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## Methodology for characterizing vehicle fleet composition and its territorial variability, needed for assessing Low Emission Zones

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### Abstract

To decrease traffic pollutant emissions, numerous agglomerations envisage measures such as Low Emission Zones allowing only the less polluting vehicles to drive in dedicated areas. However, their implementation and efficiency depend strongly on the local vehicles fleet composition and on its possible variability as regards the areas. The analysis of the Île-de-France mobility survey and an in-situ observation campaign through video monitoring enabled a detailed characterization of vehicle fleet composition as regards motorizations and emission regulation. These two means of observations demonstrated significant differences with the National fleet composition estimation and important territorial variability, regarding Diesel share and vehicles renewal. “Well-off” territories with less Diesel and more recent vehicles would thus be advantaged as regards air quality and less affected by traffic-restriction measure focused on old and polluting vehicles.

Simulation of pollutant emissions demonstrates the sensitivity as regards fleet description. Furthermore the traffic out of the A86 highway (the second ring road around Paris, France), heavy vehicles and cold start represent significant amounts of emissions that would not be decreased by a restriction area. Local fleet specificities and variability are thus important for implementing a Low Emission Zone that would be efficient as regards air pollution and spatially equitable.

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## 1. Introduction

Despite significant improvement of the vehicles technologies, numerous agglomerations face significant air pollution (particulate matter and NO<sub>2</sub>) causing important health effects. Road traffic is a main contributor of this pollution. Various transport policies and measures are thus envisaged – of which Low Emission Zones allowing only the less polluting vehicles to drive in dedicated areas – to decrease traffic pollutant emissions and improve air quality. The design of such measures, as well as their assessment and efficiency as regards air pollution require however a detailed knowledge of the vehicles fleet characteristics (motorisations, age and emission regulation), as these ones are determining parameters of the pollutant emissions. Furthermore these policies have a strong spatial dimension and for instance a restricted area could have a local influence (less polluting traffic), but could also affect remote areas through changes in transport modal choices, traffic rerouting outside the area, or renewal of the vehicle fleet (inside) while older vehicles could be kept or resold outside. It is thus necessary to consider also the vehicle fleet variability according to the concerned territories.

Finally, one should note that local fleet compositions are hardly known. In general, average fleet compositions are simulated at a national level, based on statistics that are available at that level (annual registrations, annual mileage driven, vehicle survival probabilities see André et al, 2013, André et al, 2014), and such compositions are used for the pollutant emissions inventories even at local or regional scale. However one can suppose that there are differences of fleet composition, depending on local habits, vehicle purchasing or renewal behaviours or other socio-economic specificities. So depending on the areas, consumers may be more inclined to buy Diesel (or petrol, or hybrid) vehicles, or to change more frequently their car. This applies also to other vehicles characteristics (vehicle size, engine power, etc.).

These research works have been conducted in the frame of a French national programme, aiming at studying the feasibility and implications (as regards air quality, mobility but also social and equity aspects), of the implementation of low emission zones in France where such policies were not allowed up to now.

More specifically, these works aimed at studying the actual local fleet composition by using advanced techniques such as video monitoring and conventional approaches such as mobility surveys. A further objective is the characterization of the possible spatial (and temporal) variability of the vehicle fleet composition. Finally, pollutant emission simulations are envisaged to analyse the sensitivity of the estimation as regards vehicle fleet composition and to estimate the potential impact of traffic-restriction measures according to the areas.

In that paper, we describe first the methodological aspects of these works: description of the mobility survey, experimental design of the video monitoring and bilan of the experimentation, pollutant emission simulation. We analyse then the vehicle fleet composition and its variability through the two investigation means. We compute thus polluting emissions on the basis of the observed vehicles fleet compositions, and highlight the main issues in terms of emissions quantities, as regards vehicle categories and geographical areas.

## 2. Methodology, data and case study

The field of application of these works is the Île-de-France area around the Paris big conurbation. Two ways for investigating fleet composition have been implemented: on one side the territorial analysis of the regional mobility survey, which provides information on the vehicles owned by the residents, and on the other side the design and implementation and demonstration of a new approach based on video cameras, deployed in several places of the road network to monitor in situ the vehicles on the road.

It should be considered first that the literature is rare around these approaches. Indeed, it seems that mobility surveys are rarely studied for detailed analyses of the vehicle fleet composition and of its territorial variability. Although there are several attempts for monitoring the fleet composition by video observation, these experiments are generally very punctual (one site) and do not address thus the question of the variability of the fleet composition. They are also rarely reported in scientific papers.

