

Evaluation of electric scooters as an alternative transportation mode for home-work trips in France

Y. Bennouna, D. El Omeiri, T. Marquez, J. Loumeto Ndounzi, C. Ramond

Abstract — In France, the transportation sector is responsible for a third of greenhouse gas emissions. Moreover, in 2020, 72.8% of nationwide home-work trips were made by car. This presents a challenge on how to reduce the associated emissions and an opportunity to promote cleaner modes of transport, for example e-mobility options such as electric scooters. The assumption being that a modal shift of car-users towards e-scooters should result in improved environmental and societal benefits. The paper follows the methodology and actions taken to evaluate the program: a) selection of users for the experimentation, b) analysis of technical specifications and GPS monitoring of e-scooters, c) continuous user-surveys to understand travel habits, and d) the development of an analysis tool to assess the environmental impact compared to other forms of transportation based on their energy consumption (kWh), CO₂, NO_x and PM₁₀ emitted. The paper presents the initial results of a pilot project in France, which aims to evaluate the influence of micro-mobility to reduce the environmental footprint of home-work trips, and identify user-behaviour challenges and opportunities in the shift of transportation modes.

Keywords—*electric mobility, micro-mobility impact, transportation modes.*

I. INTRODUCTION

Urban mobility, due to the preponderance of private thermal vehicles, poses substantial environmental and societal challenges. In 2018, the transport sector accounted for 30% of French greenhouse gas emissions (95% of which are emitted by road transport, mostly private vehicles, i.e., cars, vans, trucks), and 22% of emissions in the European Union [1], thus contributing to

the acceleration of climate change and its global consequences.

In addition, the transport sector is also one of the main sources of air pollution, generating for example 55% of NO_x (nitrogen oxide) emissions, 14% of PM₁₀ and 17% of PM_{2.5} (fine particles) in metropolitan France in 2018, with increasingly proven effects on human health (48,000 deaths in metropolitan France in 2016) [2]. In addition, the use of thermal vehicles also causes noise pollution, especially during traffic congestion in urban areas.

Moreover, travel by private vehicle in cities raises issues on land use, generating significant parking and road space requirements, to the detriment of other potential uses (vegetation, social areas, facilities, etc.), even though such travel represents a minority of trips.

Finally, road travel in personal vehicles is the main source of traffic jams, which continue to exist in cities today. In 2017, traffic jams represented an average of 40 minutes per Parisian motorist, a figure that has remained stable for the last ten years. All these negative environmental and health impacts have not prevented the overwhelming dominance of private car travel between home and work (74% of employed people use it) [3].

This article presents the implementation of an experimental approach in the use of electric scooters for home-work trips which aims to evaluate the environmental impact towards a massive deployment of micro-mobility.

II. CONTEXT OF PROJECT

In France, sales related to micro-mobility (mechanical and electric machines + accessories) represented sales revenue of 209.9 million euros in 2017, 56.6% more than in 2016. In particular, Personal Light Electric Vehicles (PLEV)

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accounted for 195.4 million euros in revenue for 1.7 million units sold. In 2018, 5.7% of the French population used a PLEV regularly. Globally, the growth of this market is expected to continue in the coming years, with an annual increase of 7% by 2024 [4].

This growth in the use of PLEV is driven by several perceived advantages by users and local authorities: flexibility and small size adapted to multimodality, quality of life gains linked to outdoor activities, potential time savings, as well as the absence of polluting emissions [5] and CO₂ during use [6]. However, this growth also brings challenges that, if not addressed, can diminish the benefits of this means of transport: user safety, sharing of public space with other forms of mobility, environmental impact related to manufacturing, transport and a frequent short life span. Because of the recent mass-use of PLEV, research quantifying its social benefits is still ongoing related to health and social implications (e.g., user perception, sharing economy) [7] [8] [9].

The French Ministry of Ecologic Transition has, within its energy certificate programmes (CEE), included the payment of a financial contribution to information, training and innovation programmes in favour of energy demand management or the reduction of energy poverty [10]. These programmes are defined by decrees of the Ministry in charge of energy. In this regard, the programme Mobiprox, is part of this CEE financing.

The programme responds to three objectives: a) evaluate the energy impact of mobility in PLEV, b) increase awareness of these new forms of mobility in all their aspects (prevention, energy reduction, regulations, uses), and c) set up an observatory of micro-mobility, accessible to the general public. It's aimed at public organisations and companies.

Over a period of two years the programme intends to carry out a large-scale experimental on over 550 users of electric scooters in 12 regions in France.

