# Would nighttime deliveries be useful to reduce air pollution in cities?

## Econometrical evidence from Paris

*(Work in progress – please, do not quote)*

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# Context

- Road transport responsible for 65% of NOx pollution in Paris (Ville de Paris, 2023)
- Freight transport for 20% (Degraeuwe et al., 2019)
- Freight road transport is projected to grow by 100% by 2050

➔ Long-term solution: electrifying the fleet:
- In 2024, only 2.2% of new trucks were electric in Europe
- EU regulation 2024/1610: as of 2040, average $CO_2$ emissions of new trucks = -90% as compared to 2019 → Not better for NOx

➔ In the meantime: Low Emissions Zones and **off-peak deliveries** (trucks avoid road congestion)

# In this research

**2 distinct blocks:**

1) **Estimation of the impact of nighttime deliveries on NOx pollution**
- **Econometric method:** to model both the impact of various vehicles' road occupation rate on **traffic speed** and on **NOx pollution**
- **Using the econometric estimates:** 1) contribution of each vehicle type to NOx pollution, 2) contribution of one truck (resp. LDV) to NOx pollution depending on the hour of the day, 3) impact of nighttime deliveries

**2) Cost-Benefit Analysis of nighttime deliveries** using the estimated impacts on traffic speed and NOx pollution (incl. health, noise, wages, time…)

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# Literature on off-peak deliveries' impacts on pollution

| Study | Location | Methodology | Impact of trucks' off-hour driving on NOx |
|---|---|---|---|
| Holguin-Veras et al., 2018 | New York, Bogota, Sao Paulo | On-board GPS equipement | -65% **for that truck** (22:00-6:00) |
| Kianoush et al., 2021 | Region of Peel (Canada) | More aggregate trip speed and stop information | -11.3% |
| Beziat & Savagodo, 2021 | Lyon (France) | Agent-based modelling | -3% (if 50% of off-peak deliveries) |
| Yannis et al., 2006 | Athens (Greece) | Traffic assignment model | -9% (for CO) (7:00-10:30) |
| Sathaye et al., 2010 | Los Angeles, Long Beach (US) | Air pollution dispersion model, annual daily traffic data | -19.6% (for PM2.5) (3:00-9:00 to 18:00-22:00) |
| Saleh et al., 2022 | Greater Toronto and Hamilton Area (Canada) | Regional travel demand model with rebound effect | -0.05% (100% wholesale and retail 19:00-23:00, 100% accomod. & food 23:00-6:00) |

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# Existing economic analyses of nighttime deliveries

| Study | Location | Methodology | Methodology of economic analysis | Economic analysis results |
|---|---|---|---|---|
| Holguin-Veras et al., 2012 | New York | On-board GPS equipement | CBA: Noise, congestion, operating costs, air pollution | Optimal level of incentive to food and retail sectors: $10000-$15000/year per receiving firm |
| Mommens et al., 2018 | Belgium | Freight transport agent-based model | Cost comparison only: $CO_2$, $NO_x$, PM2.5, accidents, infrastructure, noise, congestion | Best scenario: all small and 1/3 of large supermarket |
| Ukkusuri et al., 2016 | New York | Macro regional travel demand model, meso sub-simulation network | Monetized traffic benefits compared to monetary incentives given to receivers | Highest when 10% daytime freight vehicles shifted (the max studied) |

# Data sources

Hourly data for Paris *intra-muros* between Dec. 8, 2024 and Jul. 7, 2025:

- **Multimodal traffic counters** for 6 vehicle types (8 counters for the speed analysis and 24 for the pollution analysis) from Paris' city open data
- **All-vehicles traffic counters** (4400 counters, 35% of roads in Paris)
- **Air pollution** (6 stations) from Airparif
- **Weather** (temperature, wind speed, humidity, rain, luminosity) (4 stations) from MeteoFrance
- **Boundary layer height** from ECMWF
- **Electricity consumption** in Paris Metropolis from ODRE

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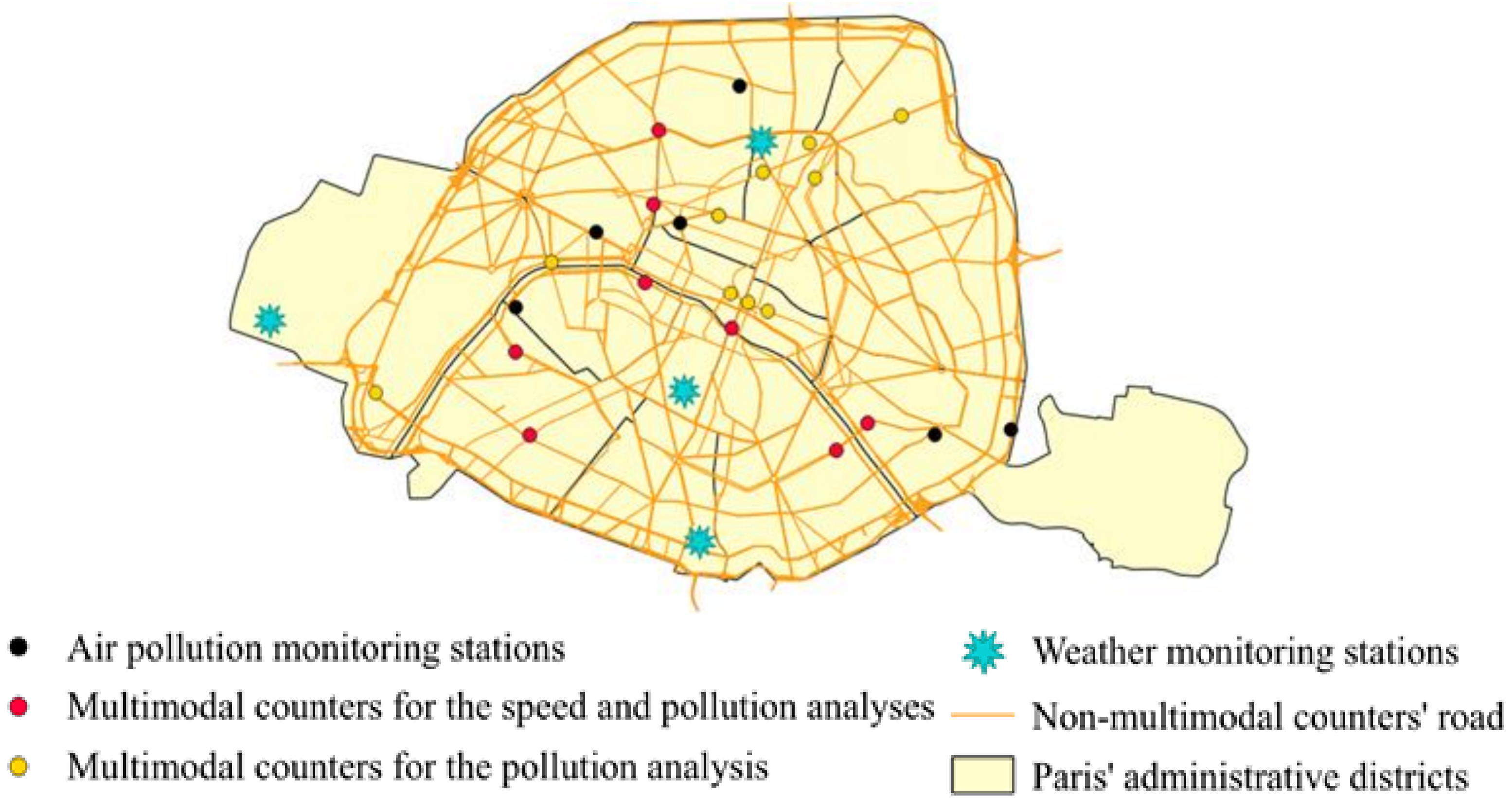
# Map of the various measurement stations



