Estimating the direct <u>and</u> indirect impacts of off-hour deliveries

Exploratory results from the City of Lyon, France

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Research statement

- A focus of city logistics public policy makers has been to reduce the number of kilometers travelled by freight vehicles, especially during peak hours
- As a result, Off-Hour Delivery (OHD) schemes have been an important topic in the recent literature (Verlinde, 2015; Holguín-Veras et al., 2016)
- OHD is a relevant policy due to its potential positive impacts:
  - Lower congestion levels, especially during passenger peak-hours
  - Higher speeds for freight vehicles during operating hours, which translate into lower CO2 emissions per travelled km
  - Higher speeds also allow for optimization of delivery rounds: more deliveries per round, fewer travelled kilometers per deliveries, and lower carrier costs
  - Better quality of service for freight recipients
  - Less stress for drivers
- However, it could be argued that OHD may also have negative <u>induced</u> effects on passenger road transport, at least in the medium term… Intuitively:

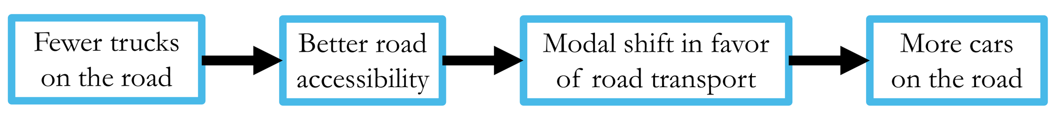

Figure 1 : Theoretical induced effects of large scale OHD schemes on passenger transportation

<u>In this paper, we propose a macroscopic simulation of an extreme scenario</u>

All road freight deliveries are diverted to the night-time (9pm – 6am).

We propose an environmental assessment (carbon footprint) of both freight <u>and</u> passenger road transport in two scenarios: Business-as-Usual (BAU) and full-OHD.

Theoretical Framework

The available scientific literature provides plenty of examples of models taking into account passenger & freight flows, as well as the relationship between agents (firms and persons), their location choices, and their mobility choices. LUTI models (Land-Use Transportation Interaction), especially, provide an interesting theoretical framework for such analyses.

In LUTI models, agents' location choices are explained, in part, by an area's accessibility level. This accessibility is itself explained by the mobility choices of individuals, and the resulting traffic conditions. These choices are made, for a large part, on the basis of the location of individuals, thus forming the famous "land-use transport feedback cycle" described by Wegener (2004).

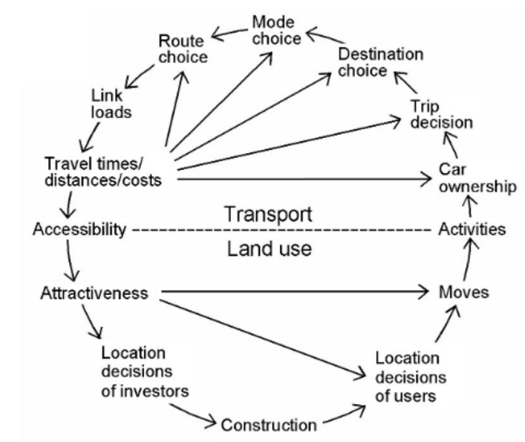

Figure 2 : LUTI models as described by Wegener (2004)

We limit our analysis to specific portions of this cycle: the links between traffic conditions, accessibility and modal choice. Since we focus only on medium-term impacts of OHD, other dimensions (such as location choices, vehicle ownership, mobility behavior) are considered fixed. Therefore, below is the (simplified) framework we analyze:

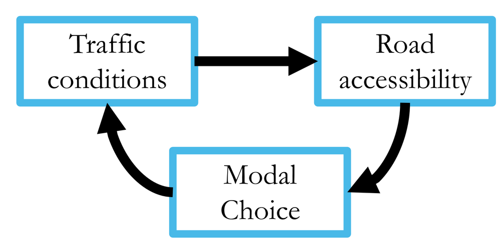

Figure 3 : Simplified theoretical framework

Methodological framework

- The data for this paper is provided by several tools and models:
  - Passenger OD matrices (attraction, distribution and modal choice parameters) are provided by the SIMBAD model, a LUTI model calibrated for the city of Lyon (see Nicolas et al, 2009)
  - Freight OD matrices are generated by the FRETURB model (see Toilier et al, 2018)
  - Trip assignment is performed using the VISUM software
  - The environmental assessment is carried out using a standard emission model, COPERT

  → All tools are calibrated for the city of Lyon, for the year 2011

The methodology involves three steps: (1) simulating traffic conditions if all freight flows were diverted to the night-time, (2) estimating modal choices given these simulated traffic conditions, and (3) measuring CO2 emissions for the new simulated traffic conditions.