III. METHODOLOGY

For the evaluation of the impact of micro-mobility on energy consumption and pollutant emissions, a methodology was developed to compare different data obtained during the pilot program. The data collected was divided into two types: measured data, and substituted data, where:

- Measured data: which are obtained by GPS tracking thanks to boxes installed on the PLEVs of individual users participating in the program. Examples of "measured" data: travelled distance recorded by the tracer. "Measured" emissions and energy consumption were estimated based on recorded distance.
- Substituted data obtained by interpreting questionnaires answered by program participants, as well as by relying on data from the literature. Examples of substitute data: reference values for energy consumption or emissions related to the modes of transport used by the program participants before their modal shift to micro-

mobility (e.g., type of vehicle, fuel type, consumption per km).

In order to make a comparison that accurately describes the environmental impacts of modal shift to micro-mobility, the following phases was developed:

A. Data collection on mobility practices

Data was gathered on: a) the current practices of

TABLE I
CHARACTERISTICS OF MOBILITY PRACTICES

For PLEV	For substituted transport
Weigh of the electric scooter	Transportation modes
Storage capacity of the battery	For cars: fuel type, type of body work, fuel consumption, CritAir label,
Declared autonomy	For motorcycles: cylinder capacity

mobility, and b) survey on users' previous practices.

a) For current practices, information was gathered for the selected PLEV on its weight, energy storage and declared autonomy. Also, several criteria were gathered for the characteristics of substituted-transportation mode: motorisation type (gasoline, diesel, electric), type of bodywork (city, compact, SUV), consumption (L / 100km), Crit'Air Label (from 0 to 5), and for two-wheel drive

TABLE II
EXAMPLE OF USER QUESTION GATHER MOBILITY PRACTICES

Question 19: For your current travels on electric scooter, please estimate the distance travelled in kms (on a daily round trip basis) for each mode of transport replaced.		
Mode of transport replaced	Distance (Mon-Fri)	Distance (weekend)
Walking		
Car		
2 wheels vehicle		
Bus		
Train		
Metro		
Bicycle		
Electric Bicycle		

The total survey contained 52 questions, part of these questions are sent monthly.

(<250cc, >250cc), see table I.

b) On the users' previous practices, an exhaustive questionnaire of 52 questions was provided to participants. The questions addressed information like: PLEV ownership, displacement and frequency, motivation for use, selection of over 40 types of PLEV in the market, alternative means of transport, and maintenance. Table II, shows a sample question to estimate percentages of modal transport experiences use during the week.

To evaluate the impact of micro-mobility on energy consumption and pollutant emissions, the calculations performed were based on measured trips data and simulated trips data. Where the measured trips were obtained by GPS tracking, either through the boxes installed on the PLEVs of individual users or through data provided by fleet rental companies, and simulated trips

based on alternative substitute (i.e., transport replaced), see Fig.1 example.

B. Emissions calculation of substitute transport

A key aspect of the programme is the calculation of avoided energy consumption and emissions. As these are estimated based on trip and transport modes hypothesis, attention has been given to the methodology for its calculation. In this regard, emission linked to manufacturing and emissions linked to usage were taken into account.

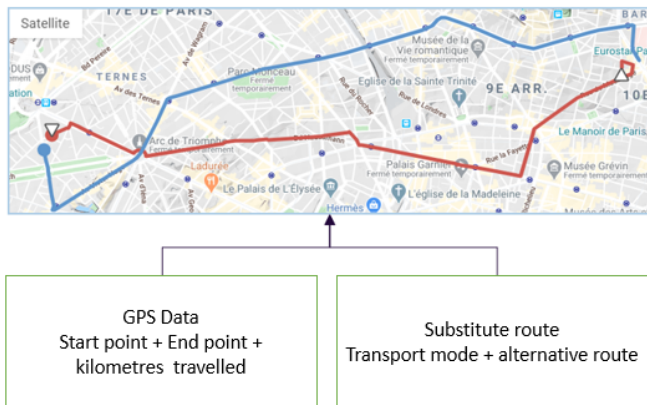


Fig. 1. Measures for trips via GPS tracking provided by fleet rental company (in red), and simulated route adapted to transportation mode (in blue).

1) Emission linked to manufacturing

The factors linked to manufacturing were simplified into motorisation type (gasoline, diesel, electric) and the type of bodywork (city, compact, SUV). To have one reference across these factors during the manufacturing phase, the assumption was that the vehicles were manufactured in China and took into considerations the comparative life cycle CO₂ emissions reported by Q. Qinyu [11], as the scooters are mostly manufactured in China. Furthermore, as to convert the emissions from manufacturing into emission per kilometre, the lifespan of the vehicles was assumed at 10 years with an average distance travelled of 15000 km per year [12].

