Capstone Report

Impacts of implementing a Zero-Emission Delivery Area in Paris

MSc Sustainable Impact Analysis

Hayeon NAM
Iqra SHAIKH
Mohammed Ouassime EL YAMANI
Takahiro NOMOTO

Supervised by Martin KONING,
Research Director at Université Gustave Eiffel

June 2024

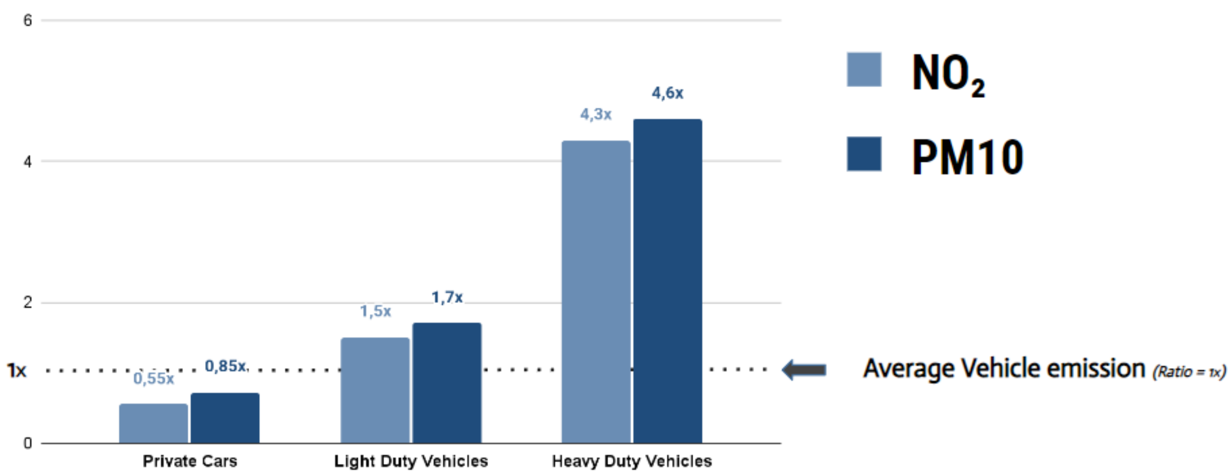
Acknowledgements

We extend our heartfelt gratitude to Respire & Clean Cities for entrusting us with this capstone project as part of the MSc SIA 2023-2024 program. Our deepest thanks go to our supervisor, Martin Koning, for his unwavering support and insightful guidance throughout this journey. Additionally, we express our sincere appreciation to Carine Staropoli, the director of the MSc SIA program.

Executive Summary

During the 2024 Summer Olympics, the City of Paris and the Prefecture of Police implemented a *de facto* limited traffic zone in the center of Paris. This paper explores the benefits of creating a Zero-Emission Delivery Area in Paris which encourages the use of electric vehicles and cargo bikes for last mile deliveries. The analysis explores the link between road traffic and air pollution in the City of Paris, including the impact an additional vehicle has on air pollution, in particular this analysis explores the pollutants NO_2 and PM_{10}.

Figure 1: Emissions Ratio relative to the Average Vehicle



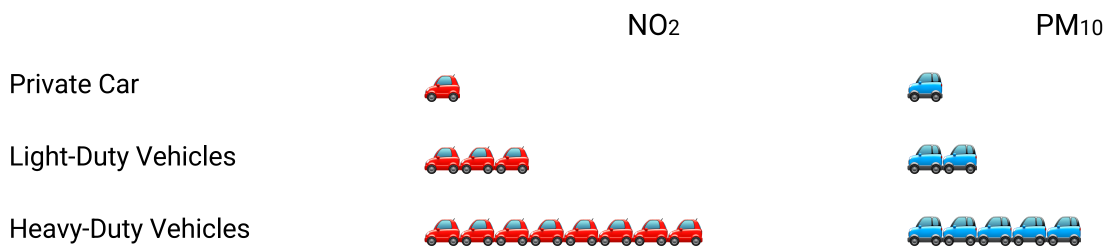
Source: Authors.

NO_2 and PM_{10} have well researched adverse health impacts whereby changes in pollution concentrations are linked to changes in health outcomes including mortality and respiratory related hospitalizations. As a result of their dire health consequences, NO_2 and PM_{10} are regulated pollutants with emission and concentration levels and standards being monitored and set at the European Union level. Additionally, PM10 pollutants are associated with non-exhaust emissions from brake and tyre wear[1]. Road transport contributes significantly to NO2 and PM10 air pollution in the European Union[2]. Based on traffic data that cannot differentiate private cars from trucks or Light-Duty vehicles, our analysis demonstrates that the “average vehicle” in Paris contributes 0.0049 ppm NO_2 and 0.0019 ppm PM_{10}.

[1] Fussell et al. 2022. *A Review of Road Traffic-Derived Non-Exhaust Particles: Emissions, Physicochemical Characteristics, Health Risks, and Mitigation Measures;*
[2] EEA. *National emissions reported to the Convention on Long-range Transboundary Air Pollution (LRTAP Convention).* See Appendix 4, Figure A1 for more details.

Due to a lack of data from official monitoring stations, PM2.5, the pollutant responsible for the most significant health damage, could not be taken into account. The results of this study therefore only partially reflect the impact of transport-related air pollution on human health, and should be read as such. It is well known that different vehicle types and classes contribute differently to pollution levels where Light-Duty and Heavy-Duty Vehicles pollute more as illustrated in Figure E2.

Figure 2: Pollutant Emissions Ratios by Vehicle Type



Source: Authors. Note: Rounded to the nearest whole numbers. These ratios are based on the emissions ratio shown in Figure E1 and use private cars as the point of comparison.

To assess different policy options, our analysis explores six different scenarios aimed at reducing pollution levels by electrifying a certain percentage of Light-Duty and Heavy-Duty Vehicles on the streets of Paris and/or shifting a certain percentage of deliveries into cargo bikes. In each scenario, relevant factors such as health benefits, changes in CO_2 emissions, noise and congestion levels, are calculated.

Table 1: benefits associated with each scenario

		Health Impacts	Cargo Cyclist Health	Noise Pollution Reductions	CO2 Emissions Reductions	Congestion Reductions
Status Quo	2022 Traffic Flow Structure in Paris					
Scenario 1	**50%** LDV to **Electric**	✓		✓	✓	
Scenario 2	**50%** HDV to **Electric**	✓		✓	✓	
Scenario 3	**100%** LDV and **100%** HDV to **Electric**	✓		✓	✓	
Scenario 4	**85%** LDV to **Electric** + **15%** HDV to **Cargo Bikes**	✓	✓	✓	✓	✓
Scenario 5	**10%** LDV to **Cargo Bikes** + **5%** HDV to **Cargo Bikes**	✓	✓	✓	✓	✓
Scenario 6	(**30%** LDV to **Electric** + **10%** LDV to **Cargo Bikes**) + (**30%** HDV to **Electric** + **5%** HDV to **Cargo Bikes**)	✓	✓	✓	✓	✓

Source: Authors. Cyclist health refers to benefits of physical activity for cargo bike drivers in Scenario 4-6.

The most notable benefits are health impacts and CO_2 reductions, whereby in the most ambitious scenarios annual benefits (see Appendix 6 and 7) could account for:

- **~70 lives are saved in the long term** and **22 lives in the short term**
- **50 respiratory related hospitalizations avoided**
- Emission reductions of **500,000 tonnes of CO_{2e}**

Figure 3: What is the equivalent of 500,000 tonnes of CO_{2e}[3]?

[3] Impact CO_2, Comparateur carbone, ADEME, https://impactco2.fr/outils/comparateur.

Table of Contents

List of Tables

List of Figures

List of Abbreviations & Definitions

Average Vehicle	Aggregate of all motorized vehicles (except electric bicycles, mopeds, and motorcycles) circulating in Paris and used to measure the traffic flow and air pollutants emission data in the Econometrics section.
CO_2/ CO_{2e}	Carbon Dioxide/ Carbon Dioxide Equivalents
EEA	The European Environment Agency
EF	Emission Factor
HDV	Heavy-Duty Vehicle
HIA	Health Impact Assessment
LDV	Light-Duty Vehicle
LEZ	Low Emission Zone (an areas where the most polluting vehicles are regulated)
NO_2	Nitrogen Dioxide
PC	Passenger Car
PM_{10}	Particulate Matter 10 micrometers or less
R	The equivalent ratios between converting vehicles into Crit'Air E and removing and average vehicle
RR	Relative Risk Coefficient
ZTL	Zone Trafic Limité/ Limited Traffic Zone
ZLA	Zone livraisons apaisée/ Zero-Emission Delivery Area

I. Introduction

As part of traffic management during the Olympic Games, the Paris municipal authorities and the Paris police prefecture have *de facto* implemented Limited Traffic Zones (Zone à Trafic Limité: ZTL) during the summer of 2024. The ZTL is intended to eliminate through traffic, facilitate access and circulation of pedestrians and bicycles, and reduce air and noise pollution. In addition to this ZTL, a Zero-Emission Delivery Area (Zone livraisons apaisée: ZLA) could be implemented, which will require last-mile deliveries to be conducted utilizing zero-emission vans or trucks as well as cargo bikes. This initiative should improve air quality while mitigating noise pollution, thereby enhancing the overall quality of urban life in Paris.

1. Context

Paris stands prominently among the most polluted urban centers in Europe, a circumstance underscored by the recent launch of an infringement procedure against France by the European Commission for surpassing prescribed thresholds of pollutant concentrations[4]. This environmental concern is accompanied by health concerns[5] which is especially notable in the Île-de-France region[6]. According to Santé Publique France, long term exposure to atmospheric pollutants negatively impacts public health. Across France, approximately 40,000 deaths per year can be attributed to long-term exposure to particulate matter ($PM_{2.5}$) and 7,000 deaths per year can be attributed to long-term exposure to nitrogen dioxide (NO_2)[7]. This accounts for respectively 7% and 1% of the aggregate annual mortality. The establishment of ZLA could mark a significant turning point in advancing the expansion of Zero-Emissions Delivery Areas, particularly through the promotion of electric vehicle-based freight transportation including the usage of cargo bikes.

Globally there have been several initiatives aimed at improving air quality. Across Europe, studies show that similar Zero Emission Zones and initiatives in London, Berlin, Milan, and Stockholm have had a positive impact on air quality[8]. In the United States, the Environmental Protection Agency (EPA) recently announced a Clean Heavy-Duty Vehicles Grant Program which aims to

---

[4] European Commission. Air quality: European Commission asks France to comply with the judgment of the Court of Justice of the European Union. 18 March 2024.
[5] European Environment Agency (EEA). France – air pollution country fact sheet. 24 Nov 2023.
[6] AirParif. Air quality is improving in Île-de-France, but the stakes are rising. 13 April 2023.
[7] Impact of ambient air pollution on mortality in metropolitan France: Reduction related to Spring 2020 lockdown and new data for total burden of impact for the period 2016-2019. Publié le 2 juin 2021.
[8] Urban Access Regulations EU. Impact of Low Emissions Zone (LEZs). Low Emission Zones (LEZs) are areas where the most polluting vehicles are regulated.

invest $1 billion which aims to reduce pollution by replace existing non-zero-emission Heavy-Duty Vehicles with zero-emission vehicles and includes additional investments in electric vehicle infrastructure as well as workforce development[9]. Air pollution is a prominent concern across Europe and both policy and regulation serve as key tools to address air pollution and its negative externalities.

As France transitions towards the integration of low and zero-emission alternatives, the introduction of new innovative policies, like the ZLA, demands a thorough examination of its health effects and benefits.

2. Research Questions

The aim of this paper is to explore the health and environmental implications of implementing the ZLA in the City of Paris and, most importantly, the air quality and health implications. To do so, the following research questions below were set to identify the impacts of the introduction of the ZLA:

i. **What is the contribution of freight transport to air pollution in the City of Paris?**
ii. **What are possible scenarios to implement a ZLA policy?**
iii. **What are the actual impacts of implementing the ZLA based on proposed scenarios?**

The first question involves understanding how the ZLA would influence road traffic today. A recent study found that pollution changes associated with relative increased freight transportation during the pandemic would have cost around 7 lives[10] . Our aim is to expand and build on the existing knowledge and literature. The second question involves an in-depth exploration around how this policy may be implemented and the tradeoffs with different implementation strategies. The last question involves understanding how the ZLA would influence road traffic today, identifying the different environmental and health impacts.

[9] Environmental Protection Agency (EPA). Clean Heavy-Duty Vehicles Grant Program. April 2024.
[10] Lucie Letrouit & Martin Koning, 2023. "How large are the costs of local pollution emitted by freight vehicles? Insights from the COVID-19 lockdown in Paris," Working Papers hal-04106196, HAL.

3. Overview of Methodologies

To effectively and adequately answer the research questions posed, several methodologies are employed as seen in Figure 1. The first two methodologies, the econometric analysis and the traffic flow & emissions analysis, aim to understand the connection between traffic flow in Paris and air pollution.

i. Understanding the link between traffic and air pollution

In the econometric analysis, we use data collected from sensors across the city, these sensors measure average vehicle flow on the road network and in addition we use pollutant concentrations from weather measurement stations. The initial findings were unsurprising, showing a clear positive correlation between increased vehicle flow and pollution levels.

ii. Identifying how freight transportation impacts air pollution

However, this data only reflects the average vehicle flow in Paris, whereas our policy targets freight flow specifically. To address this, we completed a traffic flow & emissions analysis of the current fleet composition of Paris using available open-source datasets to understand the different vehicles circulating on the streets of Paris and their specific characteristics. We then assigned emission factors to each category based on vehicle technology and Crit'Air classification. This allowed us to dissect the contribution of each subgroup of the fleet and generate multiple scenarios involving cleaner vehicle options, such as electric Light-Duty Vehicles, electric Heavy-Duty Vehicles, and cargo bikes. By doing so, we estimate their impact on pollutant concentration.

iii. Exploring the health impact of different scenarios

The results of the first two methods are used to develop different scenarios involving the replacement of thermal vehicles with very low emission vehicles or cargo bikes in order to highlight the potential changes in terms of pollutant emissions. The environmental and health benefits are thus calculated as the reduction in mortality and hospitalizations due to air pollution and the reduction in CO2 emissions.

II. Econometric Analysis:

Linking Air Pollution and Traffic

1. Objectives

The first objective is to understand the relationship between air pollution and road traffic. One key assumption that underlies the policy recommendation is that changes in the composition of vehicles on the road will change levels of air pollution. While there is a rich literature that has identified this mechanism and pathway of change, econometric analysis is used to understand the link with traffic flow and air pollution specific to the city of Paris. This is done by examining a wide variety of factors like weather (wind, air temperature) to distill what levels of air pollution can specifically be attributed to changes in vehicle traffic flow. This means that we are able to understand the impact that an average vehicle on the streets of Paris has in terms of air pollution concentrations of NO_2 and PM_{10}.

