of our paper, the passenger travel demand model used to generate the OD matrices for private cars is not presented; rather, we treat the OD matrix for PCs as an exogenous input. See Section 3.2 for more details.