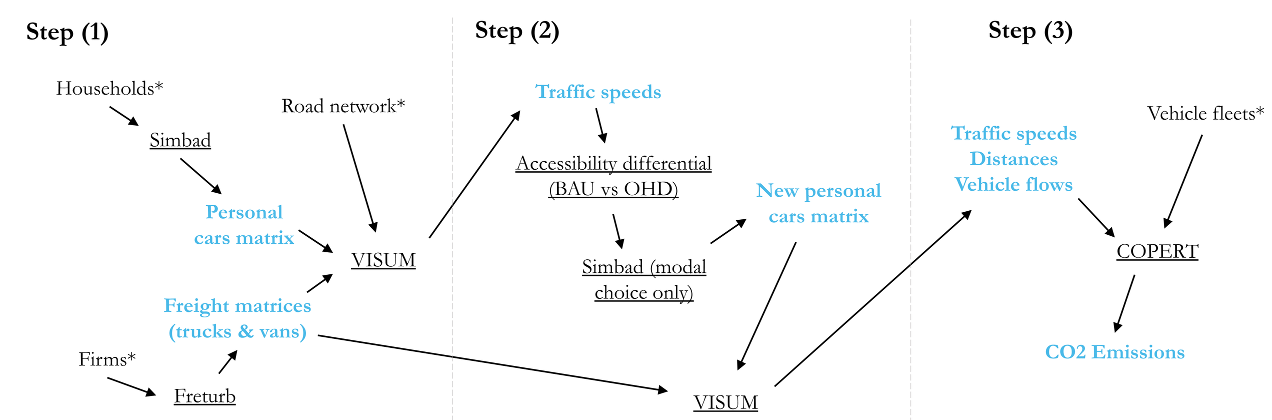

Figure 4: Methodological framework. Exogenous input data are identified by stars; modeling tools are underlined; estimated outputs are bolded in blue. The framework's visual outlook is adapted from Coulombel et al, 2018.

More on the Simbad model

- SIMBAD is a LUTI model calibrated for the city of Lyon
- Location choices of firms and households are simulated using the UrbanSim model (Waddell, 2002)
- Trip generation, distribution, and modal choices are performed at the level of 777 IRIS (the smallest statistical unit in France), for the Lyon urban area, using data from the 2006 Lyon Household Mobility Survey
- Trips are converted into passenger car flows using a vehicle occupancy rate; they are then distributed between peak hours (7-9 am & 5-7pm) and the rest of the day
- Trip assignment is performed by VISUM, which relies on a road network calibrated for the city of Lyon.
- What interests us here specifically is the two-part modal choice equation used in SIMBAD:
  - SIMBAD assigns a mode of transport, between 'soft' and motorized modes, depending on Euclidian distances, travel motives and density level of the IRIS of origin → traffic conditions do not affect this equation.
  - Then, SIMBAD assigns a mode of transport, between personal vehicle and public transit, following equation (1):

$$(MS_{PT})_{ij} = \frac{1}{1+\exp\left(k + \tau_{PT} \,.\, gtPT_{ij} \,.\, \xi_i + \frac{\tau_{PC} \cdot gtPC_{ij}}{\xi_i} + \delta \,.\, d_j\right)} \quad (1)$$

Where:

$(MS_{PT})_{ij}$ is the share of all motorized trips performed between IRIS i & j, using Public Transit

$gtPT_{ij}$ and $gtPC_{ij}$ correspond to the generalized travel times between IRIS i & j for Public Transit and Passenger Cars