2. Data Sources

The data set used covers the geographic area of Paris including the Boulevard périphérique between January 2018 to October 2020[11]. In addition to pollutant levels and traffic flow, which are our main variables of interest, this dataset includes several other variables. This allows us to control for other factors that might influence pollutant levels aside from traffic flow.

i. Air pollution data

Air pollution data was obtained from Airparif, with the concentrations of NO_2, NO_x, NO and PM_{10} in μg/m3 recorded at 8 measurement stations; the exact location of each station can be seen in Figure 2. Among these 4 pollutant data, NO_2 and PM_{10} were selected as the key elements of analysis, due to data availability for other elements of analysis, their well documented health impacts, and their close associations with traffic flows. While $PM_{2.5}$ is well known for its devastating health consequences, there is not enough data availability to generate a meaningful analysis and additionally PM_{10} serves as a tracer element for $PM_{2.5}$. NO_2 and PM_{10} are recognized for causing respiratory problems and contributing to cardiovascular issues. NO_2, a specific component of NO_x emissions, is particularly linked to combustion processes such as those found in vehicle engines[12]. On the other hand, PM_{10} is more directly associated with vehicle exhaust, tire wear, road dust, and the wear of brake pads[13]. Therefore, concentrating on these two pollutants provides a reliable indicator of traffic-related pollution.

ii. Traffic data

Hourly traffic data is sourced from the Paris city's open data website[14]. The system covers 4,400 road segments, encompassing 600 km out of the total 1,700km of roads in Paris. This includes coverage on major road networks, it can be assumed that increased traffic flows on the major road networks is highly correlated with increased traffic flows on the entire network. The data set used includes information for various buffer sizes around the pollution monitoring stations being

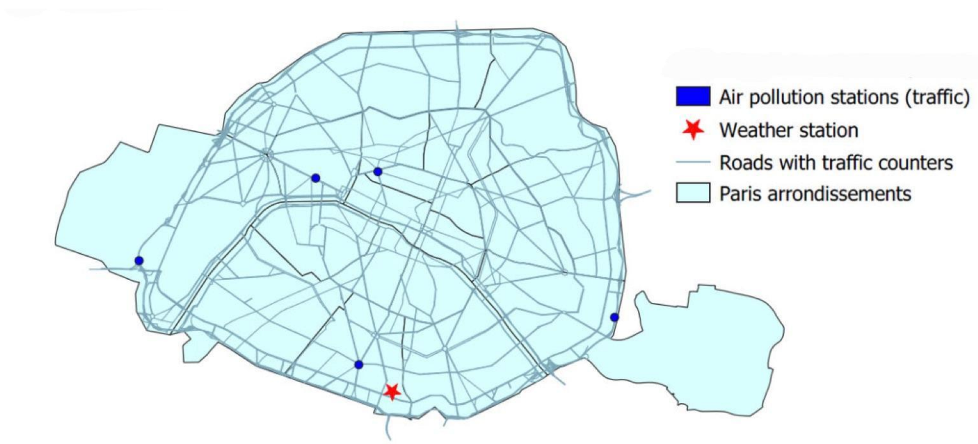
---

[11] Dataset provided by Martin KONING, a Transportation Economist and Director of Research in Economics with Université Gustave Eiffel.
[12] European Environment Agency (EEA). Explaining road transport emissions. 2016.
[13] N. Bukowiecki, P. Lienemann, M. Hill, M. Furger, A. Richard, F. Amato, A.S.H. Prévôt, U. Baltensperger, B. Buchmann, R. Gehrig, PM10 emission factors for non-exhaust particles generated by road traffic in an urban street canyon and along a freeway in Switzerland, Atmospheric Environment, Volume 44, Issue 19, 2010, Pages 2330-2340, ISSN 1352-2310,https://doi.org/10.1016/j.atmosenv.2010.03.039.
[14] Paris Data, https://opendata.paris.fr/pages/home/.

studied: 50m, 200m, and 500m. These variables are denoted as "traffic flow[buffer]" in the econometric analysis. Here, "traffic flow" refers to the average flow rate, representing the number of average vehicles[15] passing through the counting point within a fixed time interval (an hour in this case) with the diameter specified in meters, indicating the form of a circular counting area.

Alongside the average flow rate, we also have data on loops occupancy rate, noted as "tauxocc[diameter]" in the dataset. This rate indicates the percentage of time that vehicles occupy the loop within a given time frame. For example, a 25% occupancy rate over one hour implies that vehicles were present on the loop for 15 minutes during that hour. The occupancy rate provides information about traffic congestion.

Figure 4: Air Pollution & Weather Stations



Source: Authors.

iii. Weather data

Hourly weather information (temperature, atmospheric pressure, wind speed, wind direction, rainfall height, relative humidity) was measured at the unique weather station in Paris, which is located in the Montsouris Park in the south of Paris.

iv. Strike and Covid Count

Two significant factors impacting road traffic in Paris are strikes and the COVID-19 pandemic. During strikes in Paris in December 2019 against the new retirement pensions law of the government, public transportation often becomes disrupted, leading to increased private vehicle

[15] An average vehicle is any type of vehicle that is circulating on the streets of Paris, excluding bicycles, mopeds, and motorcycles.

usage and more congestion on the roads. Conversely, the COVID-19 pandemic had the opposite effect. Lockdown measures imposed movement restrictions, resulting in significantly reduced traffic volumes. In our dataset, "strike" and "covid" are represented as dummy variables, with a value of 1 indicating the presence of strike or covid regulations, and 0 indicating their absence.

v. Descriptive Statistics & Data Cleaning

Originally, the dataset contained 178,747 observations from 8 different measurement stations. However, after removing entries with missing (N/A) values, we were left with 74,576 observations from 5 remaining pollutant measurement stations. Additionally, since traffic congestion does not accurately reflect the impact of traffic flow on air pollution—due to the highly unstable relationship between traffic flow and speed during hyper congestion—we filtered the data to exclude instances where the occupancy rate exceeded 30%. This threshold indicates that vehicles were blocked on the loop for more than 18 minutes per hour, representing severe congestion. Detailed descriptive statistics for the various datasets are provided in Appendix 1.

Simply comparing the average values of each station did not reveal any clear relationship between traffic flow and air pollution. For instance, the eastern ring road (Boulevard Périphérique Est) had the highest traffic volume within the 50m and 200m buffer zones, while the Auteuil ring road (Boulevard Périphérique Aut) recorded the highest average emissions of NO_2 and PM_{10}. This suggests that a more detailed analysis is needed to understand the relationship between these variables, considering potential factors like weather conditions.

3. Econometric Modeling

Indeed, traffic flow is not the sole factor influencing pollutant levels. Weather conditions, the COVID-19 pandemic, strikes are among the numerous potential factors. It's evident that we can't account for all of these (unobserved) influences. One crucial factor we did consider was the location of pollutant measurement stations. The accuracy of pollutant measurements can be impacted by whether these stations are situated by the roadside, near parks, close to construction sites, or factors like the station's elevation. These variables can influence the measurements, complicating the isolation of the true impact of pollutants originating from traffic. The data was checked for extreme values, there were no outliers found. For our analysis, we assumed these factors to be relatively consistent over time, as the surroundings of the pollutant measurement stations typically undergo minimal change once established. A fixed effect model is applied to get rid of these unobserved traits of pollutant measurement stations.

In addition, we introduced Year, Month, Hour and Weekend dummies along with Covid and Strike indicators. This allowed us to examine annual, monthly, hourly and weekend variation in pollutant levels to capture systematic patterns over time.

$$Y_{ijt} = \beta_0 + \beta_1 * T_{jt} + \beta_2 * W_t + Dummies + \alpha_j + \epsilon_{ijt}$$

The above formula was used for the fixed effect model where Yijt represents the dependent variable, which denotes the pollutant level observed at station j at time t, for pollutant i (NO_2, PM_{10}), Tji corresponds to the observed traffic flow at station j at time t. Wt encompassess various weather variables such as average temperature, atmospheric pressure, wind speed, wind direction, and relative humidity observed at time t.

The term ‘Dummies' represents several factors, including hourly, monthly, and yearly dummies as well as weekend, Covid and strike indicators. j represents the station fixed effect. This term remains constant and unique to each station j, capturing unobserved and time-invariant traits specific to the station that may influence pollutant levels.

4. Results

The results can be found in the Appendix 2. We will highlight the main findings of buffer size 500m as it shows the best performance in terms of adjusted R squared.

i. Traffic Flow

For every one-unit increase in traffic flow, equivalent to one additional vehicle within a 500 meter buffer zone, there is a statistically significant average increase in NO_2 levels by 0.0049 µg/m³. Moreover, this association becomes more pronounced as the buffer size increases. Similarly, for every one-unit increase in traffic flow within a 500 meter buffer zone, there is a statistically significant average increase in PM_{10} levels by 0.0019 µg/m³, and this effect becomes more pronounced as the buffer size increases.

ii. Covid Lockdown

During the Covid lockdown period, NO_2 levels decreased significantly by an average of 17.97 µg/m³ compared to the absence of Covid lockdown measures. PM_{10} levels decreased significantly by an average of 6.38 µg/m³ compared to measurements taken in the absence of a lockdown. This decrease is smaller than that observed for NO_2, likely due to the fact that while car engine combustion is a main source of NO_2, PM_{10} originates not only from car traffic but also from residential combustion in households and background pollution from outside and within the City. Therefore, the lesser decrease in PM_{10} levels during the lockdown can be attributed to households remaining active in Paris.

iii. Strikes in Paris

The presence of strikes in Paris in december 2019 resulted in a statistically significant increase in NO_2 levels by 3.88 µg/m³ within a 500 meter buffer zone compared to periods without strikes. This increase is attributed to disruptions in public transportation, leading to a higher reliance on private vehicles. The presence of strikes in Paris led to a statistically significant increase in PM_{10} levels by 4.02 µg/m³ within a 500 meter buffer zone compared to periods without strikes.

iv. Seasonal Variation

In July and August, relative to December (serving as the reference month), NO_2 levels experienced a statistically significant average decrease of -17 µg/m³ and -20 µg/m³ across different buffer zones. This decline is primarily attributed to the temporary reduction in traffic volume during the summer vacation period in Paris. In August and September, relative to December (serving as the reference month), PM_{10} levels experienced a statistically significant average decrease of -3.3 µg/m³ across different buffers. The decrease in August and September could likely be interpreted as the summer vacation effect, for those with children in August and for those who avoid the holiday peak and take advantage of the lower temperatures in September.

v. Rush Hours

During rush hours[16] (7:00 AM to 9:00 AM and 4:00 PM to 7:00 PM), NO_2 levels increased significantly by an average of 15 µg/m³ compared to the reference hour of 12:00 AM. This elevation is linked to the heightened traffic congestion during peak commuting hours. Similar to NO_2, during the morning peak hours (7:00 AM to 9:00 AM), the level of PM_{10} gradually increases from 4.739 to 7.939 µg/m³ compared to the reference hour of 12:00 AM. However, unlike NO_2, we do not observe a clear increase during the afternoon peak hours (4:00 PM to 7:00 PM).

vi. Weekend Effect

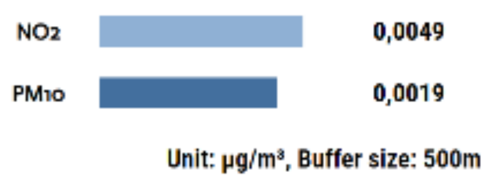
During the weekend, PM_{10} levels increased significantly by 1.276 µg/m³. This increase is attributed to leisure activities bringing more vehicles on the road, particularly near the Boulevard Périphérique. In the following chapter, this will be analyzed in more detail for different vehicle classes, emissions categories, etc.

[16] Rush hours as defined by RATP are from 7 h 30 - 9 h 30 et 16 h 30 - 19 h 30. These hours largely align with our data. https://www.ratp.fr/decouvrir/coulisses/au-quotidien/reseau-ratp-questions-de-ponctualite

5. Key Findings

As expected, the data showed a strong correlation with regards to air pollution and traffic flows in Paris including weekend effects, peak hour traffic, seasonal variations, and effects from both covid and strikes. Based on our analysis, we found that:

Figure 5: NO_2 and PM_{10} Concentrations Resulting from an Average Vehicle in Paris



Source: Authors.

An average vehicle is any type of motorized vehicle that is circulating on the streets of Paris, excluding electric bicycles, mopeds, and motorcycles. This is based on the traffic flow data given. In the following chapter, this will be analyzed in more detail to understand how different vehicle classes contribute to emissions.

6. Back of the Envelope Test

While it is known that road traffic contributes to air pollution, there are other sources of atmospheric pollution. Based on data from the EEA, it is estimated that road transport contributes approximately 37% of NOX emissions and 9% of PM_{10} emissions[17]. In the model without dummies which does not take into account other explanatory variables aside from weather, the air pollution attributable to traffic flow would be 0.012 for NO_2 and 0.0042 for PM_{10}. Whereas in the model with dummies, the air pollution attribution to traffic flow is lower with 0.0049 for NO_2 and 0.0019 for PM_{10}, which as a percentage of the model without dummies is 41.45% for NO_2 and 45.21% for PM_{10}. When compared to the percentages by the EEA it seems to be in a reasonable range for NO_2, a 4.45% difference, and may be overstated for PM_{10}, a 36.21% difference. Given that the information for the analysis is specific to Paris and the EEA calculation is based on all of EU averages, there will likely be sector specific differences that are relevant and worth further exploration in future analysis.

[17] European Energy Agency. Air quality in Europe 2022: Sources and emissions of air pollutants in Europe. There is a chart that highlights contributions to EU emission from the top sectors since NO2 is not listed, NOX is used as a proxy. See the appendix for the full chart and table.

III. Traffic Flow & Emissions:

How does freight transportation impact air pollution?

1. Objectives

In the previous section, the overall effect of an 'average vehicle' on pollution in Paris was assessed. However, this analysis does not provide any insight into the specific characteristics of the vehicles within the city and their unique influence on pollution, for example it is known that larger vehicles typically pollute more. By recognizing that removing a Light-Duty Vehicle or a Heavy-Duty Vehicle will not have the same effect of removing a passenger car, we decided to break down this 'average vehicle' concept to a more granular level. This is done in order to gain a clearer understanding of the specific vehicle distribution in Paris and how each category contributes to pollution. This is relevant as delivery vehicles typically tend to be Light-Duty and/or Heavy-Duty Vehicles.

To achieve this, the fleet is categorized by vehicle type, energy source, Crit'Air classification, and emission levels. This classification allows for a more precise analysis of each vehicle type's impact on pollution and by extension better anticipate the outcomes of various vehicle transition scenarios on pollution levels. *To do so, three key steps were undertaken:*

1) Understanding the **Paris Fleet Composition** - Since the average vehicle represents the average of all the vehicles on the streets of Paris, a key first step is understanding the different types of vehicles that make up the Parisian Fleet.
2) **Attributing air Pollution** based on key **EEA Emissions Factors** - To understand how different vehicle types contribute to air pollution in Paris analysis, the data is harmonized with EEA Emission Factors that considers factors such as: the number of vehicles; their type (e.g., passenger cars, Light-Duty Vehicles, Heavy-Duty Vehicles, etc); fuel energy sources (e.g., diesel, gasoline/petrol, hybrid, electric); and their emission classifications (e.g., Crit’Air E, Crit’Air 1, Crit’Air 2, etc).
3) **Evaluating vehicle contributions** and fleet transformation effects - Based on the previous data, vehicle classifications are compared to one another and fleets transformations associated with the six different scenarios are calculated.