## 2.1. Definition

The vehicle fleet consists in several categories: the private passenger cars (the higher share of the traffic), the motorized 2-wheelers (motorcycles and mopeds), heavy duty vehicles HDV (payload higher than 3.5 tons) of which lorries (freight) and urban buses and coaches (passengers), and light commercial vehicles LCV (payload less than 3.5 tons) of which delivery vans and cars with professional uses.

The estimation of the pollutant emissions from the road traffic relies on models (COPERT4, HBEFA, etc.) that consider separately these different categories due to their technological and use specificities. Furthermore the vehicle fleet should be declined more accurately as regards fuel used (Diesel, petrol, etc.), motorization (internal combustion engines, 2- 4-strokes, electric, hybrids), engine capacity or size, vehicle size and or weight (or payload) for the heavy vehicles as these characteristics influence to a large extend the vehicle fuel consumption and pollutant emissions. Finally the emission standard that a vehicle should fulfill is also a determining factor of the emission, as generally a new emission standard implies a decrease of the allowed emission level, and sometime it has led to significant changes of the engine or depollution technology (catalyst, diesel particulate traps, etc.). Emissions standards are revised every 4-5 years but concern only the new vehicles, and thus actual emissions factors of the vehicles vary significantly according to the age of the vehicles, independently of a possible degradation of their condition due to this age, degradation which is generally considered as negligible in most estimations.

As it can be seen, a very detailed description of the vehicles fleet is necessary to assess properly their pollutant emissions. The fleet composition will thus consist in the share of vehicles as regards categories, size, motorization, emission standards, etc.

We will further distinguish the composition of the “static fleet” (i.e. the vehicles number or share, by detailed classes, independently from their use) and the composition of the “in-use fleet” (or on-the-road or circulating fleet) as it can be observed in the street. This last one is described by the shares of the different classes in the traffic, i.e. as percentages of the total vehicles x km, and differs to the static fleet because vehicles are more or less driven, depending on their category, motorization, age and type (typically Diesel cars experienced higher annual mileage than petrol cars, newer cars more than the old ones).

As already said, vehicles fleet composition established at “a national level” (i.e. for France) are often used for estimating the road traffic pollutant emissions. In the following, we will compare the observed local fleet compositions to national estimations established in André et al, 2013, who provide static and in-use French fleet composition for the different vehicle categories, and decline them from 1980 up to 2030 and also according to urban, rural and motorway driving.

### Nomenclature

CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
EGT	Enquête globale transports (Transport survey at a regional scale)
HGV	Heavy good vehicles – Lorries with payload > 3.5 tons
LCV	Light commercial vehicles (less than 3.5 tons)
NO <sub>2</sub>	Nitrogen dioxide
PM	Particulates matters
VOC	Volatile organic compounds

## 2.2. Vehicle fleet characterization through a mobility survey

The “Enquête Globale Transport 2010” (EGT 2010, Schmidt 2013) follows the classical protocol of a mobility survey and in particular the Mobility Households Surveys (EMD) conducted in the big cities in France. The EGT2010 was carried out from 2009 to 2011 by TNS-SOFRES in the Île-de-France area (a large area around Paris, France, covering 9 departments with 11 millions of inhabitants). It was piloted and funded by STIF (transport companies and authorities association, Syndicat des Transports d’Île-de-France) and DRIEA (the regional

department of planning - Direction Régionale et Interdépartementale de l'Équipement et de l'Aménagement) in the frame of the OMNIL (Mobility observatory - Observatoire de la mobilité in Île-de-France). In all 18 000 households (about 43 000 persons) have been randomly selected according to a sampling protocol to represent the whole territory, and have completed detailed questionnaires regarding their travels from the previous day (143 000 travels). The survey analyses the mobility habits and their evolution, the transport modes, and the characteristics of the owned vehicles (2-wheeler, car or light commercial vehicle) if any. The results were adjusted according to household size, housing type, and people socio-professional characteristics.

Vehicles were described according to their type, motorisation, engine size, and age. Vehicle age was used to estimate the emission standard although their applications do not correspond strictly to a given year (i.e. all vehicles registered in 2010 were considered as Euro4 while this year introduced already new car models as Euro5).