# Descriptive statistics - Speed analysis

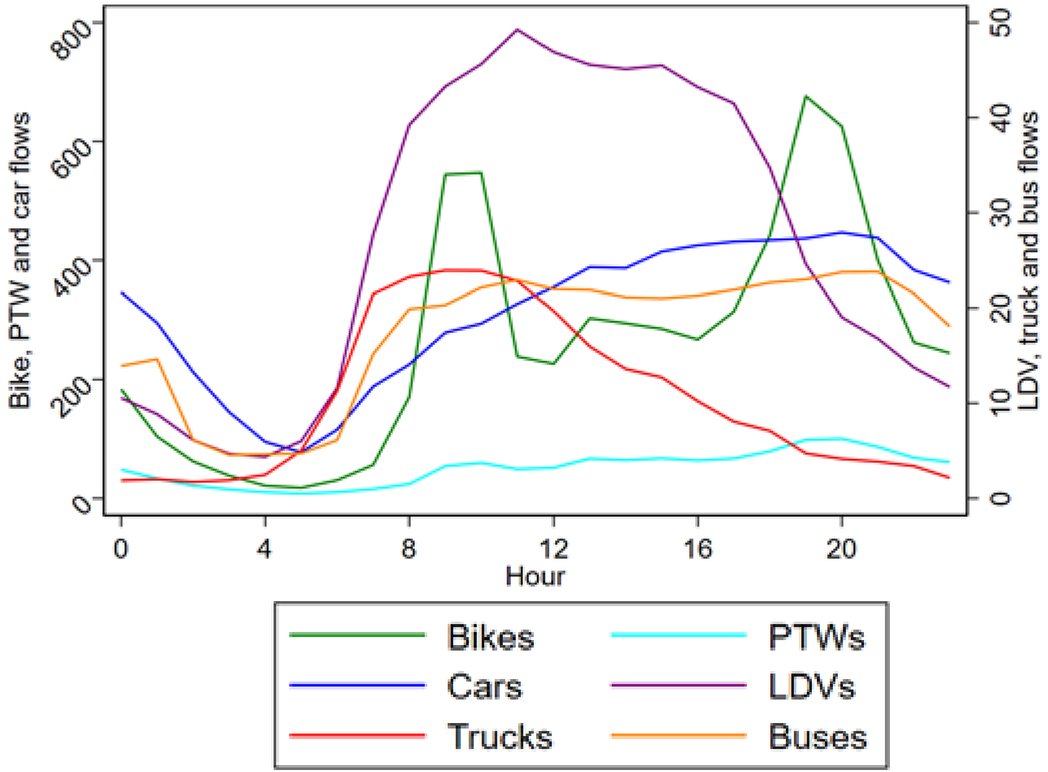
| | Mean | Stand. dev. | Min | Max |
|---|---|---|---|---|
| **Traffic** | | | | |
| Total motorized traffic flow (nb./h) | 311.68 | 205.47 | 0.00 | 3908.00 |
| Motorized occupancy rate (%) | 8.58 | 12.90 | 0.01 | 86.77 |
| Bike flow | 241.02 | 290.95 | 0.00 | 3307.00 |
| PTW flow | 47.38 | 44.05 | 0.00 | 344.00 |
| Car flow | 322.25 | 229.60 | 0.00 | 1440.00 |
| LDV flow | 23.42 | 26.50 | 0.00 | 211.00 |
| Truck flow | 8.38 | 10.95 | 0.00 | 153.00 |
| Bus flow | 16.76 | 18.50 | 0.00 | 113.00 |
| **Weather** | | | | |
| Rainfall height (mm/h) | 0.06 | 0.40 | 0.00 | 13.76 |
| Wind speed (m/s) | 3.00 | 1.37 | 0.00 | 9.29 |
| Temperature (°C) | 12.22 | 7.48 | -2.74 | 39.47 |
| Relative humidity (%) | 70.49 | 18.02 | 20.56 | 99.99 |
| Luminosity ($J/cm^2$) | 52.14 | 83.54 | 0.00 | 354.76 |
| Observations | 44293 | | | |

# Descriptive statistics - Pollution analysis

| | Mean | Stand. dev. | Min | Max |
|---|---|---|---|---|
| **Traffic** | | | | |
| Total motorized traffic flow (nb./h) | 679.74 | 272.01 | 59.42 | 4236.05 |
| Motorized occupancy rate (%) | 7.39 | 3.92 | 0.72 | 25.57 |
| Bike flow | 47.88 | 35.14 | 1.88 | 229.71 |
| PTW flow | 50.14 | 31.94 | 3.33 | 196.71 |
| Car flow | 292.68 | 100.12 | 49.92 | 460.08 |
| LDV flow | 22.43 | 15.99 | 1.71 | 89.17 |
| Truck flow | 8.92 | 9.05 | 0.17 | 38.38 |
| Bus flow | 14.25 | 5.83 | 1.38 | 36.17 |
| **Weather** | | | | |
| Rainfall height (mm/h) | 0.06 | 0.40 | 0.00 | 12.13 |
| Wind speed (m/s) | 2.99 | 1.33 | 0.00 | 9.30 |
| Temperature (°C) | 11.64 | 7.59 | -2.03 | 38.67 |
| Relative humidity (%) | 71.61 | 18.26 | 23.00 | 99.00 |
| Luminosity ($J/cm^2$) | 47.89 | 80.68 | 0.00 | 342.00 |
| **Other variables** | | | | |
| Boundary layer height (m) | 540.47 | 463.82 | 13.27 | 2513.48 |
| $NO_x$ concentration ($\mu g/m^3$) | 51.37 | 30.60 | 5.95 | 300.93 |
| Electricity consumption (MW) | 4238.56 | 1055.23 | 2248.25 | 6927.25 |
| Observations | 3119 | | | |

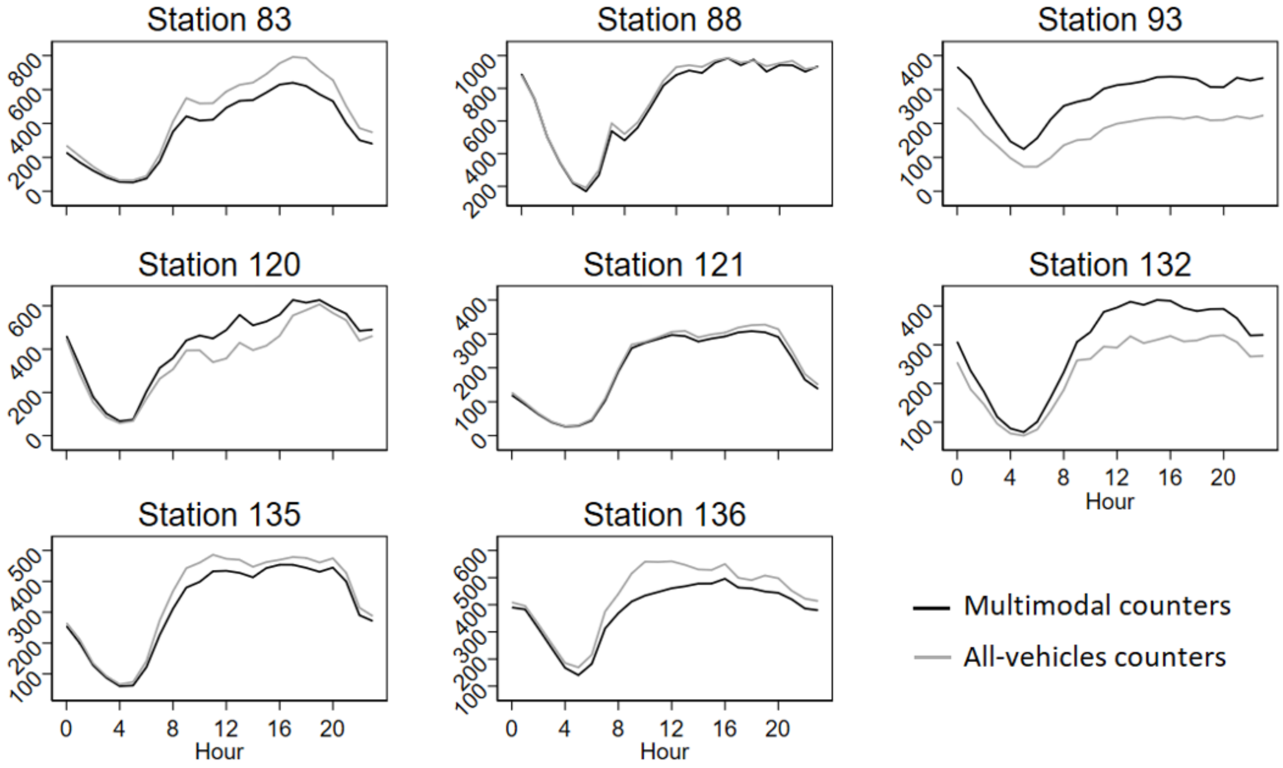
# Descriptive statistics (3)