2. Data Sources

This was achieved by collecting and analyzing data from various statistical sources, including the Paris and the Données et Études Statistiques Databases.

i. Bilan de déplacement à Paris

The 2022 Transport and Mobility Report[18] by the City of Paris, available through the city's official Open Data portal Paris Data.

ii. Parc Automobile en France 2022

National Service for Data and Statistical Studies (SDES), responsible for producing socio-economic and statistical observations in various areas, namely detailed statistics on France's vehicle fleet for the year 2022[19].

These two datasets provide detailed information on:

- **Traffic flow** within the city of Paris, *(average vehicle/km per hour)*
- **Vehicle shares per type** *(e.g., passenger cars, Light-Duty Vehicles, Heavy-Duty Vehicles, etc),*
- **Vehicle technical specifications** *(Crit'Air classification[20], engine type, fuel source, etc),*
- **Network length** *(Intra-Muros and Périphérique)*
- **Average Speed** on each network

[18] Ville de Paris, « Bilan des déplacements à Paris en 2022 », https://www.paris.fr/pages/le-bilan-des-deplacements-a-paris-en-2022-24072#la-circulation-automobile.

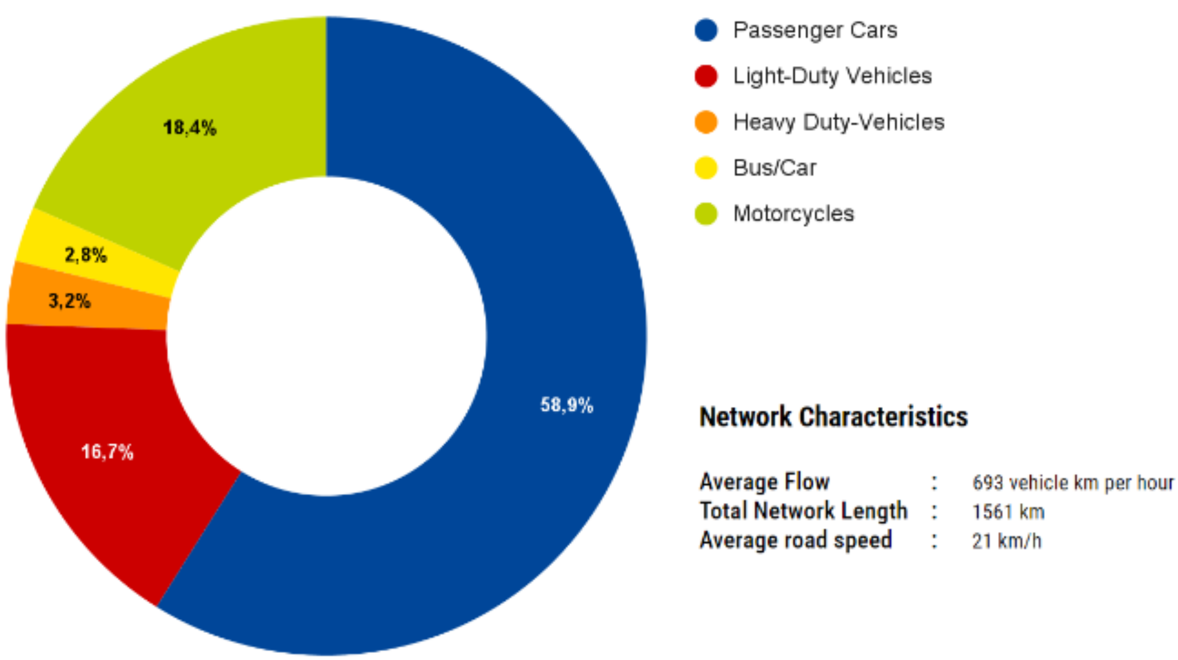
[19] Ministère de la transition écologique et de la cohésion des territoires, « Données sur le parc de véhicules en circulation au 1er janvier 2022 », https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-le-parc-de-vehicules-en-circulation-au-1er-janvier-2022.

[20] The Crit'Air Classification was chosen for this study because it is the only available statistical distribution from French national open sources. It provides a detailed breakdown of the fleet composition, enabling the assignment of more precise emission factors to each Crit'Air Class, rather than a single value for an entire category.

3. Fleet Composition: Dissecting the Parisian Vehicle Fleet

We were able to develop a comprehensive structure encompassing both the Paris Intra-Muros and the Périphérique networks.

Figure 6: Global Parisian[21] Fleet Structure based on category



Source: Authors.

In which we find that Passenger Cars (PC) still hold a predominant position in the fleet makeup, representing **58.93%** of all vehicles, thereby affirming their role as the principal mode of road transportation in the city. Light-Duty Vehicles (LDV) form **16.69%** of the flow, a substantial proportion is utilized for freight and commercial activities. Conversely, Heavy-Duty Vehicles (HDV) constitute a mere **3.21%** of the total fleet. Despite their limited numbers, the influence of HDVs on traffic congestion, road infrastructure, and pollutant concentration is disproportionately high when compared to lighter vehicles such as Passenger Cars (PC).

[21] Composition of the traffic flow on Parisian roads (including the ring-road).

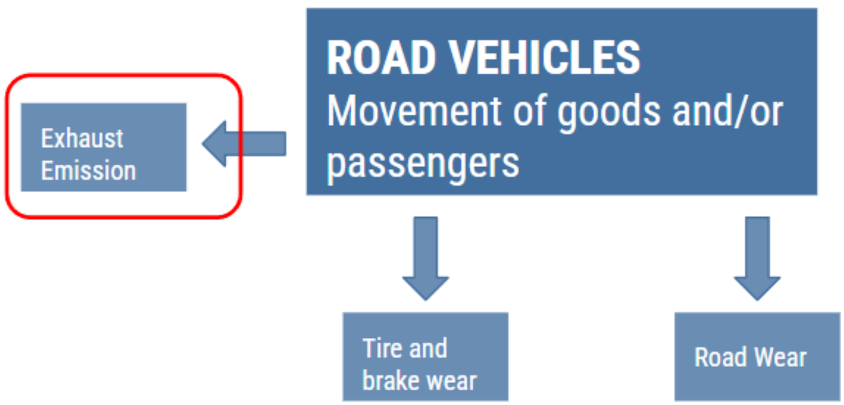
Referencing the vehicle flow data presented on the Bilan des déplacements à Paris[22] within both the Paris Intra-Muros and the Périphérique and by aggregating the two using network length as a weight, we have determined a total vehicular flow rate of **693** vehicles per hour per kilometer across a total network spanning **1,561** kilometers. Detailed insights pertaining to each specific network can be found in Appendix N°5 Table A13 and A14.
The average vehicular speed is recorded at a modest **21 km/h**. This is largely influenced by the dense traffic within the Intra-Muros network. Such limited speed reflects the traffic congestion in the city, which can be attributed to factors such as high vehicular density, urban planning constraints, and existing traffic regulation measures in a historic and densely populated urban environment like Paris.

[22] Ville de Paris, « Bilan des déplacements à Paris en 2022 », https://www.paris.fr/pages/le-bilan-des-deplacements-a-paris-en-2022-24072#la-circulation-automobile.

4. Emissions factors (EF) for the Parisian road traffic

Having structured the Parisian fleet of all major vehicle categories by the Crit'Air classification[23], (refer to Appendix N°5: Table A16), we have then assigned the corresponding emission factor (NOX, NO_2[24] and PM_{10}) to each vehicle category, following the guidelines outlined by the European Environment Agency for emission factors for road transport (See Appendix N°5: Figure A17)[25].

Figure 7: Emissions resulting from the use of vehicles



Source: Authors.

We then estimated the exhaust emission levels for each vehicle category, as well as for our theoretical average vehicle[26](cf. Appendix N°5: Table A19).

This process allowed us to calculate the impact of converting each specific type of vehicle to a Crit'Air E classification vehicle (which includes electric and cargo bikes, among others), and compare the results with those of our average vehicle. Since the removal of one light vehicle from the streets does not have the same effect on pollutant concentrations as the removal of a Heavy-Duty Vehicle or a motorcycle. See Appendix N°5: Table A20.

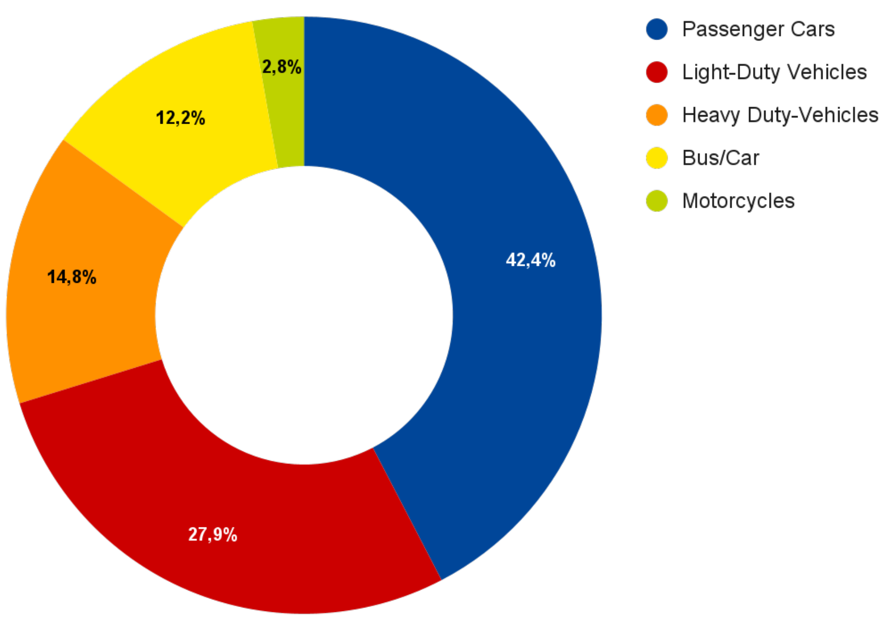
[23] Based on the availability of data regarding the distribution and emission levels of L-category vehicles in France, the analysis was conducted using the engine cylinder capacity as a primary criterion instead of Crit'Air Classification, refer to Appendix N°5: Table A16.
[24] NO2 emissions were estimated using a conversion factor of NOX, as presented in the study by Pastramas et al. (2015), see Appendix N°5: Table A18.
[25] European environment agency, "Road transport appendix 4 emission factors 2024", https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i-1/view.
[26] The Emission Factor (EF) for an average vehicle is calculated by averaging the EF for each vehicle category weighted by their respective statistical distribution within the Parisian fleet.

5. Pollutant Emission by vehicle category

By utilizing the assigned emission factors for major vehicle categories in Paris paired with the city's fleet structure (see Figure 4), we can estimate the potential emissions of NO_2 and PM_{10} for each category.

In terms of **NO_2 concentration**, passenger cars, Light-Duty Vehicles (LDVs), and Heavy-Duty Vehicles (HDVs) dominate the overall emission profile (refer to Figure 6). Notably, HDVs contribute disproportionately to the emissions despite representing only **3.2%** of the total fleet (as depicted in Figure 4).

Figure 8: NO2 concentration distribution in Paris[27]

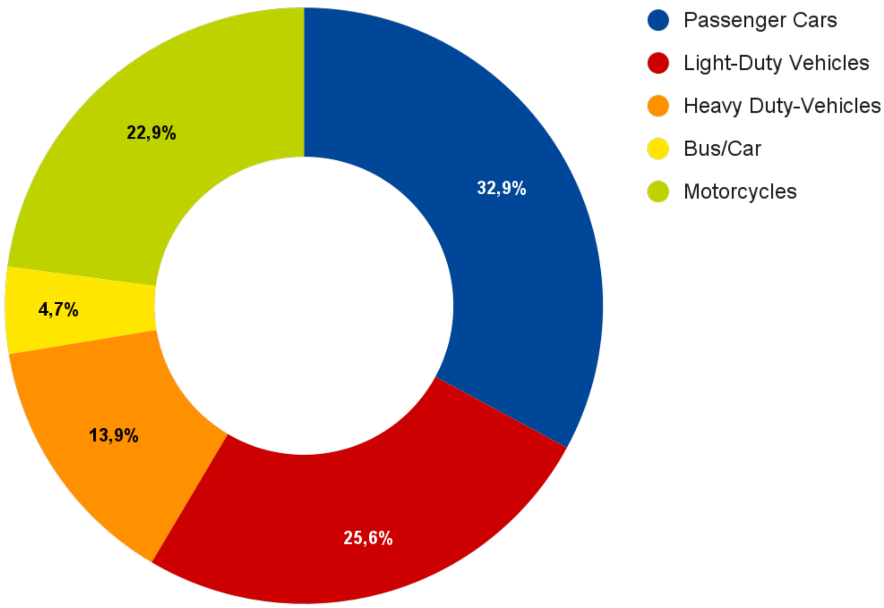


Source: Authors.

On the other hand, when considering **PM_{10} concentration**, the same three categories (passenger cars, LDVs, and HDVs) remain significant contributors. However, motorcycles emerge as a newly identified heavy emitter, contributing **22.9%** of the overall PM_{10} emissions (Figure 7). This closely aligns with the share of motorcycles in the fleet, which stands at **18.4%** according to Figure 4.

[27] NO2 emissions of the different vehicle types were estimated using a NOX conversion factor (f-NO2), as presented in the study by Pastramas et al. (2015).

Figure 9: PM_{10} concentration distribution in Paris



Source: Authors.

6. Vehicle subgroup comparison

In the following table, we highlight the effect of Crit'Air E conversion for all types of vehicles and at several speeds.

Table 2: Ratios R[28] of pollution reduction when converting vehicles into Crit'Air E, compared to the average vehicle

Source: Authors.

