Tackling car emissions in urban areas: Shift, Avoid, Improve
(Ecological Economics)

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Motivation

- **Negative externalities from cars:**
  - Climate change
  - Air pollution
  - Congestion, Sedentarity, Noise, Accidents...
- **Corrective policies more justified in urban areas:**
  - Higher impact of polluting emissions
  - More alternatives (public transportation)
- **Yet these policies are controversial** (Low-emission-zones, carbon taxes...)
  - Who would they impact most?
  - What low-emission alternatives to cars?

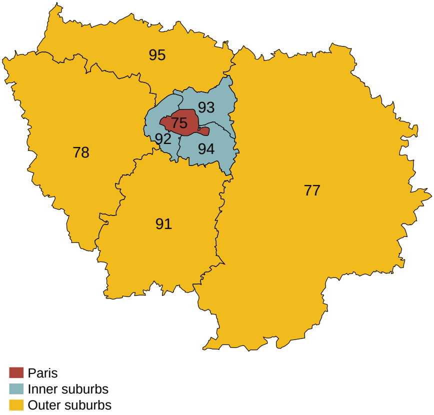
This paper

- Investigate **alternatives to car use** in the **Paris area** using the **Avoid-Shift-Improve framework** (Creutzig et al., 2018, 2022; IPCC, 2022)
- **Three levers** to decrease emissions:
  - Avoid the need to travel: focus on teleworking
  - **Shift from car to low-emission mode**
  - Improve car environmental performance: switch to electric vehicles (EV)
- Using the **latest available representative survey** on daily mobility
  - EGT 2010: 46,000 car trips made by 13,000 adult individuals within Paris area
- **Our results in a nutshell:**
  - 15% of emissions could be avoided via a shift to e-bikes & public transit
  - 5% via an increase in teleworking
  - EV transition needed for more emission reduction

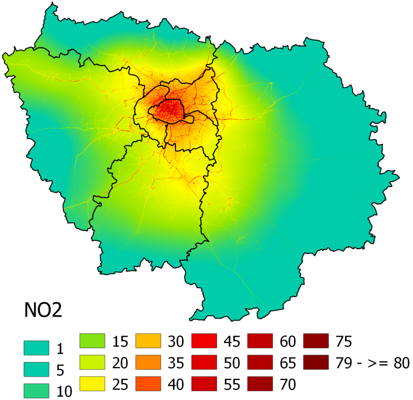
Related literature

1. **Potential for emission reductions from transport:**
   - top-down integrated assessment models
   - structural models: [Durrmeyer and Martinez, 2022]
   - bottom-up modal shift scenarios: [Mason et al., 2015, Bucher et al., 2019, McQueen et al., 2020, Philips et al., 2022, de Nazelle et al., 2010]
   - **This paper:** scenario to include under-developed mode using precise counterfactual time data, both carbon and air pollution externality
2. **Inequalities in the incidence of environmental policy costs:**
   - heterogeneity of carbon tax burden within income category: [Sallee, 2019, Douenne, 2020, Berry, 2019]
   - impact of public transport availability on elasticity of demand for car use [Gillingham and Munk-Nielsen, 2019]
   - **This paper:** heterogeneity in ability to shift away from car at very local level; characteristics associated with car-dependency
3. **Potential for teleworking and its environmental impact:**
   - jobs that can be done from home: [Dingel and Neiman, 2020]
   - impact of teleworking on emissions: [Bachelet et al., 2021, Crowley et al., 2021, Hook et al., 2020]
   - **This paper:** only transport, local air pollution externality also included

Background



(a) The Paris area



(b) concentrations NO_2, 2010

- Road traffic: 56% of NOx emissions, 33% of PM2.5, 32% of CO_2 emissions

Main data source: EGT 2010

- **35,175 individuals** from 14,885 households, reporting all trips made during last day
- **Our subsample:**
  - Adults having made at least one trip on a representative weekday **(N=23,690)**
  - Only short-distance trips made within the IDF region → only daily mobility: 101,950 trips
  - One trip may involve several transport modes
- **Scenario subsample:**
  - 12,595 individuals who used a car
  - 45,897 car trips
- **vs EGT 2020**: only 4,800 households; Modal shares did not change much (cars 38% → 34%)

Other data sources

- **Counterfactual travel time:**
  - Google Maps Direction API
  - for every non-walking trip defined as a departure location, arrival location and hour of departure, how long would it take by car, bike and public transport?
  - e-bikes: multiply cycling time by 15/19
- **EV charging stations:**
  - Aim: identify households with charging station $\leq$ 500 meters of their home
  - Sources: OpenStreetmap, National and municipal open data service
- **Emission factors:**
  - NOx, $PM_{2.5}$ and CO_2, Including cold starts for NOx and $PM_{2.5}$
  - Calculated at the journey stage level
  - Vehicle-specific emission factor for cars owned by households