Hourly variations of traffic flows per vehicle type (average on all workdays)



# Descriptive statistics (4)

Hourly variations of total motorized traffic flows according to the multimodal counters and to the all-vehicles counters



# Econometric models

$$Speed_{h,c} = \sum_{i\in\{car,LDV,truck,bus\}} \alpha_i Occ_{i,h,c} + \sum_{i\in\{car,LDV,truck,bus\}} \beta_i Occ_{i,h,c}^2 + \sum_{i\in\{PTW,car,LDV,truck,bus\}} \gamma_i Occ_{i,h,c}^3 + W_{h,c} + F_d * F_H + F_m + F_c + \epsilon_{h,c}$$

$Speed_{h,c}$ : speed proxy at a hour $h$ (4770 distinct hours in our dataset) for a specific multimodal counter $c = \frac{Flow_{h,c}*(vehlength+roadlength_c)}{Occrate_{h,c}}$

$Occ_{i,h,c}$: occupancy rate by vehicle type $i$ at a specific hour and counter

$W_{h,c}$: weather variables

$F_d * F_H$: interaction between a day-of-week fixed effect and an hour-of-day fixed effect

$F_m$: month fixed effect, $F_c$: multimodal counter fixed effect, $\epsilon_{h,c}$: error term

# Econometric models (2)

$$NOX_h = \sum_{i \in \{PTW, car, LDV, truck, bus\}} \alpha_i Occ_{i,h} + \sum_{i \in \{PTW, car, LDV, bus\}} \beta_i Occ_{i,h}^2$$

$$+ \sum_{i \in \{PTW, car\}} \gamma_i Occ_{i,h}^3 + \sum_{i \in \{PTW\}} \delta_i Occ_{i,h}^4 + W_h + W'_{h-1} + W''_{h-2} + W''_{h-3} + W''_{h-4}$$

$$+ B_h + C_h + C_{h-1} + \phi_1 \, NOX_{h-1} + \theta_1 \, \epsilon_{h-1} + \epsilon_h$$

$NOX_h$: concentration of NOx at hour $h$ (there are 3119 distinct hours in this dataset)

$Occ_{i,h}$: occupancy rate by vehicle type $i$ at $h$

$W_h$: all weather variables (rainfall height, wind speed, temperature, relative humidity, luminosity) at $h$

$W'_{h-1}$: wind and luminosity at $h - 1$, $W''_j$: wind at hour $j$

$B_h$: boundary layer height at $h$, $C_j$: electricity consumption at hour $j$

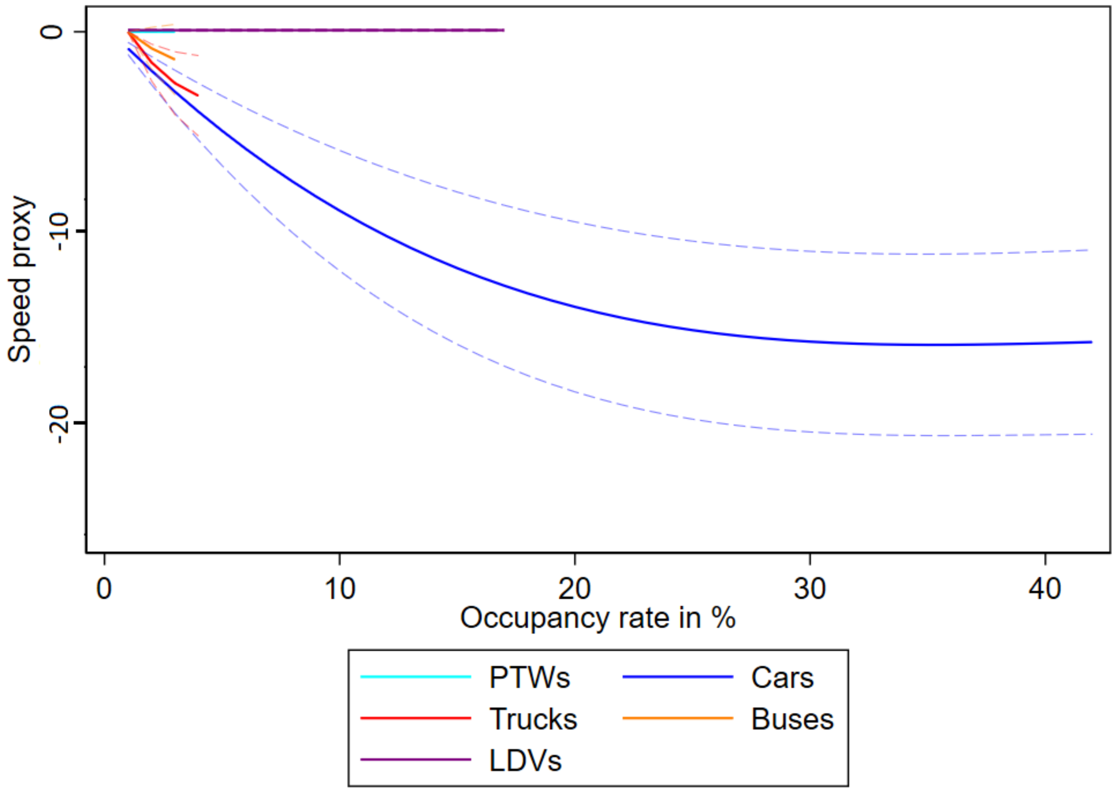
$NOX_{h-1}$: lagged NOx concentration (i.e. the autoregressive term)

$\epsilon_h$: error term, $\epsilon_{h-1}$: lagged error (i.e. the moving average term)

# Econometric estimates for the speed proxy

| | | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|
| Occ. rate | - PTWs | | -0.110 | 0.040 | | |
| | - Cars | -1.269*** | -1.247*** | -0.888*** | -1.465*** | -0.936*** |
| | - Trucks | -2.271*** | -2.146*** | -1.365** | -1.578*** | -2.356*** |
| | - Buses | -1.229* | -1.181* | -0.656 | -0.648** | -0.430 |
| | - LDVs | | -0.311 | 0.183 | | |
| $(\text{Occ. rate})^2$ | - PTWs | | 0.003 | -0.005** | | |
| | - Cars | 0.033*** | 0.033*** | 0.011*** | 0.042*** | 0.020*** |
| | - Trucks | 0.379*** | 0.359*** | 0.121** | 0.258*** | 0.390*** |
| | - Buses | 0.250* | 0.249* | 0.071* | 0.138** | 0.078 |
| | - LDVs | 0.029*** | 0.072 | 0.007 | 0.020* | 0.035*** |
| $(\text{Occ. rate})^3$ | - PTWs | -0.0001*** | -0.0001 | | -0.0001*** | -0.00009*** |
| | - Cars | -0.0002*** | -0.0002*** | | -0.0003*** | -0.0001** |
| | - Trucks | -0.017*** | -0.017*** | | -0.012*** | -0.018*** |
| | - Buses | -0.011* | -0.011* | | -0.006** | -0.003 |
| | - LDVs | -0.002*** | -0.003*** | | -0.001*** | -0.002*** |
| Observations | | 41,553 | 41,553 | 41,553 | 41,553 | 41,553 |
| Nb. of stations | | 10 | 10 | 10 | 10 | 10 |
| Fixed effects: | | | | | | |
| Day of week * Hour of day | | X | X | X | | |
| Weekend * Hour of day * Counter | | | | | X | |
| Month | | X | X | X | X | |
| Counter | | X | X | X | X | X |