Furthermore indication on the annual mileage driven was also requested. Due to the coverage of the survey, it enabled thus a territorial analysis of the vehicle fleet composition, in term of ownership (where the vehicles are owned) rather than of geographical distribution (where the vehicles are driven). By combining this static fleet composition with the corresponding annual mileage it is thus possible to estimate an “in-use fleet composition” and to analyse its spatial variability, even if that does not provide exact information on the geographical allocation of the traffic, as the annual mileage driven by a car is obviously not totally travelled in the car origin department.

However the survey concerns only the vehicles owned by the residents, and thus vehicles in transit, public transports and lorries were not taken into account, although they could represent a significant part of the traffic. The analyses proposed here are thus dedicated to the cars (2-wheelers and light commercial vehicles have been also described in Carteret et al. 2014a and b). Due to the survey protocol, vehicles statistics have been adjusted according to the weight of each household, i.e. what it represents within the entire survey sample.

### 2.3. Vehicle fleet monitoring through video monitoring

The approach envisaged in these works relies on the in-situ video monitoring of the vehicles, the capture of their licence plates, and the search in the national vehicles registrations file, to get the detailed technical characteristics of the vehicles. The vehicle fleet composition can thus be estimated, according to vehicles categories, motorization, size, and pollution standards (indirectly from the vehicle age). One should notice that this approach provides a description of the “in-situ fleet”, as vehicles are captured according to the frequency of their use. However, if we consider the identified individual vehicles, independently from their multiple passages and captures by the camera, we can also estimate a description of the static fleet, although excluding vehicles that would have been never used.

The traffic monitoring by video is currently implemented for traffic management, incident detection, etc., and thus many cameras are already installed on the road network. However these systems can be insufficient for our purpose as: their main objective (safety) does not allow other use, they do not register continuously or at all the data, their focalisation is not accurate enough for enabling the capture of the licence plate. Dedicated systems exist however, for speed control (radar), for parking management, for dedicated traffic surveys (origin – destination), which enable the automatic capture of the only licence plate, and its conversion to alphanumeric characters.

In these works we elaborate an experimentation protocol based on such dedicated systems. The experimentation is conducted and demonstrated in the Île-de-France area. A larger implementation and the use of existing video systems should obviously improve the coverage (other cities and areas) and the accuracy of the observations, and that should also enable a monitoring of the fleet composition over time.

#### 2.3.1. Sites selection

One of the main difficulties of the approach is the selection of appropriate places to monitor the vehicles fleet. Ideally many systems could be deployed, allowing a large coverage of the road network, but even in that case, it would be necessary to correctly weight the different observation sites.

In that frame, we have deployed the systems in 3 main areas, selected to represent the diversity of the Île-de-France region. Paris was chosen as a central area with a high density, facing severe air pollution due to high traffic levels, even if Paris records a low motorization rate. The Hauts-de-Seine (92) was selected as one of the well-off areas of the region mostly located in the west part of Paris, while Seine-Saint-Denis (93) belongs to the less-favoured departments and is located in the east.

However, depending of the road axes, the fleet can be a mix of vehicles coming from every place and driving to various destinations. To enrich the coverage of the protocol, we decided to monitor the fleet on axes that drain a large mix of traffic (from east, from west) on one side, and also to capture the very local fleet composition, through very local streets or roads, on which the traffic is mainly internal. In that aim, the regional travel and traffic modelling tools (MODUS, Ladegaillerie 2008) were used to identify the main axes of traffic converging to the Paris area, as well as streets with a high share of local traffic (origins and destinations in the same department).

In all 9 sites were experimented, 3 in each of the selected areas. For Paris 2 local sites were selected (Boulevards Voltaire and des Italiens) as well as a main axis on the ring (Boulevard périphérique - porte d'Auteuil). In Seine-Saint-Denis, the Avenue Jean-Jaurès - Aubervilliers was chosen as it drains a high traffic to Paris, and 2 local streets (Boulevard Alsace-Lorraine - Rosny-sous-Bois, and Boulevard Jean-Jaurès - Livry). In Hauts-de-Seine, the "Grande-Rue"- Sèvres was selected as a converging axis to Paris, while Avenue de la Redoute - Asnières and Boulevard de la République - Saint-Cloud were chosen due to their local traffic.

### 2.3.2. Devices and periods of monitoring

Depending on the sites, 1 to 3 video cameras were installed, monitoring only one way of the traffic. The devices were of two types:

- mobile cameras installed on a tripod in safe places or in a vehicle parked on the side of the concerned street; the drawbacks of these systems were their limited autonomy (12 hours) and the risk of being damaged or masked;
- fixed systems mounted on traffic- or street-light posts; these systems are better in term of autonomy and protection, but their installation is more complex.

