Congestion caused by urban freight

Research Brief 1.1c

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Project Objective

Although road congestion caused by freight activities is often pointed out as a major issue, few studies model time losses at a macroscopic level within a "multi-class traffic" framework. This research proposes such empirical assessment for the Paris region, using a simple method based on individuals' trip durations. We seek to highlight varying and reciprocal congestion impacts (time losses caused by trucks on light vehicles, and *vice-versa*), which is not common in the literature.

Problem Statement

Academic research has mostly focused on the effects of large vehicles (trucks) on small vehicles' (cars' and vans') travel times, especially with the use of "private car equivalency factors". By contrast, few studies deal with the "reciprocal" phenomenon, where cars and vans may disturb the travel time of trucks. Moreover, traditional approaches for measuring road congestion mostly rely on simulated traffic data or on count data collected for a limited portion of the road network. This questions the transferability of traffic models, between urban areas as well as different places within a given agglomeration.

We here investigate road congestion at a "macro" level, using information available in most urban areas. Since our simple method provides consistent results, it could be transferred to other cities. In addition, the Paris region is one of the most congested areas in Europe but the contribution of freight trips to these aggregate time losses has been largely under-researched. Because truck traffic on French local networks is "underpriced" as compared to its social cost, this research provides parameters useful for policy appraisals.

Research Methodology

To investigate reciprocal congestion, we estimate a reduced form of a classical multi-class "volume-delay function." The originality is here linked to the introduction of interaction terms showing the differentiated responses of small vehicles' travel times to surrounding traffic conditions, as compared to trucks' travel times:

$$\ln(D_{ikt}) = \mu_0 + \mu_1 \ln(D_{ik}^0) + \mu_2 \ln\left(\frac{F_{iSkt}}{K_{ik}}\right) + \mu_3 \ln\left(1 + \frac{F_{iLkt}}{F_{iTkt}}\right)$$

$$+ I_i^{\,S}\left[\hat{\mu_1} \ln(D_{ik}^0) + \hat{\mu_2} \ln\left(\frac{F_{iSkt}}{K_{ik}}\right) + \hat{\mu_3} ln\left(1 + \frac{F_{iLkt}}{F_{iTkt}}\right)\right] + \mu_4 X_{ikt} + \varepsilon_i$$

where D_{ikt} is the time spent by the individual i over OD k during the time period t; D_{ik}^0 is the minimal travel time if roads were empty; $(^{F_{iSkt}}/_{K_{ik}})$ describes the "flow-to-capacity ratio" of small vehicles faced, on average, by the traveler i; $(1 + \frac{F_{iLkt}}{F_{iTkt}})$ is the share of large vehicles within total road traffic met by the traveler i and the vector X_{ikt} includes control variables suspected to influence the travel duration.

To fix ideas, suppose that individual i is driving a car. In that case, the influences of minimal travel time, of the small vehicles and large vehicles traffic on his own travel time will be equal to $(\mu_1 + \hat{\mu_1})$, $(\mu_2 + \hat{\mu_2})$ and $(\mu_3 + \hat{\mu_3})$ respectively. By contrast, if individual i is driving a truck ($I_i^{\,S} = 0$), respective elasticities are μ_1, μ_2 and μ_3. As a consequence, $\hat{\mu_1}$, $\hat{\mu_2}$ and $\hat{\mu_3}$ can be considered as "sensitivity premiums".

To test this model empirically, we combine various data sources. Information on road capacities and speed limits in the Paris region comes from a GIS ("BD Topo"). We only focus on the main roads and we consider a total network of 6,200 km. Information on private passengers' travel characteristics comes from the regional household mobility survey ("Enquête Globale Transport") which was administered to a representative sample of 18,000 households and 143,000 trips for over a week in 2011. Lastly, we rely on the urban goods movements survey (UGMS), administered in 2010 by the Laboratory of Transport Economics. A total of 345 freight tours were observed with an embarked investigator and broken down into 2,000 freight trips. We work with a final sample of 39,500 usable trips for which we enjoy many variables.