Pollutant	Speed	Ratio Pollution Reduction Compared to Average Vehicle		
		PC	LUV	HDV
NOX	12 km/h	0,52 x	1,17 x	7,83 x
	14 km/h	0,53 x	1,21 x	7,62 x
	16 km/h	0,54 x	1,24 x	7,48 x
	18 km/h	0,55 x	1,27 x	7,37 x
	20 km/h	0,56 x	1,30 x	7,28 x
	22 km/h	0,57 x	1,32 x	7,21 x
	24 km/h	0,57 x	1,33 x	7,15 x
	26 km/h	0,58 x	1,35 x	7,10 x
	28 km/h	0,58 x	1,36 x	7,07 x
	30 km/h	0,58 x	1,37 x	7,04 x
NO2	12 km/h	0,68 x	1,54 x	5,05 x
	14 km/h	0,70 x	1,58 x	4,88 x
	16 km/h	0,71 x	1,61 x	4,75 x
	18 km/h	0,71 x	1,64 x	4,66 x
	20 km/h	0,72 x	1,66 x	4,58 x
	22 km/h	0,72 x	1,68 x	4,52 x
	24 km/h	0,72 x	1,70 x	4,47 x
	26 km/h	0,72 x	1,72 x	4,43 x
	28 km/h	0,72 x	1,73 x	4,41 x
	30 km/h	0,72 x	1,74 x	4,39 x
PM	12 km/h	0,53 x	1,56 x	5,11 x
	14 km/h	0,54 x	1,55 x	4,83 x
	16 km/h	0,54 x	1,54 x	4,61 x
	18 km/h	0,55 x	1,53 x	4,43 x
	20 km/h	0,55 x	1,51 x	4,28 x
	22 km/h	0,55 x	1,50 x	4,15 x
	24 km/h	0,55 x	1,48 x	4,04 x
	26 km/h	0,55 x	1,46 x	3,95 x
	28 km/h	0,56 x	1,44 x	3,87 x
	30 km/h	0,55 x	1,42 x	3,80 x

Taking for example, a set speed of **20 km/h** which closely relates to the average speed of the Parisian network, we get the following ratios (R):

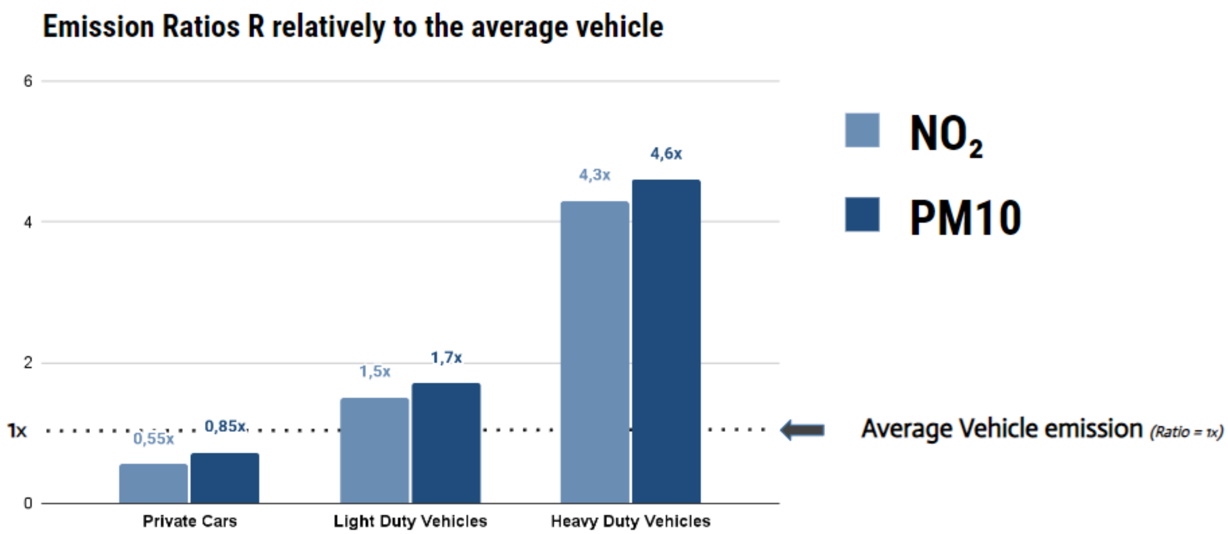
- Converting one Light-Duty Vehicle (LDV) to Crit'Air E, has the equivalent effect of removing **1.66x** average vehicle from the street **in terms of NO_2 emission.**
- Converting one Heavy-Duty Vehicle (HDV) to Crit'Air E, has the equivalent effect of removing **4.58x** average vehicle from the street **in terms of NO_2 emission.**

[28] R : The equivalent ratios, between converting a set vehicle into Crit'Air E and removing an average vehicle from the streets

7. Key Findings

This analysis revealed several key factors that have influenced our scenario development and policy recommendations. The first is that the composition of the vehicles is highly relevant when considering the emission factor of different vehicle types.

Figure 10: Overview of EF by Vehicle Type Compared to an Average Vehicle



Source: Authors.

Another way to visualize this is to compare emissions factors from Light-Duty Vehicles and Heavy-Duty Vehicles to private vehicles as seen in Figure E2.

IV. ZLA Scenarios

Exploring policy implementation

1. Scenario Development

In the previous section of this report, we observe a significant impact of LDVs and HDVs on pollutant concentrations. Therefore, the Zero-Emission Delivery Area (ZLA) scenarios will primarily focus on converting these two categories into cleaner variants (Crit'Air E[29]), specifically electric vans, electric trucks and cargo bikes.

Table 3: ZLA Scenarios

Scenario	Description
Status Quo	2022 Traffic Flow Structure in Paris
Scenario 1	**50%** LDV to **Electric**
Scenario 2	**50%** HDV to **Electric**
Scenario 3	**100%** LDV and **100%** HDV to **Electric**
Scenario 4	**85%** LDV to **Electric** + **15%** HDV to **Cargo Bikes**
Scenario 5	**10%** LDV to **Cargo Bikes** + **5%** HDV to **Cargo Bikes**
Scenario 6	(**30%** LDV to **Electric** + **10%** LDV to **Cargo Bikes**) + (**30%** HDV to **Electric** + **5%** HDV to **Cargo Bikes**)

Source: Authors.

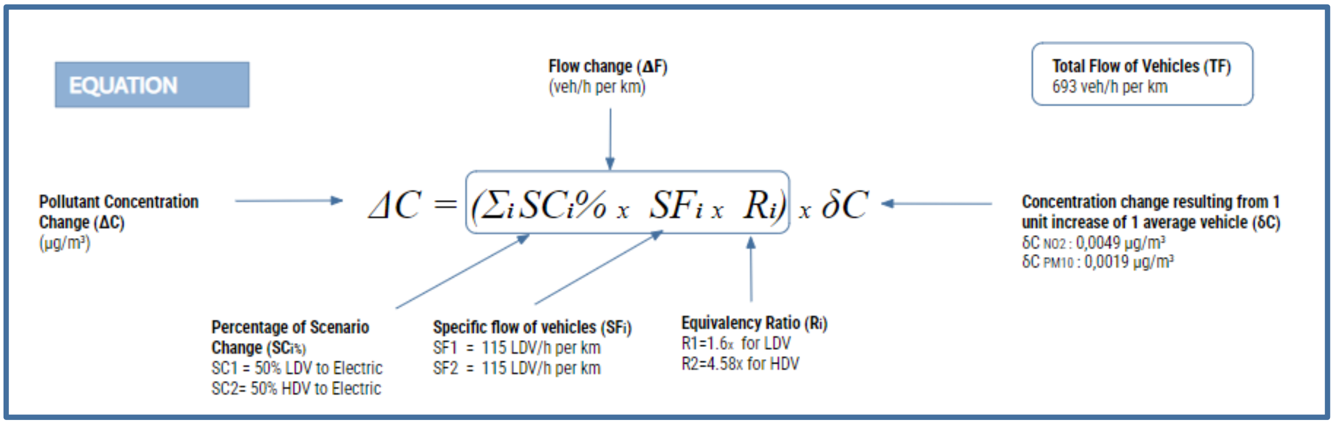
The first three scenarios are concerned with converting a certain percentage of the current fleet to electric vehicles. Conversely, the last three scenarios explore the incorporation of a specific proportion of cargo bikes in addition to electric vehicles. The selection of cargo bikes was deemed a viable option given the context of our study. Given that cargo bikes are well within the Crit'Air E classification due to their zero-emission nature, and their potential benefits for alleviating congestion and providing additional health advantages for its users.

[29] Crit'Air E are all 100% electric or hydrogen vehicles.

2. Effect of the ZLA scenarios on pollutant concentration

The effect on pollutant concentration, denoted as ΔC, was evaluated using the subsequent simplified equation:

Figure 11: Pollutant Concentration change equation



Source: Authors.

Where:

- **ΔC :** represents the **change in pollutant concentration** after implementing one of the scenarios, measured in micrograms per cubic meter *(μg/m³)*.
- **TF :** stands for the **total flow** within the Parisian network, with a reference figure N° of **693** vehicles per hour per kilometer *(veh/h per km)*.
- **SF :** indicates the **specific flow for a particular vehicle category**. For example, the specific flow for Light-Duty Vehicles (LDV) can be calculated as SF (LDV) = TF x 16.7%.
- **SC% :** signifies the **Scenario Change**, which is the percentage of vehicles targeted for conversion to Crit'Air E standard.
- **R** : corresponds to the equivalent ratios for converting a specific vehicle into Crit'Air E in comparison to removing an average vehicle from the streets in terms of pollutant emissions.
- **δC** : is the change in pollutant concentration resulting from a one-unit increase in an average vehicle[30].

[30] δC : Refer to Figure 3 in the first section of the Econometric Analysis

By running the pollutant change equation for the six different scenarios, we obtained on Table 3 the following results:

Table 4: Scenario's Effect on Pollutant Concentration

Scenario	Description	Δ NO_2 (µg/m3)	Δ PM_{10} (µg/m3)
Status Quo	2022 Traffic Flow Structure in Paris		
Scenario 1	**50%** LDV to **Electric**	**0.47**	**0.17**
Scenario 2	**50%** HDV to **Electric**	**0.25**	**0.09**
Scenario 3	**100%** LDV and **100%** HDV to **Electric**	**1.44**	**0.51**
Scenario 4	**85%** LDV to **Electric** + **15%** HDV to **Cargo Bikes**	**0,94**	**0.33**
Scenario 5	**10%** LDV to **Cargo Bikes** + **5%** HDV to **Cargo Bikes**	**0,12**	**0.04**
Scenario 6	(**30%** LDV to **Electric** + **10%** LDV to **Cargo Bikes**) + (**30%** HDV to **Electric** + **5%** HDV to **Cargo Bikes**)	**0,55**	**0.20**

Source: Authors.

- Least ambitious scenario: 0.12 µg/m³ reduction in NO_2 and 0.04 µg/m³ reduction in PM_{10}.
- Most ambitious scenario: 1.44 µg/m³ reduction in NO_2 and 0.51 µg/m³ reduction in PM_{10}.

Another important aspect that the scenarios has an effect on, is the share of electrical vehicles relatively to the non-electrical vehicles, so we computed the flow change of these scenarios, since it will help up later on asses the different impacts, such as noise and CO_2 emissions (knowing that electric vehicles generate less noise) as well as congestion (as cargo-bikes use less space and usually use cycle lanes, freeing up road space).

Furthermore, the scenarios also affect the share of electric vehicles (EVs) compared to non-EVs. So, we calculated the flow change for each scenario (Table 4.), which will help us later assess various impacts, including:

- Noise reduction (since EVs produce less noise).
- Congestion relief (as cargo-bikes use less space and use cycle lanes, freeing up road space).

V. Health Impact Assessment

How might changes in pollutant concentrations impact health?

1. Objectives

Since the 1970s, there has been a rich literature exploring the link between air pollution and life expectancy including a Global Burden of Disease, Injuries, and Risk Factor study which assessed 188 countries from 1990-2013 and found that air pollution could be attributed for 5.5 million deaths and 141.5 million disability-adjusted life-years (DALYs)[31]. Our analysis aims to understand the health impacts associated with the pollutant concentration changes in NO_2 and PM_{10} in the various scenarios identified previously. The health impact analysis (HIA) aims to understand both the short-term and long-term impacts that result from NO_2 and PM_{10} exposure, these impacts are defined using the Guide for the Production of Quantitative Evaluation of Impacts on Health (EQIS)[32] as seen below.

i. Short-term impacts occur within a few days of exposure to atmospheric pollution and represent conditions that worsen health and or exacerbate chronic pathologies (or diseases). These aggravations can manifest themselves by symptoms which may lead to care, hospitalizations, or even deaths. The relative risks associated with short-term effects are classically derived from multicenter studies based on time series analyses.

ii. Long-term impacts are defined as the contribution of exposure to atmospheric pollution to the development of chronic pathologies (e.g. respiratory, cardiovascular, neurological, etc.). These pathologies will result in clinical symptoms throughout life, and may, in the most serious cases, lead to death. The relative risks associated with long-term effects are classically from cohort studies of individuals followed over many years.

[31] Feigin VL, Roth GA, Naghavi M, Parmar P, Krishnamurthi R, Chugh S, Mensah GA, Norrving B, Shiue I, Ng M, Estep K, Cercy K, Murray CJL, Forouzanfar MH; Global Burden of Diseases, Injuries and Risk Factors Study 2013 and Stroke Experts Writing Group. Global burden of stroke and risk factors in 188 countries, during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet Neurol. 2016 Aug;15(9):913-924. doi: 10.1016/S1474-4422(16)30073-4. Epub 2016 Jun 9. PMID: 27291521 ;

[32] Pollution atmosphérique. Guide pour la réalisation d'une évaluation quantitative des impacts sur la santé (EQIS). EQIS avec une exposition mesurée. 2019

There are three main impacts analyzed:

- The first impact is non-accidental mortality which impacts people of all ages and is linked to both changes in pollutant concentrations of NO_2 and PM_{10}.
- The second impact is hospitalizations from respiratory causes which also impacts people of all ages and is linked to changes in pollutant concentrations of NO_2. Hospitalizations from respiratory causes are also linked to $PM_{2.5}$, however since our two pollutants of interest are PM_{10} and NO_2, this factor is not included in the analysis. These short-term impacts occur within a few days of exposure. The third and final impact is the long-term impact on total mortality[33], which is linked to changes in pollutant concentrations of NO_2. A Committee on the Medical Effects of Air Pollutants (COMEAP) study found that Mortality and long-term exposure to NO_2 represents the risk associated with the mixture of pollutants including NO_2 as a tracer, and thus, these benefits also reflect the benefits of pollution reductions in particle emissions. It is important to note that the long-term impact on mortality takes into account the short-term impact on mortality.

Table 5: Health Impacts associated with NO_2 and PM_{10}

Health Impacts	NO_2	PM_{10}
Short-term Impacts		
Non-Accidental Mortality	✓	✓
Hospitalizations from Respiratory Causes	✓	
Long-term Impacts		
Total Mortality	✓	

Source: Authors

There are other effects that are not included in our analysis. These include short term impacts like asthma, strokes, and other cardiovascular ailments, for which the effects of pollutants are well documented and quantified. In addition to long term impacts like lung cancer and low infant birth weights that are also well documented and quantified, other long-term impacts such as children asthma, cardiovascular ailments, type 2 diabetes, strokes, and Parkinson's disease have

[33] Long-term Total Morality is based on adults age 30 +. For our analysis, we base it off adults age 35+ given that mortality rates for Paris are given in age brackets (i.e. 24-34).

been linked to air pollution but the exact impact of air pollution on these diseases is not yet fully determined.

2. Data Sources

i. Relative Risk Coefficients specific to France

The relative risk coefficients (which measure risks associated with changes in pollutant concentrations in increments of 10µG/M3) used in the present study for NO2 and PM10 are taken from the Guide for the Production of Quantitative Evaluation Impacts on Health (EQIS) published by the French public health body, Santé Publique[34]. For impacts where effects can be reliably quantified[35], the relative risk coefficients identify key elements like mortality rate[36] and hospitalizations[37] and a dose-response function is used to estimate the magnitude of the health impact as a function of exposure to air pollution. We average data between the years 2019 and 2021 as 2020 has Covid outliers and most of our analysis is based on 2022 data. Where data is available for France and not for Paris, the population of Paris to France is used to identify what is attributable to Paris. For a list of values, please refer to appendix six.