# Econometric estimates for the speed proxy (2)

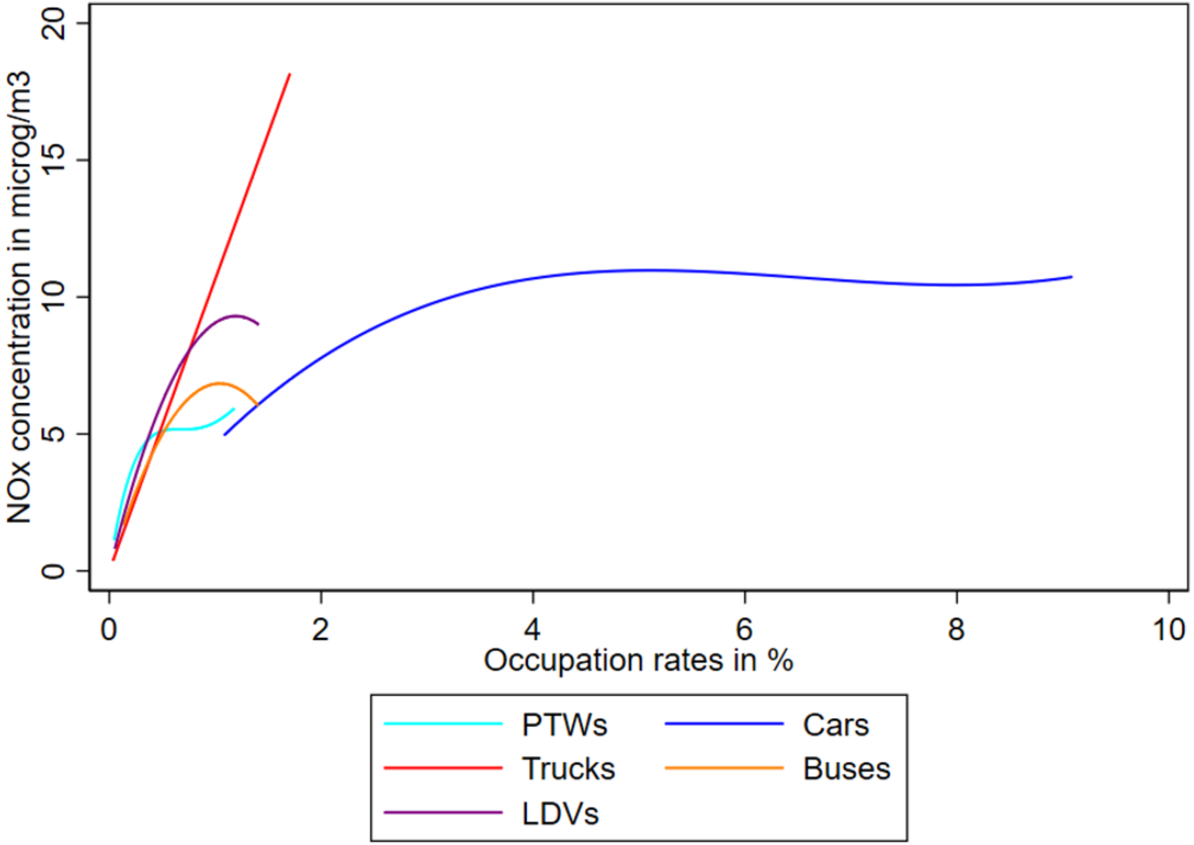


# Econometric estimates for the NOx concentration

**Baseline spec. :**
Autoreg. term = 0.92
Moving average = 0.19

| | | (1) | (2) | (3) | (4) |
|---|---|---|---|---|---|
| Occ. rate | - PTWs | 25.9444 | 24.4598 | 37.5123** | 60.0585*** |
| | - Cars | 5.4635*** | 5.5676*** | 7.1377*** | 8.6473*** |
| | - LDVs | 15.6009*** | 16.3190*** | 9.5901** | 6.6505* |
| | - Trucks | 10.6510*** | 10.6607*** | 11.2985*** | 15.3579*** |
| | - Buses | 13.1013*** | 11.7865*** | 14.6387*** | 18.3033*** |
| $(\text{Occ. rate})^2$ | - PTWs | -47.0189* | -43.6492 | -61.0567** | -97.1400*** |
| | - Cars | -0.8774*** | -0.8744*** | -1.0607*** | -1.5775*** |
| | - LDVs | -6.5404*** | -6.6549*** | -4.5021*** | -3.7855** |
| | - Buses | -6.2706*** | -5.8329*** | -6.7636*** | -9.4230*** |
| $(\text{Occ. rate})^3$ | - PTWs | 35.8074* | 32.7183* | 44.2143** | 70.6107*** |
| | - Cars | 0.0447*** | 0.0437*** | 0.0494*** | 0.0816*** |
| $(\text{Occ. rate})^4$ | - PTWs | -9.3070* | -8.4194* | -11.1622** | -17.9563*** |
| Number of observations | | 2646 | 2646 | 2810 | 2810 |
| BIC | | 18947 | 18962 | 20259 | 20494 |
| ARIMA AR | | 1 | 2 | 1 | 1 |
| ARIMA MA | | 1 | 5 | 1 | 1 |
| Explanatory variables | | | | | |
| Meteo. | | X | X | X | |
| Lagged var. | | X | X | | |

# Econometric estimates for the NOx concentration (2)



# Applications

- **Contribution of each vehicle type to the NOx pollution**

In the presence of all vehicles: speed proxy = 10.48 ; mean pred. NOx = 51.55

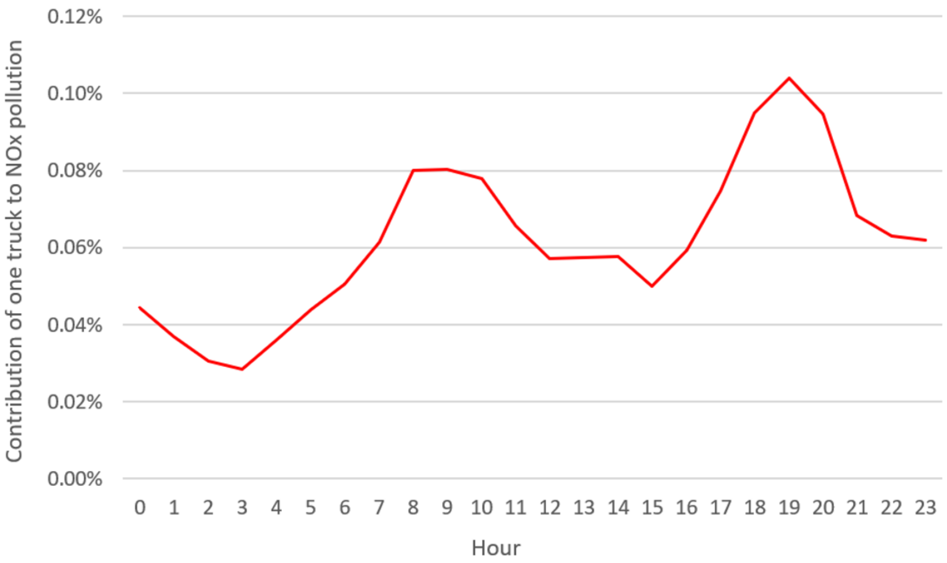
When suppressing each type of vehicle:

| | Mean pred. speed proxy (km/h) | Mean pred. NOx (no speed) | Contrib. of veh. to NOx (no speed) | Mean pred. NOx | Contrib. of veh. to NOx |
|---|---|---|---|---|---|
| No PTWs | 10.4 | 46.73 | 9.4% | 46.72 | 9.4% |
| No cars | 15.9 | 43.24 | 16.1% | 38.54 | 25.3% |
| No LDVs | 10.42 | 46.71 | 9.4% | 46.76 | 9.3% |
| No trucks | 11.5 | 46.36 | 10.1% | 45.91 | 11.0% |
| No buses | 11.1 | 46.83 | 9.2% | 46.12 | 10.6% |
| Total of contrib. | | | 54.2% | | 65.6% |