2) Emissions linked to usage

During the phase of usage four indicators were estimated: kWh, CO₂, NO_x and PM₁₀ during usage. The CO₂ was estimated based on the motorisation type,

TABLE III
EMISSION FACTORS USED FOR THE USAGE PHASE

Motorisation type	CO ₂ Volumetric density
Gasoline or hybrid	2,392 kg CO ₂ / L
Diesel	2,640 kg CO ₂ / L
Electric	0,0599 kg CO ₂ / kWh

The calorific energy conversions used to transform into energy are: 35 475 kJ/L for gasoline, 38 080 kJ/L for diesel, and 3,6 kJ for 1kWh of electricity.

carburant rate of consumption per 100km (as informed by the users) and its related CO₂ volumetric density (table

III). The NO_x and PM₁₀ were obtained using the tool by Airparif [13], which provides the values in mg / km after providing the type of trip (one-way, round trip), distance and mode of transport (car, two wheels, diesel, gasoline, electric, bicycle or walking), and the values from the Crit'Air label (an air quality certificate given to vehicles in France to indicate their environmental class).

C. Emissions calculation of electric scooters

For the emissions calculation of electric scooters, a database was created which took into account more than 40 models existing in the market. Several indicators were integrated into the database: weight (excluding battery), battery storage capacity, construction materials, emissions for phases of construction, packaging and delivery, emissions per km travelled. The data from each model was then coupled with a LCA carbon emission calculation developed by the International Transportation Forum (ITF) [14].

The final emissions calculation was based on an extrapolation by linking the database, informing the characteristics of all the models of PLEVs available on the market, with the calculation formulas inspired by the ITF adapted to the disparity of the models. This made it possible to evaluate the environmental impact of each participant in the experiment according to the model of electric scooter they reported using.

Throughout the programme, and as more information is available on the lifespan of electric scooters, it will be possible to adjust the assumptions made and adapt them based on the robustness of the models. Moreover, the calculation of the weight of the batteries according to their storage capacity is based on a conversion value adapted to the batteries of electric cars. This calculation could be improved by a specific study of the batteries of electric scooters.

D. Integration of all data and calculations in a data architecture

Given the complexity of combining the quantitative and qualitative data to evaluate the impacts of modal shift, a data architecture was developed which aims to link all used variables and sources: Survey results that allowed to define user profiles (mobility practices before/after the purchase of a scooter, technical characteristics of the modes of transport used (cars, motorised two-wheelers and electric scooters), GPS tracking data (positions, distances travelled and speeds reached), Environmental impact calculation formulas to translate the data collected into indicators covering energy consumption and emissions of atmospheric pollutants (e.g., CO₂, NO_x and PM₁₀).

The main innovation of this data architecture lays in the precise monitoring of the environmental impacts generated by modal shifts towards micro-mobility, in real time and over a period of 2 years for a potential panel of 550 participants. Thus, in a precise way, on a large scale