Nevertheless both systems have been subject to various dysfunctions.

### 2.3.3. Bilan of the experimentation

The experimentation was conducted from middle of May to middle of June 2013, a period without holidays and quite representative of the usual conditions. For the main axes, the monitoring last a whole week, 24h per day, to capture possible temporal variations. The local sites were monitored continuously during 2 representative days (Tuesday and Thursday) of the week.

In all, about 600,000 vehicles were monitored and their license plates captured during a total monitoring period of 33 days. Due to various dysfunctioning several periods were inhibited and if we compare the number of observations with local traffic statistics, one can estimate that the overall sampling efficiency of the whole experimentation is about 50%. Nevertheless, that represents already a very satisfying sampling of the whole traffic.

The 600,000 observations correspond to 406,000 individual vehicles (some of them being observed several times or in several places), and 92.5% were correctly identified through the national vehicle registration file, from which detailed technological characteristics were obtained, allowing the elaboration of the fleet composition.

Table 1 : Number of identified observations by sites of which urban buses, coaches and lorries

Area	Site	All vehicles	Of which :		
			Urban buses	Coaches	Lorries
Seine-Saint-Denis (93)	1	11831	386	13	147
	2	13626	276	8	236
	3	90204	956	157	1693
Paris (75)	4	5315	352	6	109
	5	11709	88	14	160
Ring road	6	363254	100	1175	4453
Hauts-de-Seine (92)	7	9568	3	68	180
	8	10149	95	24	138
	9	41265	836	54	265

Depending on the places, 5,300 to 13,000 observations were registered and identified on the local sites, 41,000 in the Grande-Rue, Sèvres, 90,000 in the Avenue Jean-Jaurès, Aubervilliers, and 363,000 on the Boulevard Périphérique, Porte d'Auteuil, Paris (see Table 1).

We notice that urban busses were observed in sufficient number to enable satisfying analysis in most sites except 2. Coaches were insufficiently observed on 4 local sites. Lorries are sufficiently numerous on all sites (see Table 1).

#### 2.3.4. Data analysis for the estimation of fleet compositions

As already noticed, the elaboration of a fleet composition from the monitored data requires weighing rules, which were established as follows:

- To avoid an overweighing by the sites which were instrumented longer, the effective monitoring durations were reduced to a common basis,
- The Boulevard Périphérique site was considered separately,
- To obtain fleet composition representing each of the areas (Paris, Seine-Saint-Denis, or Hauts-de-Seine) the 2 or 3 sites were weighted according to what they represent in term of traffic volume within the given area (these statistics were provided by the MODUS regional traffic model),

To derive an average fleet composition for the whole Île-de-France region, we considered the traffic simulation over the whole road network, morning peak-hour during a weekday (see next section). The aggregation of the traffic volumes according to different areas enabled to determine the share of different areas (Table 2): Paris (without the ring) represents 7% of the total traffic, the Boulevard Périphérique accounts for 4.3%, and the 2 investigated areas (92 and 93) for around 9% of the total traffic (in all 29% of the traffic). The fleet composition of these areas will be weighed by these figures.

Table 2 : Traffic distribution according to the areas (traffic modeling, weekday, morning peak-hour, data Airparif)

Area	Traffic (% of vehxkm)
BP-Boulevard Périphérique (Ring road)	4.3%
Paris (75)	7.0%
Hauts-de-Seine (92)	8.8%
Seine-Saint-Denis (93)	8.6%
Other areas	71.3%

Because of the lack of statistical data, the remaining part of Île-de-France was arbitrary supposed to have a fleet composition that would be a combination of the fleets of the 2 periurban departments (60%) and of the fleets observed in Paris and on the Ring (20% respectively). In all, the Île-de-France vehicle fleet composition consists thus in 22% of the Parisian fleet, 19% of the Ring fleet, and 29.5% of each of the Hauts-de-Seine and Seine-Saint-Denis fleets.

#### 2.4. Pollutant emissions estimation

To analyse the sensitivity of the pollutant emission to the vehicles fleet composition, a case study was implemented with the computation of the vehicles emissions. This case study describes the whole Île-de-France road network, in all 37,697 road-links, during the morning peak hour a weekday in 2013. Hourly traffic flows and vehicle speeds are provided for the different vehicles categories (passenger cars, buses, lorries, light commercial vehicles and 2-wheelers). A share of cold-engine driven cars is also available for each link. The meteorological conditions are those of spring (11°C).