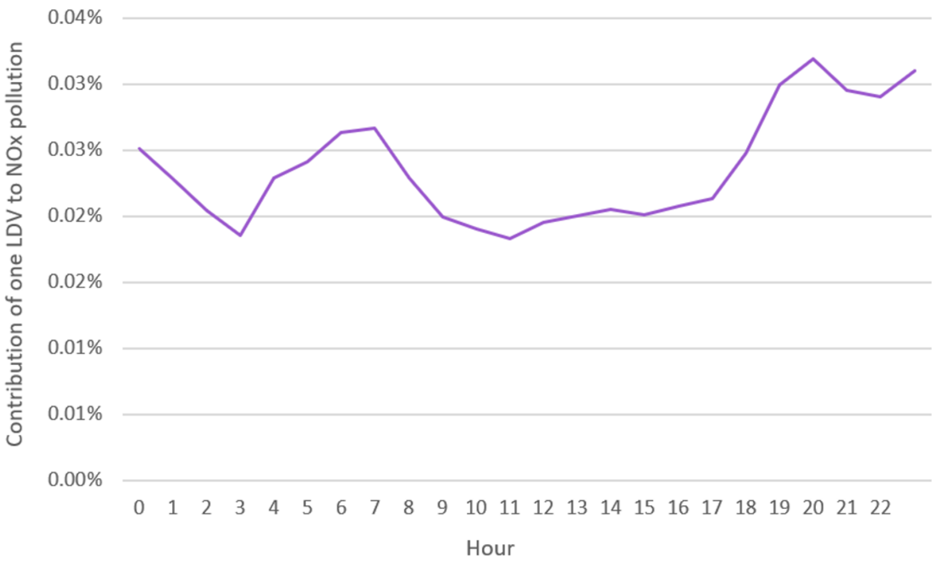
# Applications (2)

## Contribution of a truck and of a LDV to NOx pollution, depending on the hour at which it is driven

Truck




LDV



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# Applications (3)

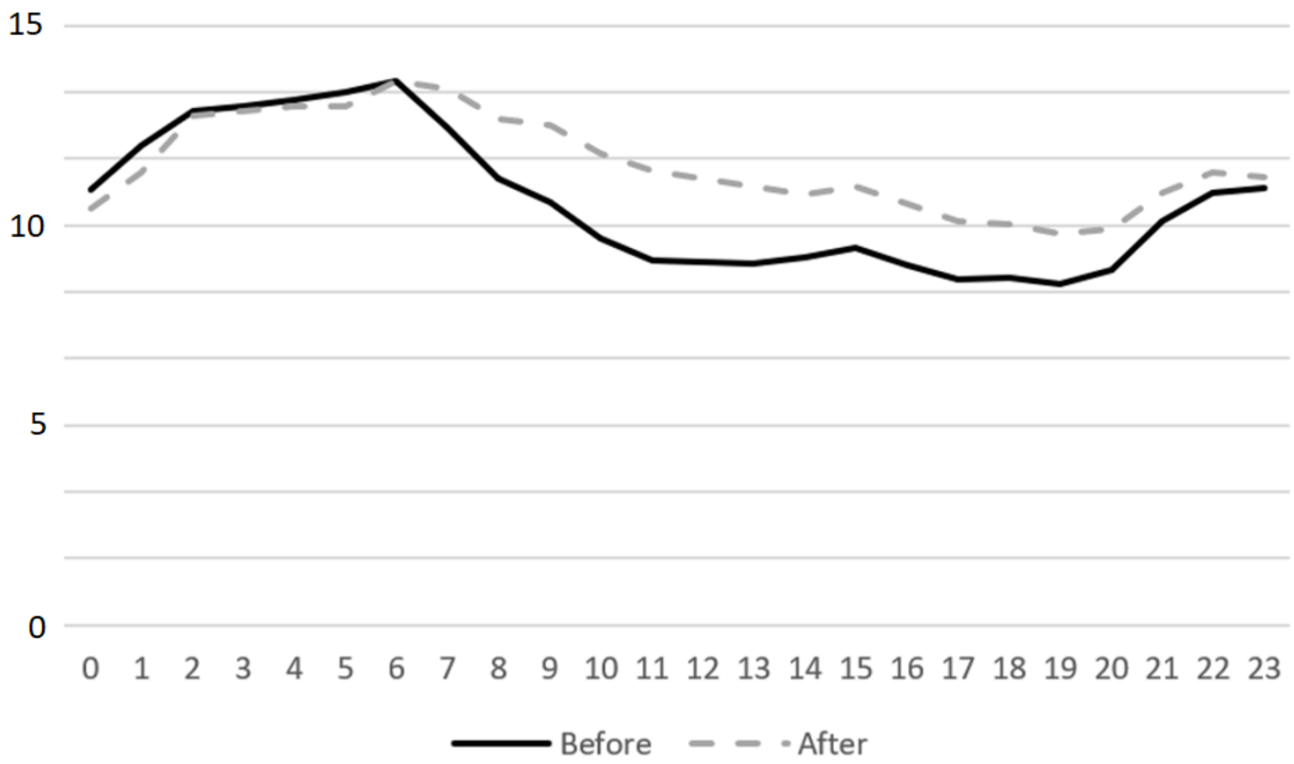
**Estimation of the impact of various schemes of nighttime deliveries according to the combination of the two models**

Before: speed proxy = 10.48 ; mean pred. NOx = 51.55

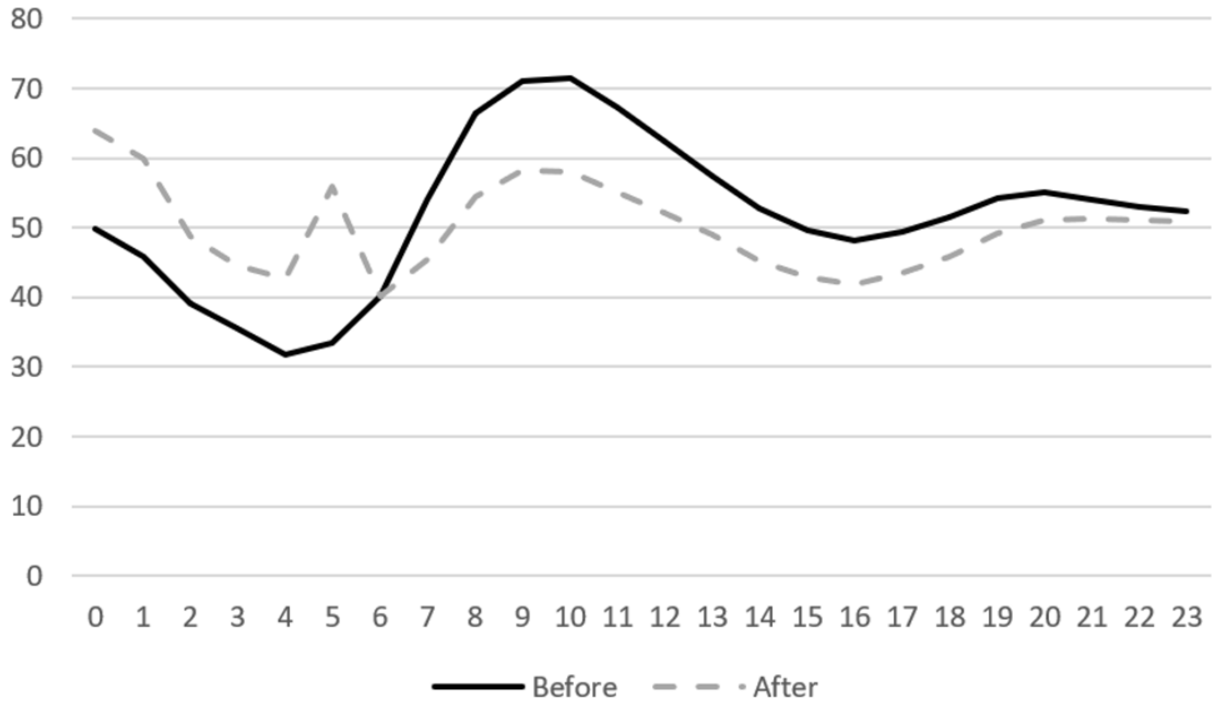
| | Mean pred. speed proxy after | Mean pred. NOx after (no speed) | Mean pred. NOx after | Reduction of NOx |
|---|---|---|---|---|
| 8-20 to 0-6 | 11.4 | 50.330 | 49.965 | 4.4% |
| 7-23 to 0-5 | 11.6 | 49.979 | 49.511 | 5.3% |
| 7-23 to 0-5, 90% trucks, 20% LDVs | 11.3 | 50.394 | 47.296 | 9.4% |
| Idem with full rebound effect | 10.9 | 50.545 | 50.230 | 3.8% |