ξ_i is the motorization rate of IRIS i at the origin

d_j is the density of IRIS j at destination

k, τ_{TC}, τ_{VP} et δ are coefficients: their values vary with the income level of the household performing the trip, as well as with travel motives

→ Modal share of personal cars will vary depending on traffic conditions (generalized times between i & j for Passenger Cars)

Case study : the Lyon Urban Area

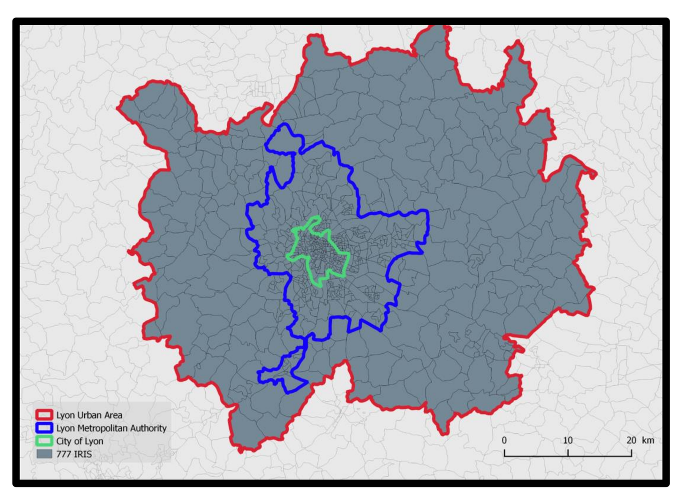

Figure 5 : The Lyon Urban Area, Metropolitan Area and City

	Lyon	Lyon - ML	Lyon - UA	ML	ML - UA	UA	Total
Total trips (k)	**1 070.9**	**898.9**	**89.0**	**1 432.8**	**428.2**	**836.2**	**4 756.0**
Share 'soft' modes (%)	41.0%	12.2%	0.0%	29.4%	2.7%	14.1%	23.1%
Share Public Transit (%)	28.9%	32.1%	16.6%	12.9%	6.3%	1.7%	17.6%
Share Passenger Cars (%)	30.1%	55.7%	83.4%	57.7%	91.0%	84.2%	59.3%
Motorization Rate (No car p. household)	**0.9**	**-**	**-**	**1.2**	**-**	**1.7**	**1.3**
Morning peak-hour (7am - 9am) hourly traffic (k vehicles)	**33.4**	**58.3**	**13.4**	**86.4**	**49.1**	**64.0**	**304.6**
PC % Traffic	83.2%	86.0%	70.8%	86.9%	80.1%	90.2%	85.2%
Vans % Traffic (in PCU where 1 van = 1.5 PC)	8.5%	6.6%	11.2%	5.3%	6.4%	3.9%	6.1%
Trucks % Traffic (in PCU where 1 truck = 3 PC)	8.3%	7.3%	18.0%	7.8%	13.5%	5.9%	8.7%
Afternoon peak-hour (5pm - 7pm) hourly traffic (k vehicles)	**29.7**	**53.0**	**10.9**	**79.3**	**43.1**	**60.1**	**276.1**
PC % Traffic	93.6%	94.6%	86.8%	94.6%	91.3%	96.1%	94.0%
Vans % Traffic (in PCU where 1 van = 1.5 PC)	2.8%	2.3%	4.5%	1.9%	2.4%	1.3%	2.1%
Trucks % Traffic (in PCU where 1 truck = 3 PC)	3.5%	3.1%	8.7%	3.5%	6.3%	2.6%	3.9%
Night (9pm - 6am) hourly traffic (k vehicles)	**6.2**	**9.2**	**1.5**	**15.8**	**6.8**	**12.2**	**51.7**
PC % Traffic	93.7%	93.7%	81.2%	95.1%	90.1%	96.5%	93.9%
Vans % Traffic (in PCU where 1 van = 1.5 PC)	2.8%	3.0%	10.2%	2.7%	6.2%	2.0%	3.3%
Trucks % Traffic (in PCU where 1 truck = 3 PC)	3.5%	3.3%	8.6%	2.3%	3.7%	1.6%	2.8%
Rest of the Day hourly traffic (k vehicles)	**9.3**	**13.7**	**3.7**	**22.1**	**12.5**	**15.8**	**77.1**
PC % Traffic	62.9%	63.1%	31.7%	67.9%	49.0%	74.5%	63.0%
Vans % Traffic (in PCU where 1 van = 1.5 PC)	17.7%	16.4%	23.8%	12.1%	14.7%	9.1%	13.9%
Trucks % Traffic (in PCU where 1 truck = 3 PC)	19.4%	20.6%	44.5%	20.0%	36.3%	16.3%	23.1%