In link to our study, we will consider the traffic and the resulting pollutant emissions according to their spatial allocation in Paris, the ring road / Boulevard Périphérique, Hauts-de-Seine and Seine-Saint-Denis, and other departments. We will also consider their repartition according to the following areas: inside the Paris centre (intra-ring), inside the crown from the ring road to the A86 motorway (the second ring road, because this A86 perimeter was discussed as a possible low emission zone), and outside (remaining part of the Île-de-France).





Table 4 declines the cars fleet composition as regards the pollutant emission standards, which vehicles satisfy. In all, the Île-de-France distribution is quite close to the national one (gaps are less than 2% and distributed between the categories). One should then conclude that the Île-de-France cars fleet is quite similar to the national one.

The distributions by departments can also appear as relatively similar as differences are relatively limited for each emission standard. However, when we consider the cumulative differences regarding the more recent (and less polluting) vehicles (i.e. Euro 4 and 5) and on the other side the older and more polluting ones (pre-Euro to Euro2) one can observe significant discrepancies between the areas. By the way, recent cars (Euro 4 and 5) can represent 36-37% of the fleet in Hauts-de-Seine and Yvelines, while they are only 26% in Seine-Saint-Denis and 32-33% in Paris and Val-de-Marne. In the same time, older cars are respectively 31-32% against 39% (Seine-Saint-Denis and Paris) and 36% in Val-de-Marne. These double shifts by around 8-10% less older to and more new cars (and vice versa) led to a significant gap between the fleets in term of age and emission standards, and should also result in significant differences in term of average level of pollutant emission by the corresponding fleets.

### 3.1.2. In-use fleet composition

In the following, we focus the analyses on 3 areas: Paris, Hauts-de-Seine and Seine-Saint-Denis as they were identified as contrasted areas and selected for the video experimentation. We consider also the entire Île-de-France area and compare them to the national estimation.

Due to a higher use compared to petrol cars (annual mileage), the share of Diesel cars in the traffic is higher when considering the in-use fleet. The share observed in Île-de-France is 64% (Table 5). It is however less by 7% than the national estimation (71%), demonstrating the specificity of local fleet. Once again, we observe large variations between the areas: Paris accounts for less than 50% of Diesel cars, Hauts-de-Seine 59% and Seine-Saint-Denis has the maximum of Diesel cars traffic (65%).

One should also observe that the annual mileages as recorded through the EGT2010 mobility survey are significantly higher than the national estimations (which are based on the French national mobility survey), for both petrol and Diesel cars (Table 6). This is certainly linked to the high level of urbanization of the Île-de-France region, to longer daily distances traveled, and to long distances for holidays and weekends.

Table 5: In-use-cars-fleet composition as regards motorization in the Île-de-France area and its territorial variability (EGT 2010-STIF-OMNIL-DRIEA data), and comparison with Ifsttar national estimation (year 2010).

In-use fleet composition (% veh x km)	National estimation (2010)	Ile-de-France	Paris (75)	Hauts de Seine (92)	Seine-Saint- Denis (93)
Diesel	71	64	49	59	65
Petrol	29	35	51	40	35
Hybrids, electric, others	0.2	0.7	0.5	0.9	0.3

Table 6: Cars annual mileages as regards motorization in the Île-de-France area and territorial variability (EGT 2010-STIF-OMNIL-DRIEA data) and comparison with the Ifsttar national estimation (year 2010).

Annual mileage	National estimation (2010)	Ile-de-France	Paris (75)	Hauts de Seine (92)	Seine-Saint- Denis (93)
Diesel	14,700	16,100	22,000	19,000	17,300
Petrol	8,400	9,900	15,300	10,200	9,400
Hybrid, others		10,800	≈8,000	≈14,000	≈3,000
Electric		1,400	250		
Together	12,100	13,095	17,900	14,100	13,300



Compared to the national estimations (year 2013 for a correspondence with the experiment period), the cars traffic is lower (by 3-5%) and compensated by an increase of light commercial vehicles in Paris, Boulevard Périphérique and Seine-Saint-Denis. Meanwhile, the cars share in Hauts-de-Seine is higher by 3-4% and the LCV share is lower by 2-3%. We have thus quite different traffic structures for these two groups of areas.

Lorries traffic is lower than the national estimations (factor 2) on all observation sites. Except on Boulevard Périphérique, the bus traffic is much higher than the national estimation (factor 5 in Paris, 2-3 for the other sites).