→ **CBA**

# Hourly profile of the speed proxy before and after the introduction of nighttime deliveries (90% trucks and 20% LDV from 7-23 to 0-5)



# Hourly profile of the NOx concentration (in microg/$m^3$) before and after the introduction of nighttime deliveries (90% trucks and 20% LDV from 7-23 to 0-5)



# Cost-Benefit Analysis – Scenario 90% trucks, 20% LDVs

**Benefits:**
- ↘ transport time for drivers, riders and bus users: because less congestion during the day
- ↘ morbidity and mortality due to NO2: because less pollution (because less congestion for all vehicles)
- ↘ noise nuisances during the day: because fewer trucks and LDVs during the day
- ↘ fuel expenses: because trucks and LDVs drive faster
- ↘ CO2 externalities: because trucks and LDVs drive faster
- ↘ total hours worked by truck and LDV drivers: because trucks and LDVs drive faster

**Other benefits (not included in the CBA):**
- ↘ accidents: because fewer trucks and LDVs during the day (will be added soon)
- ↘ wear and tear on trucks and LDVs and road infrastructure: because less stop-and-go
- ↗ reliability of deliveries: because less congestion by night
- ↘ need for heavy investments in road infrastructure: because fewer trucks and LDVs during the day

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# Cost-Benefit Analysis – Scenario 90% trucks, 20% LDVs

**Costs:**

- ↗ noise nuisances during the night: because additional trucks and LDVs during the night
- ↗ hourly wage of drivers and employees at the delivery point: because night shift wage rate > day shift wage rate

**Other costs (not included in the CBA):**

- ↘ health for trucks and LDV drivers: due to night shifts (will be added soon)
- Investments in less noisy vehicles: to reduce the noise nuisances
- Organisational costs: to reorganise the logistics chain so as to allow for nighttime deliveries

# Cost-Benefit Analysis – Scenario 90% trucks, 20% LDVs

**Key hypotheses:**

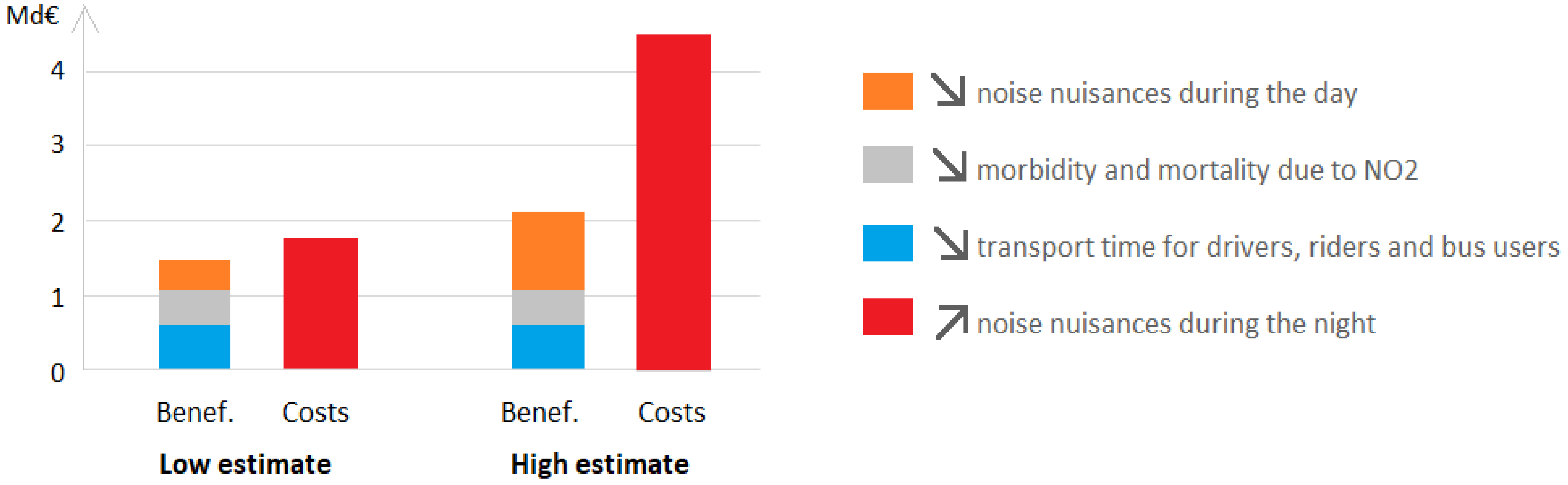
- **Low estimate** = only the jobs of truck drivers, long-haul drivers, delivery riders and couriers working **in Paris** are shifted to the night (90% of them on 50% of their working hours)
- **High estimate** = adding the same jobs in **Paris' inner suburbs** (on 25% of their working hours) and **warehouse workers** (on 25% of their working hours)
- **Health impact of NOx pollution** estimated using EQIS methodology (impact on asthma, pneumopathies, death)
- **Transport time for drivers, riders and bus users** (survey by Institut Paris Region)
- **Hourly wage of drivers**: 12€/h during the day, 14€/h by night

# Cost-Benefit Analysis – Scenario 90% trucks, 20% LDVs

Estimated impact of nighttime deliveries in Paris during one year:

| **Benefits (M€)** | Low estim. | High estim. | **Costs (M€)** | Low estim. | High estim. |
|---|---|---|---|---|---|
| ↘ transport time for drivers, riders and bus users | 600 | 600 | ↗ noise nuisances during the night | 1746 | 4506 |
| ↘ morbidity and mortality due to $NO_2$ | 463 | 463 | ↗ hourly wage of drivers | 7 | 18 |
| ↘ noise nuisances during the day | 406 | 1047 | | | |
| ↘ fuel expenses | 3 | 9 | | | |
| ↘ $CO_2$ externalities | 1 | 4 | | | |
| ↘ total hours worked by truck and LDV drivers | 1 | 3 | | | |

# Cost-Benefit Analysis (2)



# Discussion and conclusion

**In this paper:**

- Econometric method to estimate NOx reduction when nighttime deliveries
- CBA analysis of nighttime deliveries using the econometric predictions regarding speed and NOx