Table 1 : Descriptive statistics of BAU traffic conditions in the Lyon Urban Area

- Our case study is the Lyon Urban Area : in France, an urban area is defined by INSEE as a group of municipalities encompassing an urban pole (> 10 000 jobs), and the surrounding rural and urban municipalities among which at least 40% of employed residents work in the urban pole or the municipalities attracted to this pole
- We distinguish 3 distinct zones: the city of Lyon (the densest part of the agglomeration), the Lyon Metropolitan Area (intermediary levels of density), and the rest of the Urban Area ; we distinguish 4 time periods: Morning Peak-Hour (MPH, 7-9am), Afternoon PH (APH, 5-7pm), Night (9pm-6am) and Rest of the Day (ROD)
- Table 1 shows the heterogeneity of mobility behavior in the Lyon Urban Area, depending on the place of residence of households: the motorization rate and the share of passenger car use increase the further away from the agglomeration's core
- Similarly, the distribution of freight trips is not homogeneous in time or space, with a higher share of total traffic during the MPH and ROD periods, especially for trips between the city of Lyon and the rest of the urban area

Results

	Lyon	Lyon - ML	Lyon - UA	ML	ML - UA	UA	Total
Passenger trips (k) - BAU	**228.2**	**373.7**	**61.5**	**599.7**	**280.1**	**466.3**	**2 009.4**
Passenger trips (k) - OHD	**243.0**	**394.7**	**64.0**	**610.1**	**283.2**	**466.7**	**2 061.6**
Δ passenger trips BAU - OHD	+ 6.1%	+ 5.3%	+ 3.9%	+ 1.7%	+ 1.1%	+ 0.1%	+ 2.5%
Distance per PC trip (km) - OHD	**3.34**	**7.45**	**26.32**	**6.76**	**18.27**	**16.71**	**11.01**
Distance per PC trip (km) - BAU	**3.41**	**7.57**	**26.44**	**6.84**	**18.36**	**16.69**	**11.00**
Δ of Distance per PC trips BAU - OHD	+ 1.9%	+ 1.6%	+ 0.4%	+ 1.2%	+ 0.4%	-0.1%	- 0.2%
Average Speed - BAU	**21.9**	**27.6**	**42.0**	**28.4**	**40.3**	**44.7**	**33.4**
Average Speed - OHD	**22.2**	**28.4**	**43.5**	**29.0**	**41.0**	**45.0**	**33.8**
Δ Average Speed	+ 1.1%	+ 2.5%	+ 3.5%	+ 1.9%	+ 1.9%	+ 0.7%	+ 1.2%
Total travelled vkm (k) - BAU	**841.7**	**3 111.3**	**2 024.0**	**4 512.0**	**5 939.7**	**8 247.3**	**24 676.0**
% PC	90.7%	89.5%	80.0%	89.8%	86.2%	94.5%	89.7%
% Vans	6.0%	6.4%	10.3%	5.4%	6.1%	2.9%	5.3%
% Trucks	3.3%	4.1%	9.7%	4.8%	7.7%	2.6%	5.0%
Total travelled vkm (k) - OHD	**907.4**	**3 317.5**	**2 097.6**	**4 638.1**	**6 019.2**	**8 245.4**	**25 225.2**
% PC	91.3%	90.1%	80.6%	90.0%	86.4%	94.5%	89.9%
% Vans	5.6%	6.0%	10.0%	5.3%	6.1%	2.9%	5.2%
% Trucks	3.1%	3.9%	9.4%	4.7%	7.6%	2.6%	4.9%
Δ VKM BAU - OHD	7.2%	6.2%	3.5%	2.7%	1.3%	-0.02%	2.2%
Tons CO2 - BAU	**220.4**	**741.7**	**508.2**	**1 068.5**	**1 386.8**	**1 529.3**	**5 454.9**
% PC	77.8%	75.0%	54.2%	73.6%	62.6%	83.7%	72.2%
% Vans	5.5%	5.5%	7.3%	4.5%	4.7%	2.7%	4.5%
% Trucks	16.6%	19.6%	38.5%	21.9%	32.7%	13.6%	23.3%
Tons CO2 - OHD	**232.0**	**765.1**	**510.1**	**1 069.6**	**1 379.5**	**1 520.6**	**5 476.9**
% PC	79.5%	76.5%	55.4%	74.5%	63.2%	83.8%	72.9%
% Vans	5.0%	5.0%	7.0%	4.3%	4.5%	2.6%	4.3%
% Trucks	15.5%	18.5%	37.6%	21.3%	32.3%	13.5%	22.8%
Δ CO2 BAU - OHD Freight	**-3.0%**	**-3.2%**	**-2.3%**	**-3.4%**	**-2.3%**	**-1.1%**	**-2.5%**
Δ CO2 BAU - OHD PC	**+7.0%**	**+5.0%**	**+2.6%**	**+1.3%**	**+0.5%**	**-0.5%**	**+1.5%**
Δ CO2 BAU - OHD Total	**+5.0%**	**+3.1%**	**+0.4%**	**+0.1%**	**-0.5%**	**-0.6%**	**+0.4%**