As regards cars in-use fleet (Table 9), we observe a lower Diesel rate in Île-de-France (64%) than in the national estimations (75% and 71% for urban). The lowest Diesel rate is observed in Hauts-de-Seine (58%) and the highest in Seine-Saint-Denis (68%). These figures are in good agreement with the results from the EGT2010 survey.

We observe thus a significant contrast in Diesel / Petrol repartition between these 2 areas (9-10% between the areas, in all 15-30% in absolute variations). Finally we observe also a quite interesting share of alternative vehicles (hybrids, electric, etc.) in Paris and Hauts-de-Seine (2.8 and 2.2%), while their rate remains low in Seine-Saint-Denis and insignificant in the national estimations.

Table 9: In-use-cars fleet composition as regards motorization and emission standards. Comparison of the observed vehicle fleets by areas and the estimated Île-de-France fleet with the Ifsttar national estimations (urban and all traffics, year 2013).

Vehicle category	National Urban fleet (2013)	Video observations			Boulevard périphérique	National Urban, rural, motorway	Estimation Ile de France
		Paris (75)	92	93			
Diesel	70.8	66.1	58.3	68.4	66.3	74.5	64.3
Petrol	28.7	31.1	39.5	30.7	31.9	25.0	33.8
Others	0.5	2.7	2.2	0.9	1.8	0.5	1.9
Euro-0-1-2	13.4	16.6	14.1	24.8	13.7	13.0	17.6
Euro-3	24.1	21.4	20.1	29.0	21.0	24.3	23.0
Euro-4	35.4	31.9	35.4	29.5	35.5	35.7	33.0
Euro-5	27.1	27.4	28.3	15.8	28.0	27.0	24.5
Others	-	2.8	2.2	0.9	1.8	-	1.9

In Seine-Saint-Denis, we observe a high share of traffic by old and polluting cars: 54% of pre- and Euro3, while they would be 37% in the national estimation, and only 34% in Hauts-de-Seine, this means a very high difference between the 2 departments (reaching 20% in absolute). We observe the highest share of recent and clean cars in Hauts-de-Seine (64% of Euro 4 and 5 cars, close to the national estimations), while they account for 59% in Paris, and 45% in Seine-Saint-Denis.

We have thus a much more recent and clean in-use fleet composition in Hauts-de-Seine, and particularly contrasted with Seine-Saint-Denis. Furthermore this fleet has less Diesel cars and a higher share of alternative vehicles (hybrids, electric).

Considering the spatial variability, we can add that Paris and Seine-Saint-Denis have a higher share of LCV (20% again 13% in Hauts-de-Seine), Paris has a high rate of buses (3.4%). Hauts-de-Seine has the lowest share of LCV, lorries and buses in the traffic. Seine-Saint-Denis has the oldest cars, LCV and lorries in-use fleet. Finally, it seems that buses are mainly Euro2 in Paris, while Euro3 and 4 are predominant in the other areas. By several aspects, vehicles fleets present thus significant differences between the different observed areas.

To recapitulate the differences with the national estimations, we can say that the Île-de-France in-use vehicles fleet has a higher share of LCV (18% of the veh x km, versus 14%) of which a higher rate of Petrol LCV (1.9% versus 0.9%), less lorries (1.5% instead of 2.7%) of which less articulated trucks (8% of the lorries traffic instead of 36% in the national urban estimation), a higher share of buses (1.6 instead of 0.6%), of which a high rate of articulated buses (19% of the bus traffic against 13%). The LCV in-use fleet is more recent and less polluting (72% of Euro4 and 5 against 68%), but the cars fleet has less Diesel (64 against 71%) and is older / more polluting (-5% of

Euro4 and 5), as the lorries (58% of Euro4-5 instead of 70%) and buses (25% of Euro4-5 instead of 63%). The Île-de-France in-use vehicle fleet differs thus significantly and by several aspects from the national estimations.

#### 4. Influence of the vehicle fleet composition on the pollutant emissions estimation

Table 10 recapitulates the results of the exhaust pollutants emissions simulation (including cold start) over the entire road network of the Île-de-France area, during the morning peak hour, a weekday. This simulation relies on current national in-use vehicles fleet composition, declined as urban / rural / motorway according to the road links.