Emission intensities of trips

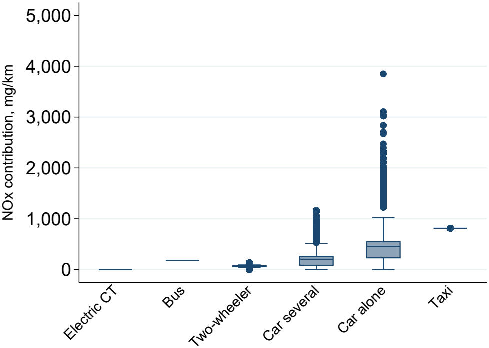
Emission factors by mode

	Unit	NOx (mg)	$PM_{2.5}$ (mg)	CO_2 (g)
Type of emission value		Real-world	Real-world	Type-approval
Walking	per passenger-km	0	0	0
Cycling	per passenger-km	0	0	0
Street-car	per passenger-km	0	7	3
Metro	per passenger-km	0	7	4
Train	per passenger-km	0	7	6
Bus	per passenger-km	181	4	104
Taxi	per passenger-km	813	66	266
Car*	per vehicle-km	406	33	133
Two-wheeler*	per vehicle-km	59	11	52

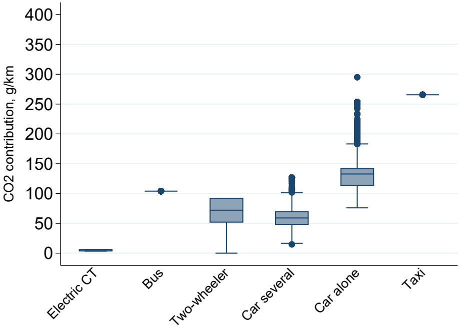
Note: *not owned by households.

Emission intensities of trips

(a) NOx

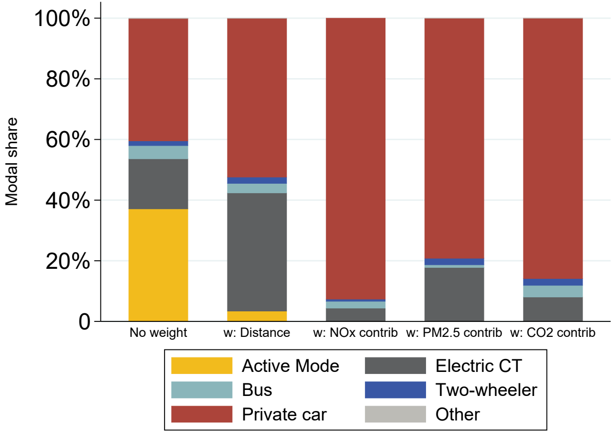


(b) CO_2



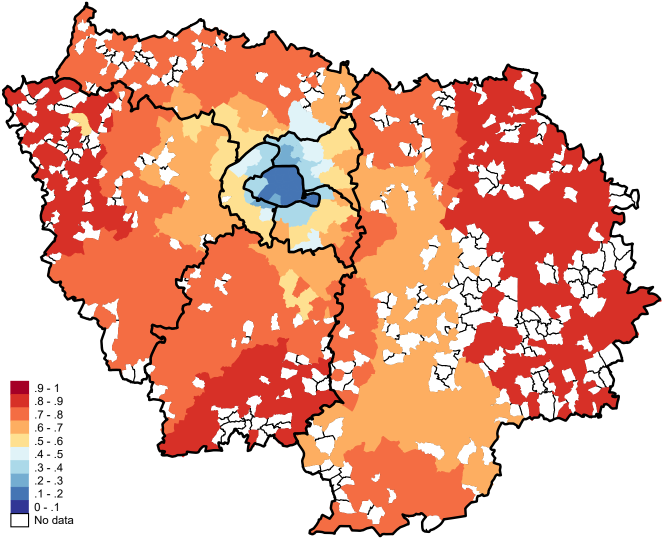
Modal shares in the status-quo

Modal shares in the number of trips, distances travelled and emissions



→ Private car represents **80-95% of polluting emissions**

Car drivers



Share of car users by sampling zone (weighted average using individual sample weights)

The environmental cost of daily mobility

- Unit emissions from 2010 **scaled down to 2020**
- Social cost of CO_2 (Quinet: €84.5/t.), NOx and $PM_{2.5}$ (EU Commission, 2020)
- Reflects **daily mobility** on **working days** only
- **Annual cost close to €1 billion**, 1/3 climate-related, 2/3 health-related