**Conclusions:**

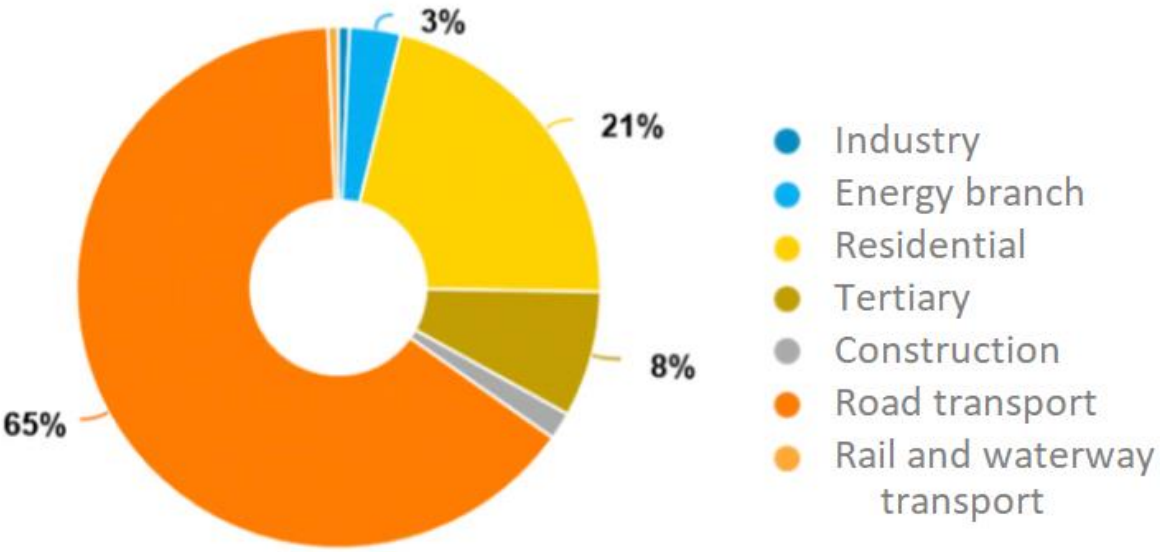
- Reduction of NOx with and without rebound effect
- CBA: costs > benefits

**To be done:**

- Robustness of the CBA: 1) scenario with rebound effect, 2) other nighttime delivery schemes, 3) other econometric specifications, 4) scenario with investments to make nighttime deliveries less noisy

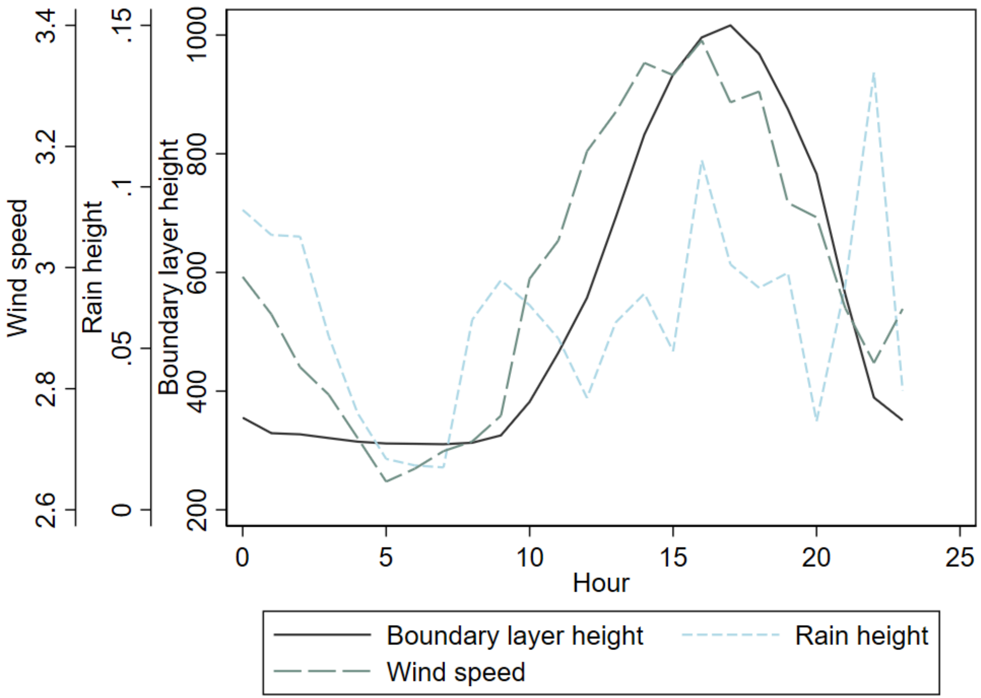
# Appendix

# Emissions of NOx by sector in Paris 2015

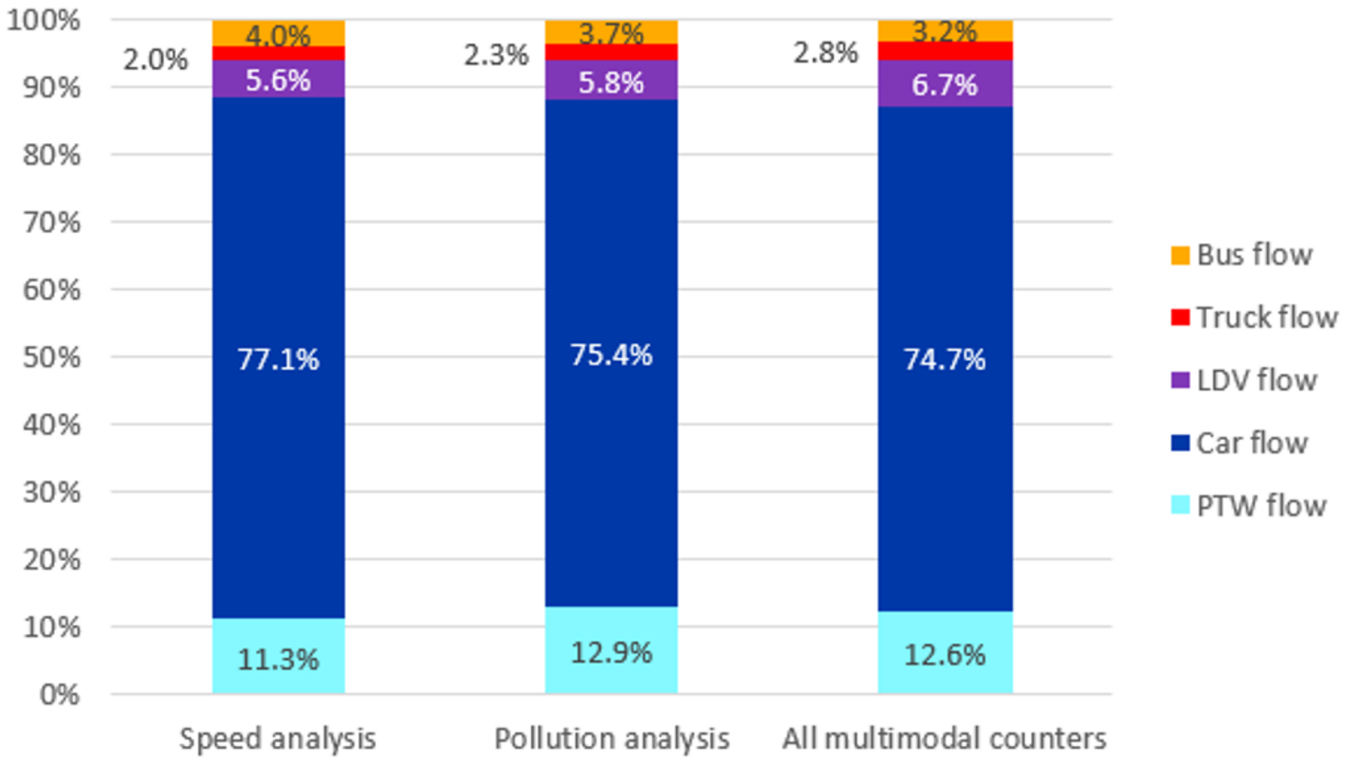



Source : https://www.paris.fr/pages/etat-des-lieux-de-la-qualite-de-l-air-a-paris-7101, data from the air pollution monitoring agency Airparif