Table 2: Traffic condition and carbon footprint of BAU and OHD scenarios

- In this model, the lower congestion resulting from OHD has three types of impacts on carbon emissions: more passenger trips (thus, more emissions), higher speeds (fewer emissions), but slightly bigger travelled distances (more emissions)
- The results for freight vehicles are consistent with other studies found in the literature : ceteris paribus, freight vehicles emit less CO2 when operating at night, due to higher speeds (despite slightly longer distances)

  → Carbon emissions due to freight transport are down 2.5% for the entire urban area, and are even lower for ODs related to the Lyon Metropolitan area
- However, because of lower congestion levels, passenger trips increase 2.5% for the entire urban area, and more than 6% for the City of Lyon
- **As a result, carbon emissions due to passenger transport are up by 1.5% for the entire urban area, including +7% for the city of Lyon**

  → All told, the significant environmental gains from freight transportation are offset by increased passenger transport, and carbon emissions increase by 0.4% for the entire urban area, and by up to 5% for the central area

Discussion & future research

- The results of this analysis show that despite important gains in freight emissions resulting from OHD, reducing the number of freight vkm travelled during the peak hours has negative effects, as passengers shift from public transit to cars
- Freight does not function in isolation and should be analyzed in the broader context of urban traffic! Policies targeting freight can have an effect on the whole urban system
- These results, though exploratory, have important implications for public stakeholders, who should be aware of potential induced effects of policies aimed at reducing freight traffic, and plan for passenger transportation accordingly (for example, by reducing road supply, or by enhancing public transit efficiency)

<u>It should be noted that these results are exploratory! More research is necessary!</u>

- In this analysis, we underestimate the potential effect of shifting deliveries to the night-time on congestion levels. Indeed, double-parking by delivery vehicles is not taken into account here. Accounting for the effect of double-parking, congestion during peak hours could actually be lowered even more (thus, producing an even greater modal shift towards passenger cars, ceteris paribus)
- Environmental gains from freight vehicles are also underestimated here: we do not take into account the potential optimization of freight rounds, which would lower the number of vkm travelled per delivery, and therefore the carbon footprint of freight operations

  → Both of these gaps will be addressed in future analyses… In the future, we will also:
- Build more credible scenarios than 'all-or-nothing' for OHD
- Conduct a more long-term analysis using other parts of the LUTI model SIMBAD, in order to investigate changes in the urban structure
- Measure negative externalities other than CO2 emissions (congestion costs, local pollutants, noise…)

Main references & Acknowledgments

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