[34] Santé publique France, « Pollution atmosphérique. Guide pour la réalisation d'une évaluation quantitative des impacts sur la santé (EQIS). EQIS avec une exposition mesurée », https://www.santepubliquefrance.fr/determinants-de-sante/pollution-et-sante/air/documents/guide/pollution-atmospherique.-guide-pour-la-realisation-d-une-evaluation-quantitative-des-impacts-sur-la-sante-eqis-.-eqis-avec-une-exposition-mesuree

[35] Group A: pollutant-effect pairs for which the level of uncertainty on transposability the risk is low and for which sufficient data are available to allow reliable quantification of the effects. Group B: couples pollutant-effects for which there is more uncertainty or for which the availability of data to quantify the effects is not necessarily guaranteed. EQIS

[36] Centre d'épidémiologie sur les causes médicales de décès (CépiDc) - INSERM, "Open data", https://opendata-cepidc.inserm.fr/

[37] https://www.scansante.fr/applications/statistiques-activite-MCO-par-diagnostique-et-actes. The value for hospitalizations is set at 5,000 per visit.

3. Methodology

To calculate the health impact, the change in pollutant concentration as identified for each specific scenario and pollutant is used in conjunction with the relative risk coefficients, dose responses, and monetized values as seen below.

$$HI \quad ps = \Delta P \quad * \; RR_{lah} \quad * \; MV$$

- HI : Health Impact
- p : specific pollutant (NO_2 or PM_{10})
- s : scenario (1-6)
- **Δ**P : Change in pollutant concentration
- RR : Relative risk coefficient (lah = low, average, high)
- MV : monetization values

4. Results

When considering health impacts, there are two main impacts of interest: short-term impacts and long-term impacts. Short-term health impacts include non-accidental mortality resulting from non-accident causes and respiratory hospitalizations. Long term health impacts include total mortality which accounts for mortality impacts on all adults age 30 and up. When considering the associated benefits, this would translate to lives saved and hospitalizations avoided. Table 5 illustrates how many avoidable deaths from air pollution can be prevented in each scenario.

Table 6: Health Impact Assessment based on Average RR

	Values	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Short Term							
Non-accidental mortality	PM_{10} - lives saved	0.66	0.36	2.05	1.33	0.17	0.78
Non-accidental mortality	NO_2 - lives saved	4.69	2.48	14.35	9.38	1.19	5.49
Total short term mortality	PM_{10} + NO_2 - lives saved	5.36	2.84	16.40	10.71	1.36	6.27
Hospitalizations	NO_2 - hospitalizations avoided	12.25	6.48	37.46	24.50	3.10	14.33
Long Term							
Total long-term mortality	NO_2 - lives saved	14.04	7.43	42.95	28.09	3.55	16.44

Source: Authors. Calculations based on methodology section and excludes monetization values.

While Table 6 shows the average risk values, it could be argued that high relative risk coefficients ought to be used which would result in 25 lives being saved in the short-term and 69 lives in the long-term. The appendix includes a table that represents the full range of risks from low to high.

5. Key Findings

Based on the results presented, a Zero-Emission Delivery Area in Paris would generate significant health benefits, both in the short and the long term. Besides reducing air pollution-related mortality, it would also provide cost savings to the government as it reduces respiratory related hospitalizations. Additionally, the health benefits of adopting a Zero-Emission Delivery Area will occur over several years, therefore it is reasonable to expect these benefits would compound over time.

VI. Impact on CO2 emissions

A recent report from the IEA, found that “if SUVs were a country, they would be the world’s fifth latest emitter of CO_2[38]“. In the scenarios presented, reductions in CO_2 emissions stem from shifting from a percentage of the LDV and HDV gasoline and diesel vehicles to electric vehicles and or cargo bikes. This section analyzes the resulting CO_2 emission reductions related to both the usage and non usage of vehicles and the delta resulting from the proposed changes in vehicle flow. The methodology used to calculate CO_2 emissions is shown below:

$$TCC \quad = CO2_v \, * \, \Delta F_v \quad * R \quad * \, T_u \, * \, RV \quad \quad * \, R_t$$

- CC : Total Cost of Carbon Reductions
- CO_2 : ton CO_2e from lifecycle usage and non usage
- **Δ**F : Change in flow/ hour/ k
- v : vehicle type
- R : road length
- RV : reference value
- T : time
- o : operating hours

Table 7: CO_2 Reductions Associated with Changes in Vehicles by Scenario

	unit (tonCO_2e/km)	unit(tonCO_2e/h)	unit(tonCO_2e/day)	unit(tonCO_2e/year)
Scenario	**Total CO_2 Emission from Usage + Non Usage**	**Hourly CO_2 Reduction**	**Daily CO_2 Reduction**	**Annual CO_2 Reduction**
Status quo	111			
Scenario 1	83	29	692	211,144
Scenario 2	102	9	215	65,520
Scenario 3	37	74	1,776	541,741
Scenario 4	55	56	1,355	413,332
Scenario 5	105	7	160	48,770
Scenario 6	82	29	695	211,890

Source: Authors. Based on the CO_2 emission methodology above excluding the reference values. It assumes 305 working days in a year.

[38] IEA. (2024, May 28). *SUVs are setting new sales records each year – and so are their emissions – Analysis*. IEA.

The key finding of the CO2e analysis is that there are significant CO2e reductions resulting from this policy implementation. Meaning that the transition to electric vehicles and/or cargo bikes represents a unique opportunity to simultaneously address air pollution and the climate crisis. If these CO2e reductions were to be monetized, this could present unique opportunities to subsidize freight operators for the avoided carbon emissions.

1. Key Findings

The section on other benefits provides useful insights into the hourly, daily, and annual benefits associated with implementing these different scenarios. Surprisingly or unsurprisingly, the top benefit stems from cyclist's physical activity. The second most beneficial impact stems from emission reductions, these CO_{2e} reductions are present in all the scenarios whereas the cyclist's health benefits are only present in scenarios 4-6. While there are noise and congestion benefits to be gained, the daily and annual benefits are marginal in comparison to benefits from CO_{2e} and cyclist's health benefits. Overall, there are several meaningful benefits generated by implementing a Zero-Emission Delivery Area that would improve the overall quality of life of Parisians. These benefits should not be ignored.

IX. Conclusion

The econometric analysis revealed the significant impact of road traffic on air pollution in Paris. The calculations then made it possible to quantify the share of this pollution attributable to LDVs and HDVs, showing that these vehicles contribute proportionally more to air pollution than the share they occupy in Parisian traffic. Consequently, replacing a thermal LDV or HDV with a Crit'Air E model has a greater effect on improving air quality compared to a personal car.

The scenarios tested subsequently provided quantified data on the health benefits (short and long term deaths and hospitalizations avoided) and environmental benefits (reduction in CO2 emissions) associated with measures restricting access to thermal vehicles in Paris and encouraging the transition of fleets to very low emission vehicles and cycle logistics.

However, several limitations to this study and the real impact of LDVs and HDVs on air quality in Paris should be highlighted. Indeed, PM_{10} are only counted on short-term deaths, while their most deadly effects appear over time. Finally, $PM_{2.5}$, which are known to be particularly harmful, could not be included due to a lack of data. The results obtained in this study are therefore very conservative and the real health impact of these vehicles could be much higher.

Since PM_{10} contains $PM_{2.5}$, reductions in these pollutants in the scenarios considered would also lead to a decrease in $PM_{2.5}$ pollution and its associated mortality. Finally, other types of pollution, influenced by the scenarios, such as noise pollution (reduced by electric vehicles and cycle logistics) and congestion (reduced by cycle logistics), were not quantified in this study.

These identified limitations could be the subject of in-depth research and would probably reinforce the health benefits of a Zone de livraisons apaisée in Paris. As it stands, this study already provides solid figures to the City of Paris, which in its strategy "The Logistics City 2022 - 2026" affirms its desire to move towards logistics operated by very low-emission vehicles and the modal shift towards cycle logistics.

Appendix

Appendix 1: Descriptive statistics

Table 8: Weather

Weather variable	Mean	sd
Temperature	13.70	7.30
Atmospheric pressure	1016.02	9.32
Wind speed	3.10	1.39
Wind direction	182.29	103.71
Rainfall height	0.07	0.53
Relative humidity	69.39	18.08

Note : The variable ”North wind” (resp. ”East Wind”, ”South Wind”, ”West Wind”) is equal to 1 if the wind direction measured on a 360 degrees scale is in the interval [0;45] or [315;360] (resp. [45;135], [135;225], [225;315]), and 0 otherwise. Relative humidity measures the ratio between the observed pressure of water vapor in the air and the maximum pressure of water vapor the air can contain at the observed temperature and pressure.

Table 9: Air pollution

Stations	NO2		PM10	
	mean	sd	mean	sd
Blv.Périph.Auteuil	80.54	30.92	36.18	18.41
Place Victor Basch	55.87	28.39	27.14	14.71
Blv.Périph.Est	61.15	32.43	27.98	15.11
Av.Champs-Elysées	38.94	20.62	28.65	16.13
Place de l'Opéra	57.28	27.16	26.91	13.85

Table 10: Traffic Flow

Stations	50m		200m		500m	
	Mean	sd	Mean	sd	Mean	sd
Blv.Périph.Auteuil	1094.62	566.51	1941.15	968.12	2041.78	1005.20
Place Victor Basch	484.58	239.01	492.21	244.24	493.88	243.60
Blv.Périph.Est	4929.49	1877.44	4929.49	1877.44	1881.76	826.00
Av.Champs-Elysées	845.35	479.55	661.56	375.89	566.25	331.83
Place de l'Opéra	552.19	309.21	534.86	300.24	657.00	346.22

Appendix 2: Econometric Results

Table 11: Regression results for pollutant NO_2 with weather variables and covid, strike and weekend dummies

Variable	**Buffer**		
	50m (1)	**200m** (2)	**500m** (3)
Traffic flow	0.0002*	0.0007***	0.0049***
	(0.0001)	(0.0001)	(0.0002)
Temperature Average	0.6600***	0.6779***	0.7002***
	(0.0246)	(0.0242)	(0.0238)
Atmospheric Pressure	-0.2386***	-0.2439***	-0.2560***
	(0.0101)	(0.0099)	(0.0098)
Wind Speed	-7.9253***	-7.9261***	-7.9570***
	(0.0643)	(0.0635)	(0.0623)
Wind Direction	-0.0434***	-0.0431***	-0.0453***
	(0.0008)	(0.0008)	(0.0008)
Relative Humidity	-0.2771***	-0.2763***	-0.2709***
	(0.0073)	(0.0072)	(0.0071)
Covid	-20.7999***	-20.4043***	-17.9567***
	(0.4662)	(0.4628)	(0.4590)
Strike	4.1381***	4.1482***	3.8829***
	(0.5748)	(0.5706)	(0.5392)
2018	17.2609***	17.3935***	16.8721***
	(0.2534)	(0.2487)	(0.2459)
2019	12.3707***	12.3601***	12.0076***
	(0.2644)	(0.2614)	(0.2573)
Weekend	0.1879	0.1500	0.0949
	(0.1829)	(0.1806)	(0.1772)
Fixed-effects			
stations	Yes	Yes	Yes
Adjusted R^2	0.5206	0.5261	0.5292
Observations	69,993	71,855	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Notes: 2020 is used as the Reference Year.

Table 12: Regression results for NO_2 with month dummies

Month Dummy	Buffer		
	50m	200m	500m
	(1)	(2)	(3)
January	7.745***	7.874***	7.350***
	(0.4210)	(0.4179)	(0.4028)
February	14.02***	14.14***	14.04***
	(0.4697)	(0.4653)	(0.4505)
March	8.916***	8.980***	8.588***
	(0.4721)	(0.4668)	(0.4522)
April	0.7955	0.6968	0.1100
	(0.5140)	(0.5087)	(0.4934)
May	-8.490***	-8.588***	-8.991***
	(0.5058)	(0.5008)	(0.4874)
June	-13.65***	-13.52***	-14.29***
	(0.5430)	(0.5366)	(0.5211)
July	-16.25***	-16.53***	-17.77***
	(0.5942)	(0.5872)	(0.5739)
August	-19.81***	-20.08***	-20.67***
	(0.5775)	(0.5728)	(0.5601)
September	-12.43***	-12.67***	-13.62***
	(0.5475)	(0.5428)	(0.5286)
October	-7.271***	-7.459***	-8.247***
	(0.4860)	(0.4837)	(0.4674)
November	-5.029***	-5.203***	-5.325***
	(0.4500)	(0.4476)	(0.4319)
Fixed-effects			
stations	Yes	Yes	Yes
Adjusted R^2	0.5206	0.5261	0.5292
Observations	69,993	71,855	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Notes: December is used as the Reference Month.

Table 13: Regression Result for pollutant NO_2 with hour dummies

1:00 − 12:00				13:00 − 23:00			
Hour Dummy	Buffer			Hour Dummy	Buffer		
	50m (1)	200m (2)	500m (3)		50m (1)	200m (2)	500m (3)
1:00	-6.266***	-6.069***	-5.167***	13:00	6.906***	6.705***	4.284***
	(0.5190)	(0.5179)	(0.5103)		(0.5554)	(0.5498)	(0.5475)
2:00	-10.11***	-9.686***	-7.784***	14:00	8.925***	8.613***	6.272***
	(0.5140)	(0.5139)	(0.5076)		(0.5527)	(0.5501)	(0.5489)
3:00	-10.33***	-9.772***	-7.298***	15:00	10.58***	10.31***	7.776***
	(0.5123)	(0.5134)	(0.5117)		(0.5656)	(0.5606)	(0.5578)
4:00	-4.359***	-3.724***	-0.8993*	16:00	12.93***	12.65***	10.28***
	(0.5270)	(0.5282)	(0.5334)		(0.5708)	(0.5664)	(0.5633)
5:00	6.845***	7.444***	10.17***	17:00	15.68***	15.58***	13.53***
	(0.5669)	(0.5668)	(0.5740)		(0.5821)	(0.5719)	(0.5672)
6:00	16.14***	16.52***	18.41***	18:00	19.52***	19.55***	17.27***
	(0.5711)	(0.5701)	(0.5706)		(0.6079)	(0.5886)	(0.5762)
7:00	17.31***	17.27***	17.27***	19:00	20.54***	20.69***	18.69***
	(0.5585)	(0.5556)	(0.5439)		(0.6062)	(0.5942)	(0.5827)
8:00	15.60***	15.58***	14.76***	20:00	18.75***	18.53***	16.37***
	(0.5528)	(0.5495)	(0.5335)		(0.5946)	(0.5815)	(0.5763)
9:00	12.11***	12.49***	12.06***	21:00	15.44***	15.15***	13.24***
	(0.5712)	(0.5566)	(0.5310)		(0.5709)	(0.5683)	(0.5668)
10:00	10.67***	10.66***	9.547***	22:00	12.27***	12.09***	11.22***
	(0.5542)	(0.5491)	(0.5341)		(0.5576)	(0.5561)	(0.5527)
11:00	8.891***	8.732***	6.888***	23:00	7.305***	7.284***	7.087***
	(0.5419)	(0.5384)	(0.5347)		(0.5760)	(0.5749)	(0.5704)
12:00	6.644***	6.365***	4.228***				
	(0.5460)	(0.5417)	(0.5409)				
Fixed-effects							
stations	Yes	Yes	Yes	stations	Yes	Yes	Yes
Adjusted R^2	0.5206	0.5261	0.5292	Observations	69,993	71,855	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: 00:00 is used as the Reference Hour.