Environmental cost of daily (weekday) mobility in the status-quo situation

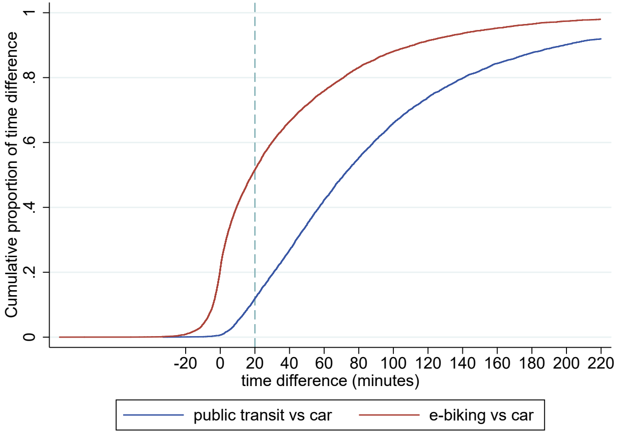
Cost category	Pollutant	Daily emissions (kg)	Unit cost (€/kg)	Daily Cost (million €)	Annual Cost (million €)
Climate-related	CO_2	17,109,104	0.0845	1.45	318
Health-related	NOx	51,604	28.03	1.45	318
Health-related	$PM_{2.5}$	3,692	419.38	1.55	341
Total				**4.44**	**977**

Modal shift scenarios

- **Aim:** identify car trips that could be substituted with e-bike or public transit, under constraints on:
  - the travel time difference between car and the substitute mode,
  - the type of trip,
  - only for e-biking: the individual's age
- **Analysis at the "trip-chain" level:** set of trips between leaving home and coming back
- **Three scenarios**, with increasingly strict constraints

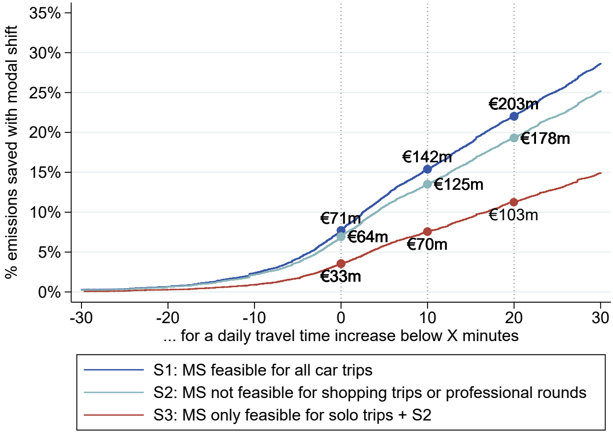
	Scenario 1	Scenario 2	Scenario 3
Trip chains for which modal shift is possible	All	All but those including work-related driving rounds & car trips for grocery shopping	All but those including work-related driving rounds & car trips for grocery shopping & trips with >1 passengers
Age constraint for e-biking	≤ 70	≤ 70	≤ 70

Modal shift scenarios - time difference between car and e-bike/public transport



Cumulative distribution function of the difference in travel time between car, e-biking and public transit at the trip chain level

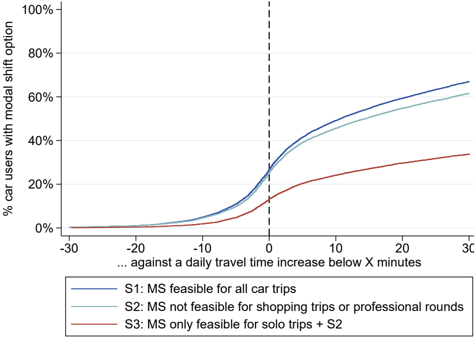
Modal shift scenarios - results



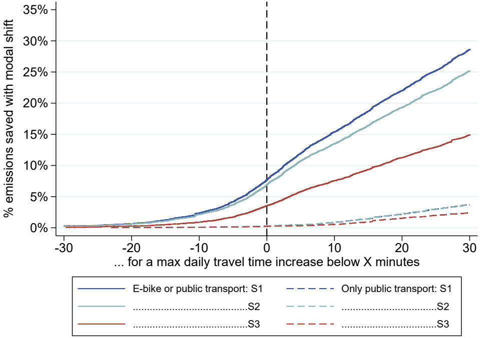
Share of emissions saved and associated monetary benefits

→ **S2: ≈14% of emissions** could be saved with an increase in daily travel time below 10 minutes

Modal shift scenarios - results



(a) Share of car users that can shift by max. daily travel time increase



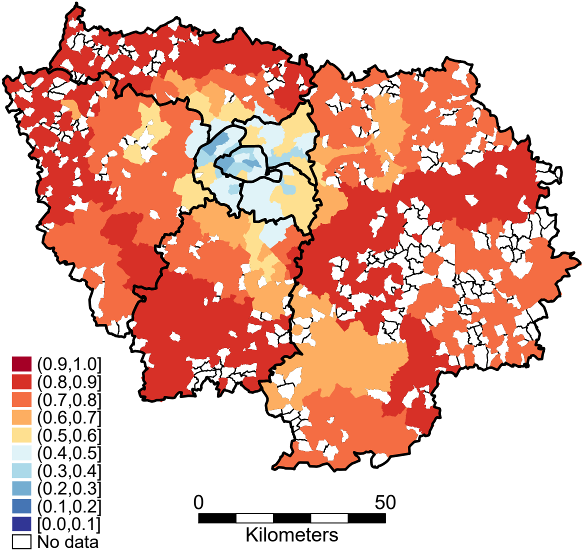
(b) Emissions saving potential of e-bike