Passenger cars represent 74% of the total traffic during that period, for around 43 to 55% of the exhaust pollutant emission quantities (nitrogen oxides NO<sub>x</sub>, particulate matter PM, carbon dioxide CO<sub>2</sub>) and 72% of the volatile organic compounds VOC. One should notice that VOC emitted by evaporation represents around 0,05 tons, i.e. 7% of the total VOC. Heavy vehicles (lorries, buses and coaches) cover only 7% of the vehicles x kilometres but are responsible of 23% of CO<sub>2</sub>, and 39% of the PM and NO<sub>x</sub> emissions, considered as 2 main issues regarding health impacts. The contribution from LCV to these 2 pollutants is also important (17-19% for 19% of the traffic). In all, cold start (mainly passenger cars) represents more than half of the total carbon monoxide CO and benzene emissions and 43% of the VOC.

Table 10: Emission results (Île-de-France, morning peak hour, week-day) when using national fleet compositions; distribution according to the vehicle categories and to the geographical areas

Type	Traffic (veh x km and %)	CO <sub>2</sub>	NO <sub>x</sub>	VOC (exhaust only)	PM
Heavy vehicles (lorry, bus, coach)	7%	23%	39%	13%	39%
Passenger cars	74%	55%	43%	72%	44%
Light commercial vehicles	19%	22%	19%	15%	17%
All	8.97 x 10 <sup>6</sup> veh x km	2.08 x 10 <sup>3</sup> tons	8.16 tons	0.72 tons	1.02 tons
Paris	7%	8%	8%	10%	7%
Boulevard périphérique / ring road	4%	5%	5%	4%	4%
Intra-A86 (Paris/ring excluded)	15%	15%	15%	15%	15%
Remaining of Île-de-France	74%	73%	72%	71%	75%

Table 11: Emission differences induced by the observed in-use fleet (Île-de-France, morning peak hour, week-day); distribution according to the vehicle categories and to the geographical areas

Type	CO <sub>2</sub>	NO <sub>x</sub>	VOC (exhaust & evaporation)	PM
Heavy vehicles (lorry, bus, coach)	-11%	+2%	+38%	+2%
Passenger cars	+25%	+13%	+82%	+0%
Light commercial vehicles	-0%	-3%	-4%	-6%
All	<b>+11%</b>	<b>+6%</b>	<b>+65%</b>	<b>+0%</b>
Paris	+0%	+2%	+20%	-1%
Boulevard périphérique / ring road	-3%	-8%	+2%	-2%
Intra-A86 (Paris/ring excluded)	+13%	+5%	+73%	+0%
Remaining of Île-de-France	+13%	+7%	+76%	+0%

As regards the geographical repartition, Paris represents 7% of the traffic and around 7 to 10% of the total emissions, 11% and 11-14% if we add the ring road. The intra-A86 area (Paris included) accounts for 26% of the total traffic and 25-30% of the total emissions of the Île-de-France area. These results show that most of the traffic

and emissions do not come from the central areas and thus restrictions applied to these areas could have a limited impact, roughly proportional to the severity level but also to the order of magnitude the area represents (i.e. a severe restriction in the Paris centre could enable an emission decrease by a few percents, maybe not significant in term of air quality).

Table 11 gives the differences in emissions, when we use the observed in-use vehicles fleet compositions (Paris and ring road as observed, elsewhere the average Île-de-France fleet and its declination in rural and motorway composition according to the national statistics), instead of the previous national estimation. Except for PM, the use of the observed vehicles-fleet lead to higher emissions, i.e. the national vehicle-fleet underestimates the emissions.

Certain results (PM) do not vary a lot. This may be due to a low sensitivity of that pollutant to the differences in the fleet, and also to compensation between different aspects. We have indeed less Diesel cars and LCV, but older vehicles in general. For NO<sub>x</sub>, we observe significant differences but they also compensate themselves to result in an overall difference of 6% (which is limited taking into account the high variability and uncertainty of that pollutant).

For CO<sub>2</sub>, the gaps are important (+25% for passenger cars, -11% for heavy vehicles) and remain in all at a level of 11%, which is really significant as CO<sub>2</sub> estimations are much more accurate than other pollutants.

Finally, exhaust VOC (and CO) emissions are largely underestimated by using national fleet composition, due mainly to the difference in Diesel rate. We notice also that VOC evaporation - although limited - was underestimated by a factor 2 with the national vehicle fleet.

Furthermore, the differences induced by the fleet composition vary according to the geographical areas, but it seems that the most important gaps concern the outside areas. .