Table 14: Regression Results for PM_{10} with weather variables and covid, strike and weekend dummies

Variable	Buffer		
	50m (1)	**200m** (2)	**500m** (3)
Traffic flow	0.0002***	0.0003***	0.0019***
	(5.98×10^{-5})	(5.9×10^{-5})	(0.0001)
Temperature Average	-0.0351**	-0.0316*	-0.0331**
	(0.0166)	(0.0164)	(0.0161)
Atmospheric Pressure	0.1997***	0.2011***	0.2012***
	(0.0063)	(0.0063)	(0.0062)
Wind Speed	-2.745***	-2.743***	-2.763***
	(0.0434)	(0.0433)	(0.0426)
Wind Direction	-0.0286***	-0.0287***	-0.0295***
	(0.0005)	(0.0005)	(0.0005)
Relative Humidity	-0.1526***	-0.1510***	-0.1495***
	(0.0046)	(0.0046)	(0.0045)
Covid	-7.511***	-7.330***	-6.377***
	(0.2517)	(0.2512)	(0.2515)
Strike	4.392***	4.318***	4.017***
	(0.4007)	(0.3967)	(0.3708)
2018	6.860***	7.036***	6.810***
	(0.1453)	(0.1445)	(0.1427)
2019	4.638***	4.748***	4.701***
	(0.1522)	(0.1520)	(0.1495)
Weekend	1.251***	1.275***	1.276***
	(0.1176)	(0.1166)	(0.1144)
Fixed-effects			
stations	Yes	Yes	Yes
Adjusted R^2	0.3168	0.319	0.3236
Observations	69,993	71,855	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: 2020 is used as the Reference Year.

Table 15: Regression results for PM10 with month dummies

Month Dummy	Buffer		
	50m	**200m**	**500m**
	(1)	(2)	(3)
January	1.425***	1.573***	1.228***
	(0.2859)	(0.2840)	(0.2778)
February	11.33***	11.33***	11.20***
	(0.3765)	(0.3717)	(0.3653)
March	5.159***	5.166***	4.779***
	(0.3066)	(0.3030)	(0.2972)
April	3.682***	3.679***	3.422***
	(0.3257)	(0.3228)	(0.3168)
May	1.012***	1.211***	1.068***
	(0.3165)	(0.3148)	(0.3097)
June	-1.226***	-1.184***	-1.579***
	(0.3402)	(0.3362)	(0.3305)
July	-0.5958*	-0.5466	-1.117***
	(0.3510)	(0.3474)	(0.3421)
August	-3.275***	-3.227***	-3.427***
	(0.3527)	(0.3497)	(0.3443)
September	-3.170***	-3.162***	-3.496***
	(0.3380)	(0.3353)	(0.3290)
October	0.5910*	0.6245**	0.2735
	(0.3185)	(0.3166)	(0.3100)
November	-0.3903	-0.3478	-0.5510*
	(0.2971)	(0.2950)	(0.2889)
Fixed-effects			
stations	Yes	Yes	Yes
Adjusted R^2	0.3168	0.319	0.3236
Observations	69,993	71,855	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Notes: December is used as the Reference Month.

Table 16: Regression Result for PM_{10} with hour dummies

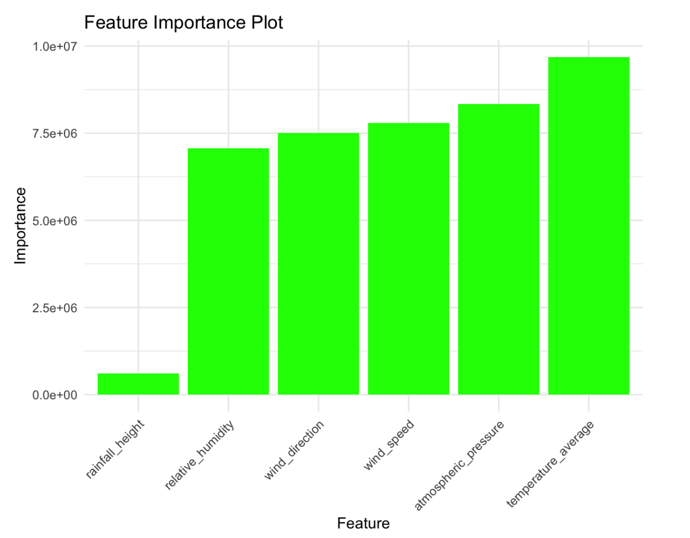
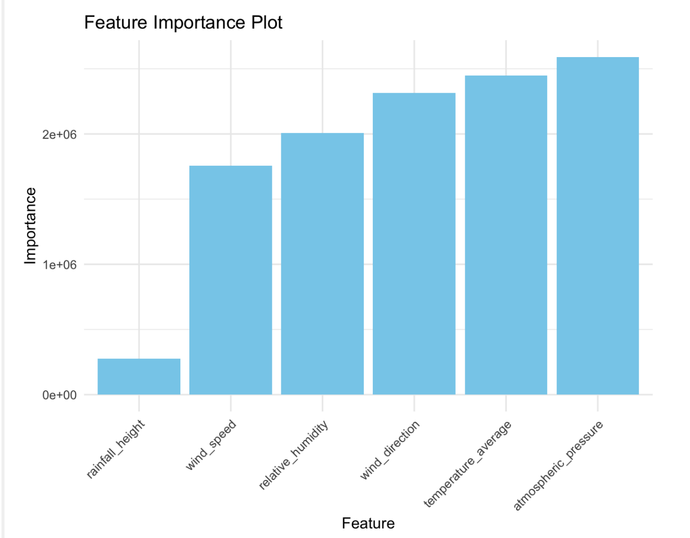
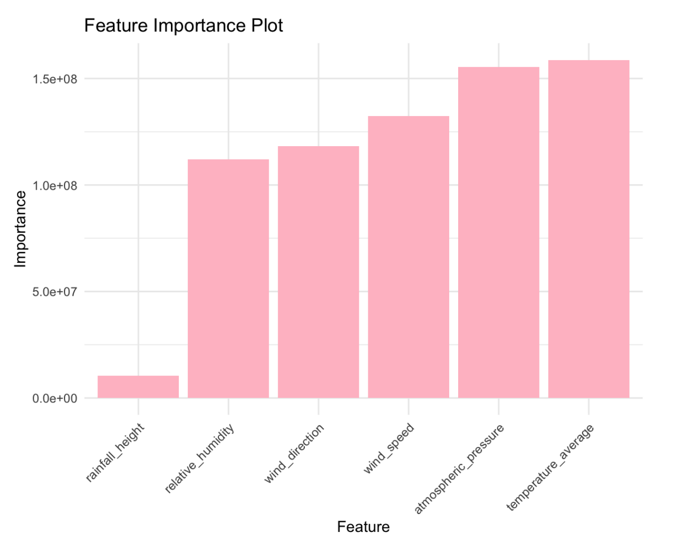
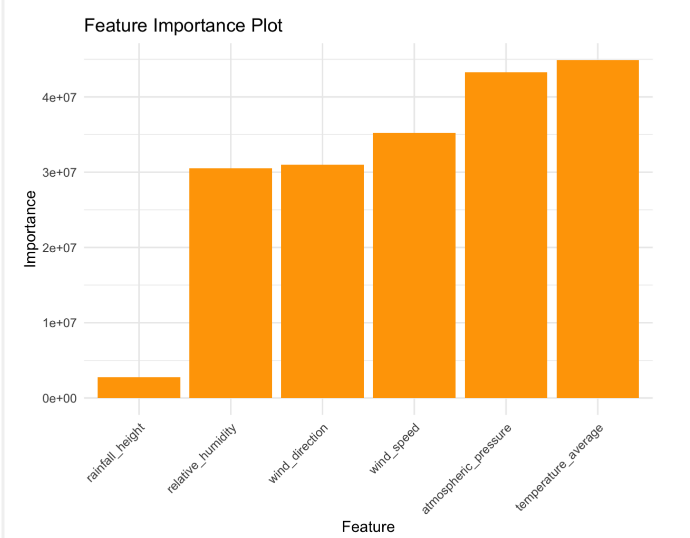
1:00 – 12:00				13:00 – 23:00			
Hour Dummy	**Buffer**			**Hour Dummy**	**Buffer**		
	50m (1)	**200m** (2)	**500m** (3)		**50m** (1)	**200m** (2)	**500m** (3)
1:00	-2.064***	-2.033***	-1.695***	13:00	5.006***	4.905***	3.934***
	(0.3223)	(0.3220)	(0.3209)		(0.3572)	(0.3553)	(0.3523)
2:00	-3.218***	-3.136***	-2.420***	14:00	4.946***	4.775***	3.916***
	(0.3180)	(0.3178)	(0.3175)		(0.3643)	(0.3625)	(0.3603)
3:00	-3.700***	-3.587***	-2.654***	15:00	4.084***	3.949***	2.964***
	(0.3153)	(0.3153)	(0.3159)		(0.3586)	(0.3570)	(0.3553)
4:00	-1.975***	-1.845***	-0.7787**	16:00	3.079***	2.821***	1.899***
	(0.3277)	(0.3271)	(0.3285)		(0.3495)	(0.3462)	(0.3443)
5:00	0.7773**	0.8963***	1.922***	17:00	2.254***	2.157***	1.231***
	(0.3399)	(0.3388)	(0.3399)		(0.3491)	(0.3457)	(0.3416)
6:00	3.735***	3.800***	4.510***	18:00	2.924***	2.937***	2.068***
	(0.3470)	(0.3464)	(0.3469)		(0.3544)	(0.3475)	(0.3400)
7:00	4.782***	4.746***	4.739***	19:00	3.613***	3.636***	2.948***
	(0.3353)	(0.3349)	(0.3329)		(0.3515)	(0.3466)	(0.3403)
8:00	6.935***	6.859***	6.392***	20:00	4.022***	3.960***	3.282***
	(0.3517)	(0.3505)	(0.3439)		0.3486)	(0.3443)	(0.3435)
9:00	8.219***	8.567***	8.152***	21:00	3.427***	3.411***	2.749***
	(0.3799)	(0.3732)	(0.3546)		(0.3435)	(0.3442)	(0.3456)
10:00	8.379***	8.524***	7.939***	22:00	3.088***	3.072***	2.742***
	(0.3799)	(0.3781)	(0.3637)		(0.3446)	(0.3449)	(0.3440)
11:00	6.941***	6.898***	6.124***	23:00	1.977***	1.964***	1.876***
	(0.3663)	(0.3648)	(0.3605)		(0.3638)	(0.3636)	(0.3628)
12:00	5.379***	5.268***	4.398***				
	(0.3608)	(0.3587)	(0.3569)				
Fixed-effects							
stations	Yes	Yes	Yes	stations	Yes	Yes	Yes
Adjusted R^2	0.3168	0.319	0.3236	Observations	69,993	71,855	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: 00:00 is used as the Reference Hour.

Appendix 3: Robustness check

Table 17: Randomforest prediction results by pollutant

	
NO_2	PM_{10}
	
NOx	NO

To determine which weather variable best explains the pollutant level, we utilized a random forest model splitting the data, with 30% allocated to the test set and 70% to the training set. Table # shows the results of our prediction, where the X-axis represents six weather variables, and the Yaxis depicts their importance in explaining pollutant levels. These importance scores were determined by assessing how much prediction accuracy decreased when each variable was randomly shuffled or removed during model training, using the mean squared error (MSE) metric. Higher importance scores indicate a stronger influence of a weather variable on pollutant levels, helping us understand which factors are most critical for accurate predictions. Across all four pollutants, rainfall height consistently appeared as the least relevant variable. As a result, we decided to exclude rainfall height from further analysis in regression, while retaining the other five weather variables due to their similar contributions.

Table 18: FE vs. OLS Regression: NO_2 Pollutant

Variable	**Coeff**	
	FE	**OLS**
	(1)	(2)
Traffic flow	0.0049***	0.0510***
	(0.0002)	(0.0005)
Temperature Average	0.7002***	-1.3463***
	(0.0238)	(0.1114)
Atmospheric Pressure	-0.2560***	0.0166
	(0.0098)	(0.0488)
Wind Speed	-7.9570***	-29.7290***
	(0.0623)	(0.3065)
Wind Direction	-0.0453***	-0.1319***
	(0.0008)	(0.0040)
Relative Humidity	-0.2709***	-0.0935**
	(0.0071)	(0.0348)
Covid	-17.9567***	-48.0708***
	(0.4590)	(2.3872)
Strike	3.8829***	15.0719***
	(0.5392)	(2.9292)
2018	16.8721***	37.8324***
	(0.2459)	(1.2117)
2019	12.0076***	27.3780***
	(0.2573)	(1.2415)
Weekend	0.0949	1.2116
	(0.1772)	(0.8644)
Fixed-effects		
stations	Yes	No
Adjusted R^2	0.5292	0.3791
Observations	74,411	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Notes: 2020 is used as the Reference Year.

Table 19: FE vs. OLS Regression: PM_{10} Pollutant

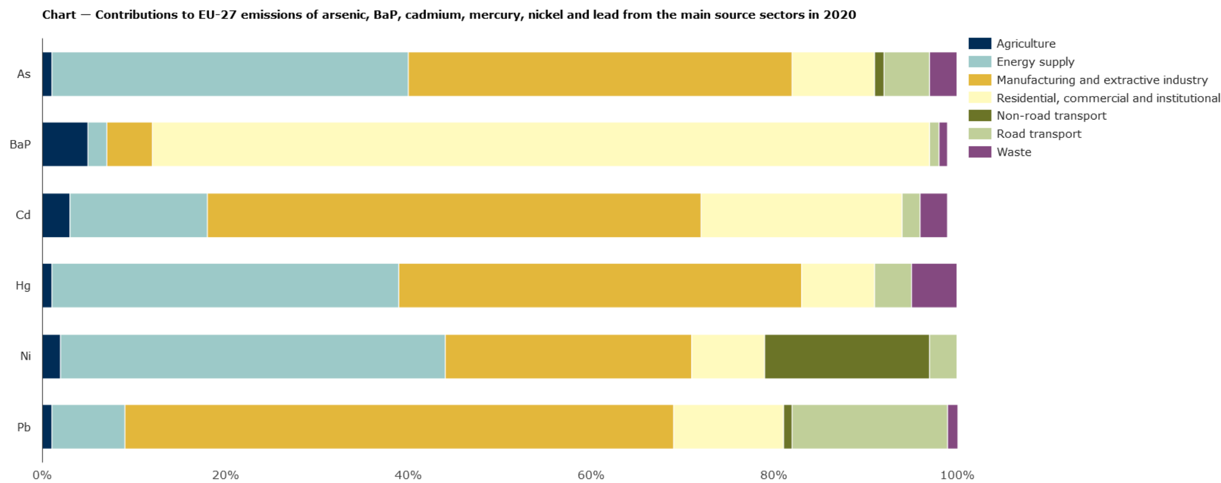
Variable	Coeff	
	FE (1)	OLS (2)
Traffic flow	0.0019***	0.0029***
	(0.0001)	(0.0001)
Temperature Average	-0.0331**	-0.0420**
	(0.0161)	(0.0143)
Atmospheric Pressure	0.2012***	0.1988***
	(0.0062)	(0.0063)
Wind Speed	-2.763***	-2.7753***
	(0.0426)	(0.0385)
Wind Direction	-0.0295***	-0.0292***
	(0.0005)	(0.0005)
Relative Humidity	-0.1495***	-0.1463***
	(0.0045)	(0.0045)
Covid	-6.377***	-5.8448***
	(0.2515)	(0.3075)
Strike	4.017***	2.5522***
	(0.3708)	(0.3773)
2018	6.810***	6.6247***
	(0.1427)	(0.1561)
2019	4.701***	4.3562***
	(0.1495)	(0.1599)
Weekend	1.276***	1.2731***
	(0.1144)	(0.1114)
Fixed-effects		
stations	Yes	No
Adjusted R^2	0.3236	0.2921
Observations	74,411	74,411

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Notes: 2020 is used as the Reference Year.