- **25%** car users could shift with a **reduction in daily travel time**
- **46%** could shift with an **increase in daily travel time $<$ 10 min.**
- Most of the shift comes from **e-bikes**

Who is "car-dependent"?

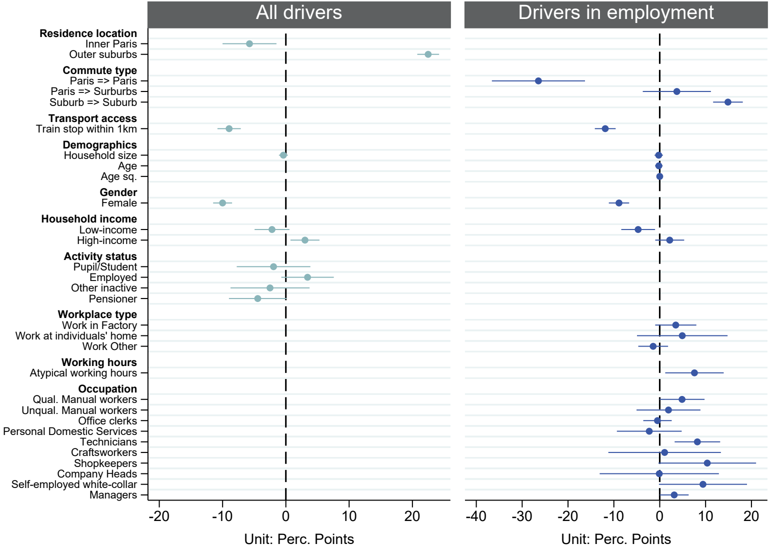
- **2 groups:**
  - The shifters: able to shift away from cars for every chain trip
  - The car-dependent: the rest
- **Car-dependent:**
  - 60% in scenario 2 (among car users)
  - Median daily distance travelled: $\approx$ 35 km vs. 10 km for the shifters
  - Characteristics associated with being car-dependent? Multi-variate logit model

Who is "car-dependent"?



Share of drivers deemed unable to shift away from car, averaged by sampling zone

Who is "car-dependent"?



Characteristics associated with being unable to shift away from car use

Avoid travel by teleworking

- **Assumptions:** Teleworking not possible for the following workers:
  - manual workers, farmers or traders, craftspeople, CEOs
  - those working in a factory, in other people's homes, in a hospital or school, in a public institution, or in a shop
- **Results:**
  - 12% of the car-dependent individuals could reduce emissions
  - If they all worked from home **two days a week**, **5.5% of emissions could be avoided**

Improve: adopt an electric vehicle

- **Charging stations:**
  - 76% of the car-dependent individuals have a private parking space at their place of residence
  - Among the others, 23% had access to a public charging station within 500 metres of their place of residence in 2020
- **Autonomy:**
  - $\leq$ 0.5% of the car-dependent individuals drive more than 200 kilometres per day
  - only 0.8% of trips are partly outside Ile-de-France
- $\rightarrow$ **Large potential**, but well-documented financial and psychological barriers, $+$ non-exhaust emissions of $PM_{2.5}$ are not negligible (OECD, 2020)

Conclusion

- **Main results:**
  - Among the Avoid and Shift options, shifting from cars to e-bikes has the highest potential: in our preferred scenario,
    - 6% drop in emissions spread across 25% of car users, with a decrease in daily travel time
    - 14% drop in emissions spread across 46% of car users, with max. +10 minutes/day.
  - Much less potential for public transportation & teleworking
  - $\approx$ 85% of emissions would remain, need for "improve" options
  - Focus on the car-dependent: atypical hours, shopkeepers, suburb-suburb commuters...

- **Main limitations:**
  - Public transportation network as in 2020: *Grand Paris* lines not included
  - No rebound effect
  - Residential locations and trip patterns considered fixed
  - No combination bicycle – public transport

Thanks! Comments welcome (marion.leroutier@ifs.org.uk)

- **Paper in open access:**
  https://www.sciencedirect.com/science/article/pii/S0921800923002148
- **Twitter thread in French:**
  https://twitter.com/pquirion1/status/1702560165344555459
- **Previous paper on who contributes to polluting emissions, using same data:**
  https://www.sciencedirect.com/science/article/pii/S0140988322001189

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