Considering the vehicles fleet differences observed in Île-de-France, we can finally calculate and estimate that - if Seine-Saint-Denis benefited from the Hauts-de-Seine vehicles fleet (less Diesel and old cars), its total road traffic emissions (during the morning peak-hour) would decrease by 14% (NO<sub>x</sub>), 11% (VOC) and 8% (PM), while the only cars emissions would decrease by 22%, 11% and 14% respectively. In the same way and with the same improved vehicle fleet, Paris would have its total emissions decreased by 10% (NO<sub>x</sub>) and 5% (PM).

These last figures highlight the importance of vehicle fleets in emission estimation, and the actual potential in term of pollutant emissions when shifting from a fleet composition to another one, these two compositions being particularly realistic as they already exist.

## 5. Discussion and conclusions

Two approaches have been implemented to characterize in detail the vehicles fleet in the Île-de-France region, and to observe its possible territorial variability. The first approach relies on the analysis of the regional mobility survey. The second one has consisted in the deployment of video camera in different places of the road network and region, to apprehend both local and inter-departmental traffics. Both approaches - although not concerning the same reference year - demonstrate specificities of the Île-de-France vehicles fleet and differences with the national estimations currently elaborated by a combination of statistics (annual registration, mobility, vehicle age and mileage, etc.) and simulation. Both approaches have demonstrated also significant differences of the fleet composition according to the territories, in particular regarding Diesel share (passenger cars and LCV) and the renewal of the vehicles and the share of recent / less polluting vehicles.

As the video monitoring data enable also characterizing the vehicles according to their provenance (registration), we have computed the cars fleet compositions by department, as they were known through the mobility survey. Table 12 ranks the Île-de-France departments as regards 2 criteria: the share of old (more polluting) cars, and the share of Diesel cars, as estimated by the mobility survey and by the video monitoring. We observe a quasi-perfect similarity of the ranking from the 2 approaches, despite a lag of 3 years between them. The 2 approaches appear thus as reliable for characterizing local cars fleets.

The mobility survey presents serious advantages as it already exists in several French big cities, sometimes at 2 periods, and has a good coverage of the territories and population, but its implementation is heavy, costly and slow (several years between surveys). Furthermore it is limited to the cars and light vehicles used by the households. The video monitoring can be implemented quite easily, covers all vehicles categories and traffics (transit, goods, etc.), and providing a good determination of representative places could even be a quasi permanent observatory of the

fleets and traffics. Although it involves technical devices, it is likely that its costs remain affordable, as video camera could be used for different purposes.

Table 12: Territorial discrimination of the cars fleets, as regards Diesel rate and vehicle age, through mobility survey (EGT 2010-STIF-OMNIL-DRIEA data), and video monitoring.

Discrimination as regards cars age	Few old cars							More old cars	
EGT2010 mobility survey	Hauts-de-Seine (92)	Yvelines (78)	Seine-et-Marne (77)	Essonne (91)	Val-de-Marne (94)	Val-d'Oise (95)	Paris (75)	Seine-St-Denis (93)	
Vidéo monitoring (2013)	Essonne (91)	Seine-et-Marne (77)	Yvelines (78)	Hauts-de-Seine (92)	Paris (75)	Val-de-Marne (94)	Val-d'Oise (95)	Seine-St-Denis (93)	
Discrimination as regards Diesel rate	Few Diesel cars							More Diesel cars	
EGT2010 mobility survey	Paris (75)	Hauts-de-Seine (92)	Val-de-Marne (94)	Seine-St-Denis (93)	Yvelines (78)	Essonne (91)	Val-d'Oise (95)	Seine-et-Marne (77)	
Vidéo monitoring (2013)	Paris (75)	Hauts-de-Seine (92)	Yvelines (78)	Val-de-Marne (94)	Essonne (91)	Seine-St-Denis (93)	Val-d'Oise (95)	Seine-et-Marne (77)	

The experiment and mobility survey analyses have demonstrated differences between the Île-de-France vehicles fleets and the national fleet estimations, from several aspects. The simulation of the pollutant emissions over the Île-de-France and during the morning peak-hour has shown that high issues (in term of emissions) concern the heavy vehicles (lorries and buses) and light commercial vehicles traffics (more than 56% of the PM and NO<sub>x</sub> emissions, but only 26% of the total traffic), the over-emissions due to the (petrol) engines cold starts (more than half of total CO and benzene and 43% of VOC emissions). In all, the central areas (Paris and intre-A86) do not concentrate a high share of the total pollutant emissions. The use of the observed vehicles fleet compositions (instead of national estimations) demonstrates significant gaps and emissions underestimations, which can compensate or not, the most significant concerning CO<sub>2</sub> and VOC.

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