The OLS model is a basic linear regression model that estimates the relationship between the dependent variable and independent variables without accounting for station-specific effects. In contrast, the fixed effects model includes station-specific fixed effects to control for unobserved heterogeneity across stations. This key difference between the two models enables us to assess whether controlling for station-specific characteristics affects the estimated coefficients and model performance. Buffer size 500m shows the best performance with adjusted R square 0.5492 and 0.3236 for NO_2 and PM_{10} respectively. We will run OLS for buffer size 500m and compare the coefficient and performance. The coefficient estimate for traffic flow remains significant in both fixed effect (FE) and OLS models. However, the magnitude of the coefficient in the OLS model is notably larger than that in the FE model. This difference suggests that the OLS model may be overestimating the impact of the traffic flow on NO_2 levels, potentially due to omitted variable bias or unobserved heterogeneity. This applies for other independent variables as well. In the PM_{10} regression, all independent variables remain statistically significant in both the fixed effect (FE) and OLS models. However, unlike the NO_2 regression, where we observed notably higher estimates in the OLS model for some variables, this trend is less prominent for PM_{10}.

Appendix 4: Sector Contributions to EU-27 Emissions

Figure 12: Contributions to EU-27 emissions of BC, CO, NH_3, NMVOCs, NOx, primary PM_{10}, primary $PM_{2.5}$, SO_2 and CH_4 from the main source sectors in 2020



Note: Only sectors contributing more than 0.5% of the total emissions of each pollutant are included in the graph. The sectoral contributions are rounded to the nearest integer.

Data sources: EEA. National emissions reported to the Convention on Long-range Transboundary Air Pollution (LRTAP Convention)

Table 20: Contributions to EU-27 emissions of BC, CO, NH_3, NMVOCs, NOx, primary PM_{10}, primary $PM_{2.5}$, SO_2 and CH_4 from the main source sectors in 2020

Emissions	Agriculture	Energy supply	Manufacturing and extractive industry	Non-road transport	Residential, commercial and institutional	Road transport	Waste
BC	8	2	8	3	37	23	19
CO	5	4	20	3	46	18	5
NH3	94		1		2	1	1
NMVOC	27	3	47	1	13	7	1
NOx	19	14	15	7	9	37	1
PM2.5	7	3	14	2	58	9	8
PM10	19	2	19	2	44	9	5
SO2	2	41	37	3	17		
CH4	56	1	12		3		27

QR code

Appendix 5: Traffic Flow & Emissions Analysis

Figure 13: Paris Intra-Muros Fleet Structure based on vehicle category

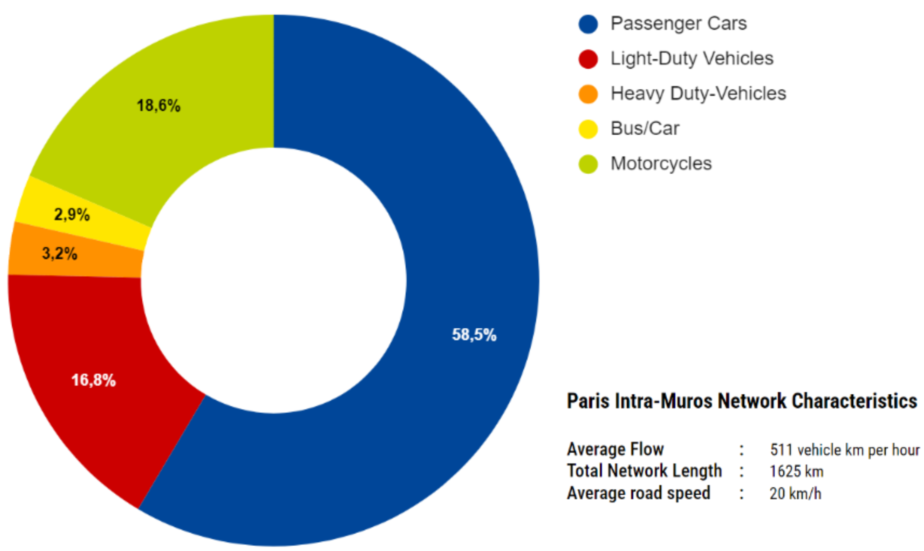
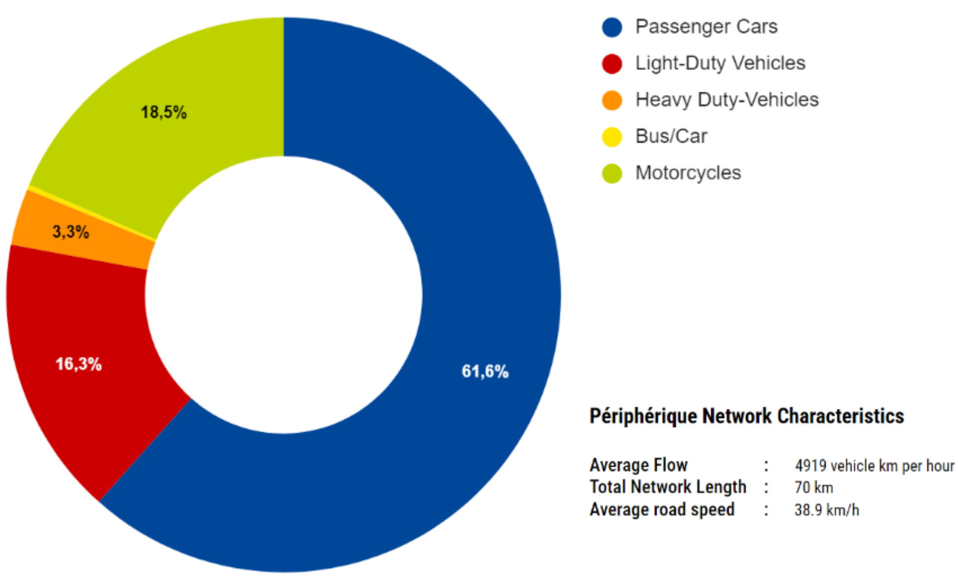


Figure 14 Table A15: Périphérique Fleet Structure based on vehicle category



PS :

- The values from the Bilan de déplacement à Paris were adjusted and standardized to focus solely on vehicles, excluding kick scooters. Taxis were combined with passenger cars, as they belong to the same category.
- The two networks were aggregated using network length to create a unified network, referred to as the Global Parisien Network.

Table 21: Global Parisian Fleet based on Crit'Air Classification and cylinder capacity

				Emission Classification					
Vahicle Category	**Ration**	**Fuel**	**Ratio**	**Crit'Air 1**	**Crit'Air 2**	**Crit'Air 3**	**Crit'Air 4**	**Crit'Air 5**	**Crit'Air NC**
Passenger Cars	58,93%	Gazoline	42,21%	63,03%	15,37%	16,35%	0,00%	0,00%	5,25%
		Diesel	55,47%	0%	54,18%	27,83%	13,32%	3,04%	1,63%
Light Utility Vehicles	16,69%	Gazoline	3,71%	49,84%	6,69%	13,18%	0,00%	0,00%	30,29%
		Diesel	95,02%	0,00%	56,86%	20,90%	12,76%	4,45%	5,04%
Heavy Duty Vehicles	3%	Gazoline	0,03%	32,63%	14,21%	21,58%	0,00%	0,00%	31,58%
		Diesel	99%	0,00%	53,93%	16,41%	9,81%	10,23%	9,62%
Buses	2,75%	Gazoline	6,01%	99,01%	0,00%	0,00%	0,00%	0,00%	0,05%
		Diesel	92,28%	0,00%	51,18%	27,49%	13,85%	6,57%	0,91%
				< 50 cm3	**< 125 cm3**	**125 à 750 cm3**	**> 750 cm3**		
L Categories	18,42%	All	100%	26,00%	28,35%	27,03%	18,62%		

Table 22: EEA Emission Factor Tool, version 2023

and cylinder capacity

Category	Fuel	Euro Standard	echn	Pollut	Alph	Beta	Gamm	Del	Epsil	Zit	Ht	Reduction Factor [	Bio Reduction Factor	21	EF [g/km] or ECF [MJ/km] or #/km or #/kWh or g/kWh
Light Commercial Vehicles	Diesel	Euro 5	DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	0,0%	0,0	21,0	0,8
Light Commercial Vehicles	Diesel	Euro 5	DPF With	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	30,0%	0,0	21,0	0,5
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	17,6%	0,0	21,0	0,6
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	DPF+SCR	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	17,6%	0,0	21,0	0,6
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	LNT+DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	17,6%	0,0	21,0	0,6
Light Commercial Vehicles	Diesel	Euro 6 d-temp	DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	90,0%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d-temp	DPF+SCR	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	90,0%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d-temp	LNT+DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	90,0%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	92,0%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	DPF+SCR	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	92,0%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	LNT+DPF	NOx	0,0	0,0	0,9	1,9	0,0	0,0	1,0	92,0%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 5	DPF	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-406,8%	0,0	21,0	1,3
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	DPF	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-309,4%	0,0	21,0	1,0
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	DPF+SCR	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-309,4%	0,0	21,0	1,0
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	LNT+DPF	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-309,4%	0,0	21,0	1,0
Light Commercial Vehicles	Diesel	Euro 6 d-temp	DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	-175,3%	0,0	21,0	0,4
Light Commercial Vehicles	Diesel	Euro 6 d-temp	DPF+SCR	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	-175,3%	0,0	21,0	0,4
Light Commercial Vehicles	Diesel	Euro 6 d-temp	LNT+DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	-175,3%	0,0	21,0	0,4
Light Commercial Vehicles	Diesel	Euro 6 d	DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	28,2%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	DPF+SCR	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	28,2%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	LNT+DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	28,2%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 5	DPF	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-406,8%	0,0	21,0	1,3
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	DPF	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-309,4%	0,0	21,0	1,0
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	DPF+SCR	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-309,4%	0,0	21,0	1,0
Light Commercial Vehicles	Diesel	Euro 6 a/b/c	LNT+DPF	NOx	0,0	0,0	0,2	1,2	0,0	0,0	1,0	-309,4%	0,0	21,0	1,0
Light Commercial Vehicles	Diesel	Euro 6 d-temp	DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	-175,3%	0,0	21,0	0,4
Light Commercial Vehicles	Diesel	Euro 6 d-temp	DPF+SCR	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	-175,3%	0,0	21,0	0,4
Light Commercial Vehicles	Diesel	Euro 6 d-temp	LNT+DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	-175,3%	0,0	21,0	0,4
Light Commercial Vehicles	Diesel	Euro 6 d	DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	28,2%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	DPF+SCR	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	28,2%	0,0	21,0	0,1
Light Commercial Vehicles	Diesel	Euro 6 d	LNT+DPF	NOx	0,0	0,0	0,1	0,7	0,0	0,0	1,0	28,2%	0,0	21,0	0,1

The tool provides a granular assessment for each specific vehicle category based on its Euro standard, but since no statistical distribution of the fleet makeup in France based on Euro standard is available, the available Crit'Air Classification was used. A bridge had to be established between the Crit'Air classification and Euro Standard to utilize the EEA tool.

In the example shown above, Diesel Light-Duty Vehicles (Light Commercial Vehicles) with Euro 5 and 6 standards, corresponding to Crit'Air 2, were selected. The target pollutant was NOx, with a speed of 21 km/h. The tool provided various emission factor values (highlighted in the red box). Due to statistical limitations, the results were aggregated to obtain a single value for this category.

This process was repeated for different vehicle categories, fuel types, Crit'Air classifications (Euro standards), pollutants, and at different speeds.

Source : European Environment Agency for emission factors for road transport

Table 23: Values of f-NO2 from Pastramas et al. 2015

Emission Standard	Crit'Air	Petrol PC	Crit'Air	Diesel PC	Crit'Air	Petrol LUV	Crit'Air	Diesel LUV	Crit'Air	HDV and Buses
Pre-Euro	Crit'Air NC	0,07	Crit'Air NC	0,15	Crit'Air NC	0,07	Crit'Air NC	0,15	Crit'Air NC	0,11
Euro 1 / Euro I	Crit'Air NC	0,06	Crit'Air NC	0,13	Crit'Air NC	0,06	Crit'Air NC	0,13	Crit'Air NC	0,11
Euro 2 / Euro II	Crit'Air 3	0,05	Crit'Air 5	0,13	Crit'Air 3	0,05	Crit'Air 5	0,13	Crit'Air NC	0,11
Euro 3 / Euro III	Crit'Air 3	0,04	Crit'Air 4	0,15	Crit'Air 3	0,04	Crit'Air 4	0,15	Crit'Air 5	0,15
Euro 3 +DPF / Euro III + CRT	-	-	Crit'Air 4	0,51	-	-	Crit'Air 4	0,51	Crit'Air 5	0,36
Euro 4 / Euro IV	Crit'Air 2	0,05	Crit'Air 3	0,46	Crit'Air 2	0,05	Crit'Air 3	0,46	Crit'Air 4	0,1
Euro 4 + DPF	-	-	Crit'Air 3	0,42	-	-	Crit'Air 3	0,42		-
Euro 5 / Euro V	Crit'Air 1	0,03	Crit'Air 2	0,33	Crit'Air 1	0,03	Crit'Air 2	0,33	Crit'Air 3	0,17
Euro 6 / Euro VI	Crit'Air 1	0,03	Crit'Air 2	0,3	Crit'Air 1	0,03	Crit'Air 2	0,3	Crit'Air 2	0,08

Source : (Pastramas et al., 2015) : Update of the Air Emissions Inventory Guidebook - Road Transport 2015 Update

PS : NO2 emissions of the different vehicle types were estimated using a NOX conversion factor (f-NO2), as presented in the study by Pastramas et al. (2015)

Table 24: Vehicle Pollutant Emission per Speed and per Category for the year 2022 (baseline)

Pollutant	Speed	Emission Factors (Baseline 2022)			
		PC	LUV	HDV	Avg Vehicle
NOX	12 km/h	0,48	1,08	7,22	0,92
	14 km/h	0,45	1,03	6,52	0,86
	16 km/h	0,44	1,00	6,00	0,80
	18 km/h	0,42	0,96	5,59	0,76
	20 km/h	0,41	0,94	5,25	0,72
	22 km/h	0,39	0,91	4,98	0,69
	24 km/h	0,38	0,89	4,75	0,66
	26 km/h	0,37	0,86	4,55	0,64
	28 km/h	0,36	0,84	4,38	0,62
	30 km/h	0,35	0,82	4,23	0,60
NO2	12 km/h	0,15	0,33	1,08	0,21
	14 km/h	0,14	0,32	0,98	0,20
	16 km/h	0,13	0,31	0,90	0,19
	18 km/h	0,13	0,30	0,84	0,18
	20 km/h	0,12	0,29	0,79	0,17
	22 km/h	0,12	0,28	0,75	0,17
	24 km/h	0,12	0,27	0,71	0,16
	26 km/h	0,11	0,27	0,69	0,15
	28 km/h	0,11	0,26	0,66	0,15
	30 km/h	0,10	0,25	0,64	0,15
PM	12 km/h	0,01	0,04	0,12	0,02
	14 km/h	0,01	0,04	0,11	0,02
	16 km/h	0,01	0,03	0,10	0,02
	18 km/h	0,01	0,03	0,10	0,02
	20 km/h	0,01	0,03	0,09	0,02
	22 km/h	0,01	0,03	0,09	0,02
	24 km/h	0,01	0,03	0,08	0,02
	26 km/h	0,01	0,03	0,08	0,02
	28 km/h	0,01	0,03	0,07	0,02
	30 km/h	0,01	0,03	0,07	0,02