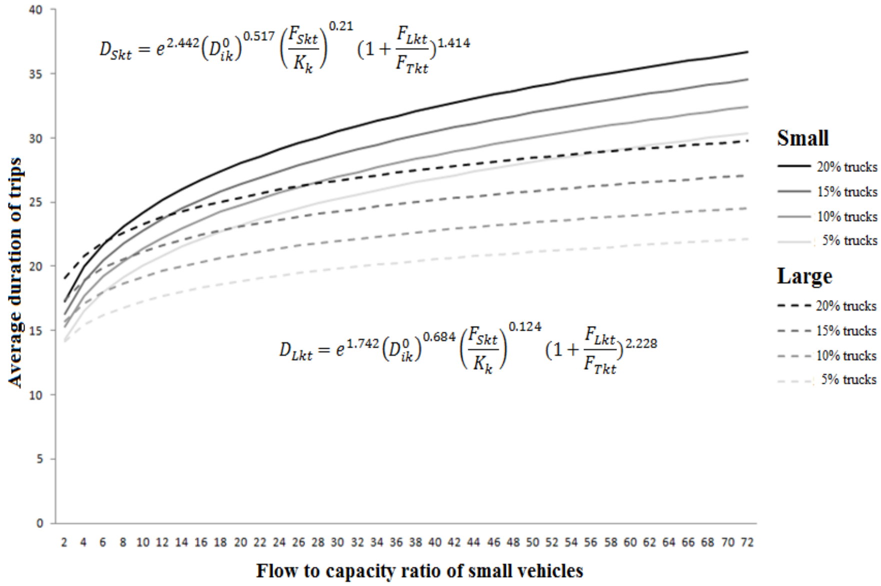
Numerical Results

Econometric estimates are rather satisfactory and explain around 70% of observed travel times' variations. Above all, they confirm that congestion effects are not homogeneous across vehicle classes. The signs of the sensitivity premiums are negative for the minimum duration variable and for the one describing the road demand of large vehicles: For a given trip - characterized by maximal speed, travelled distance and trucks flow -, small vehicles travel faster than large vehicles. By contrast, the positive sign of the interaction term with the "flow-to-capacity ratio" of small vehicles stipulates that cars and vans are more disturbed by the surrounding flow of small vehicles than trucks.

Figure 1 illustrates these differentiated congestion impacts, which depend on whether the individual is driving a small or a large vehicle. If trucks represent 5% of total traffic, the travel time of small vehicles increases from 15 minutes when road demand is insignificant to 27 minutes

(20 minutes for large vehicles) when the "flow-to-capacity ratio" of small vehicles is 70%. Contrasting the slopes of both functions, we see that cars or vans are more sensitive than trucks to the "flow-to-capacity ratio" of small vehicles.

Figure 1



Crossing these results with costs parameters, we are finally able to estimate, and to decompose, marginal external costs of congestion, for various vehicle classes. As made clear in Table 1, trucks generate the largest external costs (7.397 euros/vkm). Nearly 89% of these time losses are inflicted to private cars, 4% to vans and 7% to trucks. By contrast, the congestion impact of one additional car is more important for other private passengers than for trucks (94% of the external cost is inflicted to cars vs. 2% to trucks). Further research should build on these results to investigate optimal pricing schemes or socioeconomic appraisals of transport projects aimed at reducing trucks traffic in the Paris region.

Table 1 – External costs of congestion

	Passenger Vehicles				**Light Goods Vehicles**				**Heavy Goods Vehicles**			
Caused to	*All*	*PV*	*LGV*	*HGV*	*All*	*PV*	*LGV*	*HGV*	*All*	*PV*	*LGV*	*HGV*
External (eu/vkm)	1.051	0.983	0.047	0.022	1.077	1.012	0.042	0.023	7.397	6.607	0.274	0.515
		(93.5%)	*(4.5%)*	*(2.0%)*		*(94.0%)*	*(3.9%)*	*(2.1%)*		*(89.3%)*	*(3.7%)*	*(7.0%)*
Private (eu/vkm)	0.854	-	-	-	0.604	-	-	-	1.173	-	-	-
Social (eu/vkm)	1.905	-	-	-	1.681	-	-	-	8.570	-	-	-
Ext. as % of social	55.2	-	-	-	64.1	-	-	-	86.3	-	-	-