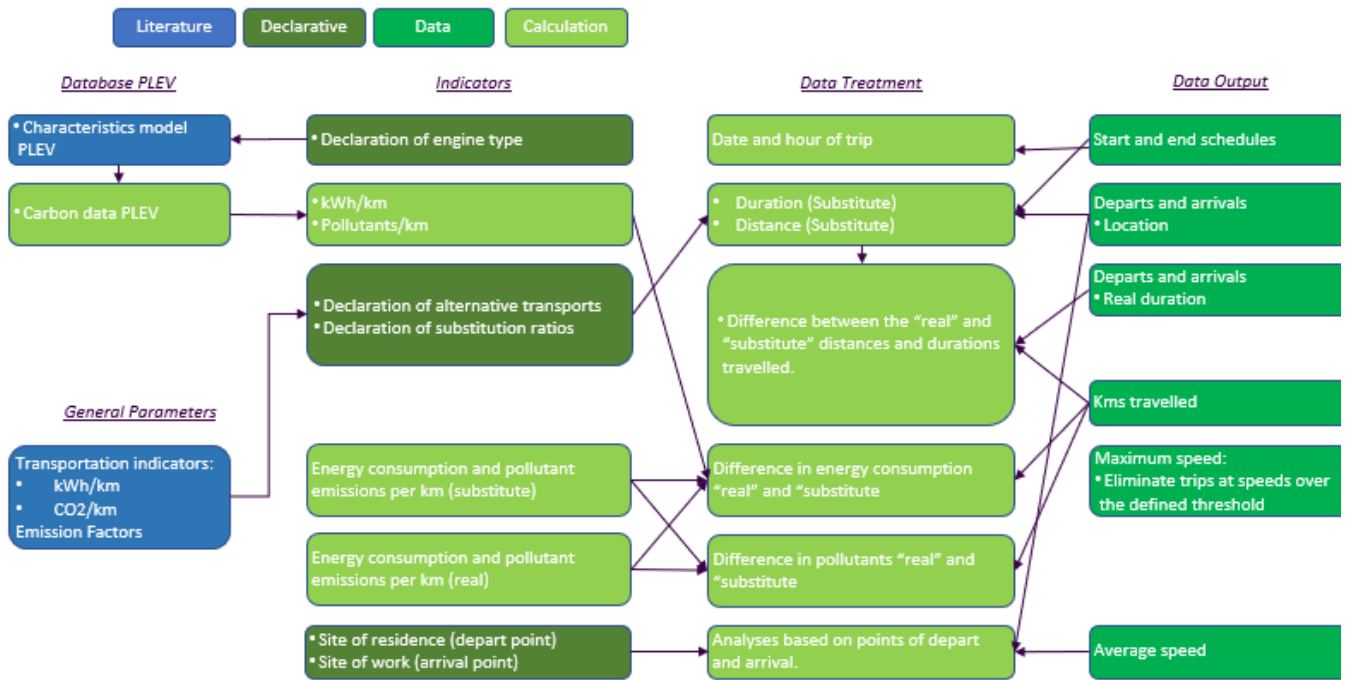


Fig. 2. Structure of data collection (based on literature, declared or calculated) and data treatment to estimate output parameters.

and over a long period of time, it would be possible to analyse changes in mobility practices, quantify the electric scooter's impact on energy consumption and atmospheric pollutant emissions, compared the trips, schedules and distances travelled, and understand the types of trips made by micro-mobility.

However, this data architecture still needs to be improved in the two main areas: 1) the treatment of trips involving the use of multi-modality. That is, the movement of the electric scooter within another means of transport, e.g., when user travels a portion of the trip in electric scooter and other portions in bus, metro or another means of transportation, and 2) precise the correct mode of the transportation replaced for each trip made on an electric scooter. Figure 2, shows the schematic architecture that allows to trace all input, output and hypothesis made.

IV. IMPLEMENTATION

The program aims to reach around 550 users by the end of December 2021. To achieve this, a partner agency specialised in survey recruiting, identified 600 people by March 2021. They were selected based on the following criteria:

- Are owners of a scooter (or gyroboat) of which they are the main users.
- Have answered a survey to qualify their motivation to participate, and qualify their relevance for the study.
- Have agreed and signed a contract to participate in the programme.
- Need to be insured either by a Mobiprox partner insurance or another (sign a liability waiver).
- Agree to be equipped with a GPS tracer and helmet.

Given the recruiting and administrative work is lengthy, as of July 2021, there were 193 recruited users. The

programme is due to last for two years, thus enabling to gather data on a complete panel (+500 users) for at least a year (2022). By July the users had communicated data (survey and trips) and over 31000 km travelled. Table IV shows the main indicators during the phase of implementation. This information was gathered and treated by the programme partners, and had the responsibility to comply with RGPD rules on data security and anonymise them for aggregate use.

During this phase of the programme ten partners collaborated in various tasks to carry out the project : an expert on emission and energy consumption and savings calculations, a service to identify of incidents and accidents, a company in charge of monthly qualitative survey of users, the electric scooter provide (company analysis side), the company providing the GPS tracking devices for electric scooters, a company in charge of monthly quantitative survey of users, the entity responsible for information on electric scooter maintenance, survey qualitative post awareness training, the data integration developer and analyst, and the programme coordinator.

TABLE IV
GENERAL INDICATORS AS OF JULY 2021
DURING THE IMPLEMENTATION PHASE

- | |
|--|
| • 193 user entities (individual and/or companies) that have provided data for the study. |
| • 8489 home-work trips realised and communicated |
| • 12 regions in France where data was collected |
| • 31 000 km travelled by electric scooter |

V. RESULTS

The results only take into account mono-modal transportation carried between the months of March and July 2021. After the start of the experimentation in March, the increase in distance travelled corresponds to an

increase of participants using electric scooters reaching 193 total users as of July. From this usage, the average distanced travelled per month per user was 58,6 km.