Table 25: Emission Factor Ratio of Transition to Crit'Air E

Pollutant	Speed	Ratio Pollution Reduction Compared to Average Vehicle		
		PC	LUV	HDV
NOX	12 km/h	0,52 x	1,17 x	7,83 x
	14 km/h	0,53 x	1,21 x	7,62 x
	16 km/h	0,54 x	1,24 x	7,48 x
	18 km/h	0,55 x	1,27 x	7,37 x
	20 km/h	0,56 x	1,30 x	7,28 x
	22 km/h	0,57 x	1,32 x	7,21 x
	24 km/h	0,57 x	1,33 x	7,15 x
	26 km/h	0,58 x	1,35 x	7,10 x
	28 km/h	0,58 x	1,36 x	7,07 x
	30 km/h	0,58 x	1,37 x	7,04 x
NO2	12 km/h	0,68 x	1,54 x	5,05 x
	14 km/h	0,70 x	1,58 x	4,88 x
	16 km/h	0,71 x	1,61 x	4,75 x
	18 km/h	0,71 x	1,64 x	4,66 x
	20 km/h	0,72 x	1,66 x	4,58 x
	22 km/h	0,72 x	1,68 x	4,52 x
	24 km/h	0,72 x	1,70 x	4,47 x
	26 km/h	0,72 x	1,72 x	4,43 x
	28 km/h	0,72 x	1,73 x	4,41 x
	30 km/h	0,72 x	1,74 x	4,39 x
PM	12 km/h	0,53 x	1,56 x	5,11 x
	14 km/h	0,54 x	1,55 x	4,83 x
	16 km/h	0,54 x	1,54 x	4,61 x
	18 km/h	0,55 x	1,53 x	4,43 x
	20 km/h	0,55 x	1,51 x	4,28 x
	22 km/h	0,55 x	1,50 x	4,15 x
	24 km/h	0,55 x	1,48 x	4,04 x
	26 km/h	0,55 x	1,46 x	3,95 x
	28 km/h	0,56 x	1,44 x	3,87 x
	30 km/h	0,55 x	1,42 x	3,80 x

Appendix 6: Health Impact Assessment

Table 26: Relative Risks Coefficient Low, Average, and High

Effect Type	Impact	Pollutant	Relative Risk (Low)	Relative Risk (Average)	Relative Risk (High)
	Non-accidental mortality	PM_{10}	1.0013	1.0030	1.0047
	Non-accidental mortality	NO_2	1.0040	1.0075	1.0110
Short Term	Respiratory Hospitalizations	NO_2	1.0115	1.0180	1.0245
Long Term	Total Mortality	NO_2	1.0080	1.0230	1.0370

Source: Author's illustration. Data is from Guide for the Production of Quantitative Evaluation Impacts on Health (EQIS) by Santé Publique.

Table 27: Relative Risks Coefficient with Relevant Dose Response Values

Impact	Notes	2019	2020	2021	Average of 2019 and 2021
Non-accidental mortality	Excludes accidental mortality	12,884	15,498	13,764	13,324
Hospitalizations from Respiratory Causes	Adjusted for Paris Population	17,097	12,382	12,054	14,576
Total Mortality (>30)*	Excludes accidental mortality	12,671	15,249	13,560	13,116

Sources: https://opendata-cepidc.inserm.fr/ and https://www.scansante.fr. Non accidental and total morality includes all causes of death except accident morality. *The total mortality rate is based on ages 35+ as ages were grouped in 10 year bins. Hospitalizations from respiratory causes are based on diseases of the respiratory system and includes the number of stays excluding GHM in J or T and meetings, the value is for the total of France which is then population adjusted to provide the numbers for Paris. The analysis uses an average of data from 2019 and 2021 to avoid any outliers from Covid.

Table 28: Health Impact Assessment Full Range of Benefits

RR Value	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
PM_{10} - lives saved						
Low	0.288	0.156	0.889	0.576	0.073	0.340
Average	0.664	0.361	2.050	1.328	0.169	0.784
High	1.039	0.565	3.208	2.079	0.264	1.227
NO_2 - lives saved						
Low	2.51	1.33	7.67	5.01	0.63	2.93
Average	4.69	2.48	14.35	9.38	1.19	5.49
High	6.87	3.63	21.00	13.74	1.74	8.04
Total Short-Term- lives saved						
Low	2.795	1.483	8.556	5.590	0.707	3.274
Average	5.356	2.843	16.398	10.712	1.356	6.275
High	7.908	4.199	24.212	15.815	2.001	9.265
Hospitalizations						
Low	7.85	4.15	24.02	15.71	1.99	9.19
Average	12.25	6.48	37.46	24.50	3.10	14.33
High	16.61	8.79	50.80	33.23	4.20	19.44
Total Long-Term - lives saved						
Low	4.93	2.61	15.06	9.85	1.25	5.76
Average	14.04	7.43	42.95	28.09	3.55	16.44
High	22.42	11.86	68.58	44.85	5.67	26.24

Source: Author. Calculations based on the methodology presented in section 5 on the health impact assessment on pollutants.

Appendix 7: Impact on CO2 emissions

Table 29: **gCO2e/km** Emission Reductions by Vehicle Type

	D-LDV	E-LDV	D-HDV	E-HDV	e-Cargo
Usage	410.80	22.00	695.20	40.00	1.50
Non Usage	55.00	130.00	105.00	245.00	65.00
Total	465.80	152.00	800.20	285.00	66.50

Source: Authors

.

References

[1] Fussell JC, Franklin M, Green DC, Gustafsson M, Harrison RM, Hicks W, Kelly FJ, Kishta F, Miller MR, Mudway IS, Oroumiyeh F, Selley L, Wang M, Zhu Y. A Review of Road Traffic-Derived Non-Exhaust Particles: Emissions, Physicochemical Characteristics, Health Risks, and Mitigation Measures. Environ Sci Technol. 2022 Jun 7;56(11):6813-6835. doi: 10.1021/acs.est.2c01072. Epub 2022 May 25. PMID: 35612468; PMCID: PMC9178796.

[2] EEA. *National emissions reported to the Convention on Long-range Transboundary Air Pollution (LRTAP Convention)*. See Appendix 4, Figure A1 for more details.

[3] Impact CO_2, Comparateur carbone, ADEME, https://impactco2.fr/outils/comparateur.

[4] Qualité de l'air : La Commission européenne demande à la France de se mettre en conformité à l'arrêt de la Cour de Justice de l'Union européenne. (2024, March 18). Représentation En France. https://france.representation.ec.europa.eu/informations/qualite-de-lair-la-commission-europeenne-demande-la-france-de-se-mettre-en-conformite-larret-de-la-2024-03-18_fr

[5] European Environment Agency. (2023, November 24). *France – air pollution country fact sheet*. https://www.eea.europa.eu/publications/air-quality-in-europe-2022/france-air-pollution-country-fact-sheet

[6] AirParif.(2023, April 13). Air quality is improving in Île-de-France, but the stakes are rising.

[7] Medina, S., Adélaïde, L., Wagner, V., de Crouy Chanel, P., Real, E., Colette, A., et al. (2021). *Impact of ambient air pollution on mortality in metropolitan France: Reduction related to Spring 2020 lockdown and new data for total burden of impact for the period 2016-2019*. Santé Publique France.

[8] Urban Access Regulations EU. (n.d.). Impact of low emission zones (LEZs). https://urbanaccessregulations.eu/low-emission-zones-main/impact-of-low-emission-zones

[9] Clean Heavy-Duty Vehicles Grant Program | US EPA. (2024, June 20). US EPA. https://www.epa.gov/clean-heavy-duty-vehicles-program/clean-heavy-duty-vehicles-grant-program

[10] Letrouit, L., & Koning, M. (2023). How large are the costs of local pollution emitted by freight vehicles? Insights from the COVID-19 lockdown in Paris (HAL Id: hal-04106196). HAL. https://hal.science/hal-04106196/document

[11] European Environment Agency. (2016). Explaining road transport emissions. https://www.eea.europa.eu/publications/explaining-road-transport-emissions

[12] Bukowiecki, N., Lienemann, P., Hill, M., Furger, M., Richard, A., Amato, F., Prévôt, A., Baltensperger, U., Buchmann, B., & Gehrig, R. (2010). PM10 emission factors for non-exhaust particles generated by road traffic in an urban street canyon and along a freeway in Switzerland. Atmospheric Environment, 44(19), 2330–2340. https://doi.org/10.1016/j.atmosenv.2010.03.039

[13] European Environment Agency. (2023, December). Emissions of air pollutants from transport in Europe. https://www.eea.europa.eu/en/analysis/indicators/emissions-of-air-pollutants-from?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b

[14] Paris Open Data(n.d). https://opendata.paris.fr/pages/home/

[15] RATP. (n.d.). Réseau RATP - Questions de ponctualité. https://www.ratp.fr/decouvrir/coulisses/au-quotidien/reseau-ratp-questions-de-ponctualite

[16] European Environment Agency. (2022). *Air quality in Europe 2022: Sources and emissions of air pollutants*. https://www.eea.europa.eu/publications/air-quality-in-europe-2022/sources-and-emissions-of-air

[17] City of Paris (2022). *Le bilan des déplacements à Paris en 2022*. https://www.paris.fr/pages/le-bilan-des-deplacements-a-paris-en-2022-24072#la-circulation-automobile

[18] Statistiques Développement Durable. (2022). *Données sur le parc de véhicules en circulation au 1er janvier 2022*. https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-le-parc-de-vehicules-en-circulation-au-1er-janvier-2022

[19] European Environment Agency. (2023). *Part B - Sectoral Guidance Chapters: Energy - Combustion*. https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i-1/view

[20] Feigin, V. L., Roth, G. A., Naghavi, M., et al. (2016). Global burden of stroke and risk factors in 188 countries, during 1990-2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet Neurology, 15*(9), 913-924. https://doi.org/10.1016/S1474-4422(16)30073-4

[21] Santé Publique France. (2019, Novembre 6). *Pollution atmosphérique: Guide pour la réalisation d'une évaluation quantitative des impacts sur la santé (EQIS) - EQIS avec une exposition mesurée*. https://www.santepubliquefrance.fr/determinants-de-sante/pollution-et-sante/air/documents/guide/pollution-atmospherique.-guide-pour-la-realisation-d-une-evaluation-quantitative-des-impacts-sur-la-sante-eqis-.-eqis-avec-une-exposition-mesuree

[22] CEPIDC. (n.d.). *OpenData-CEPIDC*. Retrieved June 23, 2024, from https://opendata-cepidc.inserm.fr/

[23] Scansante. (n.d.). *Statistiques activité MCO par diagnostic et actes*. https://www.scansante.fr/applications/statistiques-activite-MCO-par-diagnostique-et-actes

[24] Le Monde. (2019, December 10). En Île-de-France, la densification urbaine devient un sujet de crispation. *Le Monde*. https://www.lemonde.fr/economie/article/2019/12/10/en-ile-de-france-la-densification-urbaine-devient-un-sujet-de-crispation_6022288_3234.html

[25] Ministère de la Transition Écologique. (2021). *Modèle de calcul des coûts totaux de possession (TCO) des véhicules lourds*. Task-Force – transition énergétique du transport routier.
[26] Aumont, Chloé, Piégay, Gaétan, Giraudineau, Adrien, et al. (2023). *Panorama de la cyclologistique en France: Etat des lieux, enjeux et recommandations pour la filière*. Les Boîtes à Vélo – France & ADEME.

[27] Trading Economics. (2024). *Electricity prices for medium-size households in France - Eurostat data*. https://tradingeconomics.com/france/electricity-prices-medium-size-households-eurostat-data.html

[28] Statistiques Développement Durable. (2018, November). *Les véhicules utilitaires légers : une bonne complémentarité avec les poids lourds*. https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2018-11/lps190-vul.pdf

[29] Electric vehicle recharging prices. (n.d.). *Alternative Fuels Observatory*. https://alternative-fuels-observatory.ec.europa.eu/consumer-portal/electric-vehicle-recharging-prices

[30] Salary Expert. (n.d.). *Full service delivery driver salary in Paris, France*. https://www.salaryexpert.com/salary/job/full-service-delivery-driver/france/paris

[31] The Local. (2023, April 20). French food delivery platforms agree to pay workers minimum wage. *The Local France*. https://www.thelocal.fr/20230420/french-food-delivery-platforms-agree-to-pay-workers-minimum-wage

[32] European Environment Agency. (2023). *Part B - Sectoral Guidance Chapters: Energy: Combustion: Emissions of air pollutants from transport in Europe*. https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i-1/view
[33] Pastramas, C., et al. (2015). *Update of the Air Emissions Inventory Guidebook - Road Transport 2015 Update*.

[34] Antonie, C., et al. (2022). First and Last Miles by Cargo Bikes: Ecological Commitment or Economically Feasible? The Case of a Parcel Service Company in Paris. The Reference Report.

[35] Ministère de la Transition Écologique. (2020). Mobilités Coût externes et tarification du déplacement

[36] Martin, K., et al. (2021). *A tractable TCO model to identify (ir)relevancy domains of modal options for urban deliveries*. Presented at Séminaire SPLOTT, June 7, 2021.

[37] ITF. (2022). *Decarbonising Europe's Trucks: How to Minimize Cost Uncertainty* (International Transport Forum Policy Papers No. 107). OECD Publishing, Paris.
[38] IEA. (2024, May 28). *SUVs are setting new sales records each year – and so are their emissions – Analysis*. IEA. https://www.iea.org/commentaries/suvs-are-setting-new-sales-records-each-year-and-so-are-their-emissions?utm_content=buffer9819d&utm_medium=social&utm_source=linkedin-Birol&utm_campaign=buffer

[39] Transport & Environment. Europe's transport sector set to make up almost half of the continent's emissions in 2030. March 20, 2024

[40] Carbone 4 (2020). Comparaison des émissions en cycle de vie: Carburant transport routier. Carbone 4

[41] Robichet, A., Nierat, P., & Combes, F. (2022). First and last miles by cargo bikes: ecological commitment or economically feasible? The case of a parcel service company in Paris. Transportation Research Record, 2676(9), 269–278. https://doi.org/10.1177/03611981221086632

[42] Schwarz, E., Leroutier, M., De Nazelle, A., Quirion, P., & Jean, K. (2024). The untapped health and climate potential of cycling in France: a national assessment from individual travel data. *the Lancet Regional Health. Europe*, 100874. https://doi.org/10.1016/j.lanepe.2024.100874