# Hourly variations of the boundary layer height, rain height and wind speed on average during the day



# Share of each motorized vehicle type depending on the database



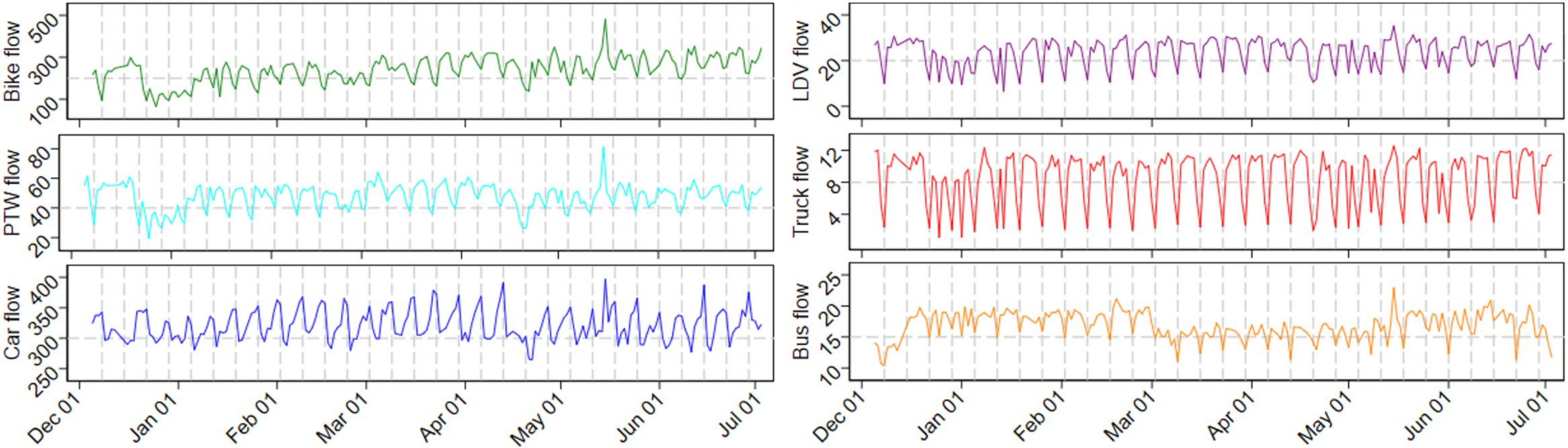
Estimates of the contribution of a truck to NOx pollution depending on the hour at which it is driven according to the combination of the two models

| Hour | Mean nb. of trucks per hour | Mean pred. NOx concentr. when no truck | Contrib. of trucks at that hour to NOx |
|---|---|---|---|
| 0 | 1.399 | 51.527 | 0.044% |
| 1 | 1.472 | 51.531 | 0.037% |
| 2 | 1.273 | 51.539 | 0.030% |
| 3 | 1.361 | 51.539 | 0.029% |
| 4 | 1.768 | 51.526 | 0.036% |
| 5 | 3.23 | 51.486 | 0.044% |
| 6 | 7.233 | 51.371 | 0.050% |
| 7 | 13.052 | 51.146 | 0.061% |
| 8 | 14.642 | 50.954 | 0.080% |
| 9 | 15.797 | 50.904 | 0.080% |
| 10 | 16.032 | 50.915 | 0.078% |
| 11 | 15.448 | 51.037 | 0.066% |
| 12 | 13.36 | 51.166 | 0.057% |
| 13 | 10.811 | 51.239 | 0.057% |
| 14 | 9.373 | 51.28 | 0.058% |
| 15 | 9.336 | 51.318 | 0.050% |
| 16 | 7.268 | 51.337 | 0.059% |
| 17 | 5.73 | 51.338 | 0.075% |
| 18 | 4.56 | 51.336 | 0.095% |
| 19 | 3.524 | 51.37 | 0.104% |
| 20 | 3.05 | 51.41 | 0.095% |
| 21 | 2.893 | 51.457 | 0.068% |
| 22 | 2.464 | 51.479 | 0.063% |
| 23 | 1.564 | 51.509 | 0.062% |

Estimates of the contribution of a LDV to NOx pollution depending on the hour at which it is driven according to the combination of the two models

| Hour | Mean nb. of LDVs per hour | Mean pred. NOx concentr. when no LDV | Contrib. of one LDV driven at that hour to NOx |
|---|---|---|---|
| 0 | 6.926 | 52.108 | 0.025% |
| 1 | 6.039 | 52.127 | 0.023% |
| 2 | 4.596 | 52.150 | 0.020% |
| 3 | 3.809 | 52.162 | 0.019% |
| 4 | 3.513 | 52.157 | 0.023% |
| 5 | 4.583 | 52.141 | 0.024% |
| 6 | 8.214 | 52.086 | 0.026% |
| 7 | 17.766 | 51.952 | 0.027% |
| 8 | 26.029 | 51.888 | 0.023% |
| 9 | 29.436 | 51.893 | 0.020% |
| 10 | 31.509 | 51.886 | 0.019% |
| 11 | 33.839 | 51.876 | 0.018% |
| 12 | 32.299 | 51.870 | 0.020% |
| 13 | 31.028 | 51.875 | 0.020% |
| 14 | 30.486 | 51.873 | 0.020% |
| 15 | 31.304 | 51.870 | 0.020% |
| 16 | 29.473 | 51.880 | 0.021% |
| 17 | 28.077 | 51.887 | 0.021% |
| 18 | 23.874 | 51.890 | 0.025% |
| 19 | 17.320 | 51.928 | 0.030% |
| 20 | 13.341 | 51.976 | 0.032% |
| 21 | 11.709 | 52.018 | 0.030% |
| 22 | 9.558 | 52.054 | 0.029% |
| 23 | 7.741 | 52.074 | 0.031% |

## Hourly variations of traffic flows per vehicle type (average on all workdays)



# Cost-Benefit Analysis – Scenario 90% trucks, 20% LDVs

**Nb of truck and LDV hours shifted to the night** = total nb of employees in logistics in Paris * share of truck drivers, long-haul drivers, delivery riders and couriers * nb of driving hours per day * nb of workdays per month * nb of months * % of truck and LDV hours shifted to the night * % of trucks and LDVs shifted to the night (90% of truck and LDV drivers)

**Benefits**

⭸ **transport time for drivers, riders and bus users** = nb of Paris inhabitants btw. 16 and 80 years old * weekly travel time * nb of weeks per year * speed gain * value of time * % non-walking trips

⭸ **morbidity and mortality due to NO2** = annual nb of new patients before the introduction of nighttime deliveries * (1-exp(-ln(risk ratio)/10)*NO2 reduction due to nighttime deliveries)

⭸ **noise nuisances during the day** = nb of truck and long-haul drivers' hours shifted to the night * marginal noise cost of truck during the day * average load * speed + nb of delivery riders and couriers' hours shifted to the night * speed * marginal noise cost of LDV during the day

# Cost-Benefit Analysis – Scenario 90% trucks, 20% LDVs

↘ **fuel expenses** = (g/km consumpt. ↘ when 12 to 20 km/h of truck / (20-12) * nb hours of truck and long-haul drivers shifted to the night / 0.9 + g/km consumpt. ↘ when 10 to 20 km/h of LDV / (20-10) * nb hours of delivery riders and couriers shifted to the night / 0.2) * speed before * delta speed due to nighttime deliveries * diesel price per L / diesel density

↘ **CO2 externalities** = (↘ g emitted when 12 to 20 km/h by a truck / (20-12) * nb of hours of truck and long-haul drivers shifted to the night / 0.9 + ↘ g emitted when 10 to 20 km/h by a LDV / (20-10) * nb of hours of delivery riders and couriers / 0.2) * speed before * delta speed due to nighttime deliveries * value of CO2

↘ **total hours worked by truck and LDV drivers** = total nb of hours worked by truck and LDV drivers * (speed after – speed before) / speed before

**Costs:**

↗ **noise nuisances during the night** = nb of hours worked by truck and long-haul drivers shifted to the night * average load * speed * marginal noise cost for trucks by night + nb of hours worked by delivery riders and couriers * speed * marginal noise cost for LDVs by night

↗ **hourly wage of drivers** = total nb of hours of drivers shifted ot the night * (hourly wage by night – hourly wage by day)