The environmental impact was analysed by comparing several declarative and calculated indicators, see Figure 2 (i.e. distance travelled by mode, equivalent energy consumption in kWh, and CO₂, PM10 and NO_x emissions) between the PLEVs and other modes of transport. During the evaluation period (March-July) there were 31000 kilometres travelled (Table V). About a third of all e-scooters trips (10 004 km) was originally made by car (Table VI). Less than half of all trips (15 881 km), before using electric scooter, were originally made by public transportation (underground, bus, trains, tramway).

From these results it is observed a positive environmental impact on all indicators, i.e., energy saving and avoided emissions, which although expected reinforce the efforts to promote alternative transportation modes.

TABLE V
RESULTS ON ENERGY REDUCTION AND
AVOIDED EMISSIONS BY ELECTRIC SCOOTERS

Month	Distance (km)	Saved energy (kWh)	avoided CO ₂ (kgCO ₂)	Avoided PM10 (mgPM10)	Avoided NO _x (mgNO _x)
March	2957	632	75	46902	444554
April	6119	1371	261	96875	932713
May	4474	1077	238	69061	761603
June	6879	1626	303	86997	721453
July	10576	2788	642	146577	1392734

The comparison was made between an electric scooter and the calculation of the respective substitute transport as assumed based on questionnaires.

TABLE VI
RESULTS ON TRIPS DISPLACED BY ELECTRIC SCOOTERS

Travel mode used before electric scooter	Displaced distance (km)
Car	10004
Bus	4107
Other public transportation (Underground, train, tramway)	11775
Walk	4044
Bike, scooter, rollerblades	3464
Motorbike	942
Electric bike	106

As means for comparison, and with the intention of raising awareness among the general public, the results were transformed into equivalent kilometres travelled by a gasoline car (Table VII). These results aim to highlight users on the potential health benefits in terms of reduction of PM10 and NO_x concentrations due to a micro-mobility shift for home-work trips. It is observed, the PM10 concentration reduction during the experimentation period is equivalent to 16534 km travelled with a gasoline car (approximately 1,1 years of one average car travel avoided). For NO_x, this impact is even greater, where the

NO_x reduction during the experimentation period is equivalent to 8085 km travelled for a diesel car and 103733 km for a gasoline car (almost 0,55 years and 6,9 years respectively of one average car travel avoided).

VI. CONCLUSION

These initial results show that a mobility shift to electric scooters has a significant impact on energy and emission emitted, which could potentially be projected to reduce negative impact on health in cities (e.g., increased risk of heart attack, coughing, and breathing problems, and irritation of the eyes, nose, and throat), and positively impact other social aspects (e.g., well-being).

TABLE VII
INFORMATION USED TO RAISE AWARENESS OF GENERAL PUBLIC (AS
AVOIDED DISTANCE TRAVELLED)

Indicator	Equivalent distance travelled
Energy	Energy saving are equivalent to an additional of 37465 to 53520 km travelled with an electric vehicle
CO ₂	CO ₂ avoided is equivalent to 7671 km of gasoline car avoided
PM10	PM10 avoided is equivalent to 16534 km of gasoline car avoided
NO _x	NO _x avoided is equivalent to 8085 km of diesel car (Crit'Air 2) and 103 733 km of gasoline car (Crit'Air 1) avoided

These are estimates based on average emission for personal vehicles, thus the values could differ depending on the emissions reference: the range of electric vehicles considered present a storage capacity from 50kWh to 80kWh with autonomies from 300km to 390km; gasoline car's emissions of CO₂ correspond to the national average emission as calculated by ADEME for the year 2018; average emissions were considered as 27,4 mgPM/km as calculated by the association AIRPARIF through the COPERT 4v11.3 methodology.

From the results, further analysis can be performed by user total trips and vehicle type to evaluate the distance avoided distance user/vehicle, and if there are limitations to PLEV usage (e.g. large distances, terrain conditions, etc). Similarly, table VII can be further detail to compare all commonly displaced modes across.

For the multi-modal trips, calculation refinement are to be carried out, specially to properly differentiate the portions of trips of multiple modes of transport (i.e., bus, metro, car, etc). Another evaluation to carry out is the long-term comparison between lifespan of the electric scooter and the equivalents proposed by the ADEME [15] and ITF. The programme will come to an end in December 2022, thus further results of the programme will be made available on its site: <https://mobiprox.fr>.

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