What drives inequalities in Low Emission Zones' impacts on job accessibility?

Charlotte Liotta

ICTA-UAB (Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona)

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Low Emission Zones

Source: franceurbaine.org

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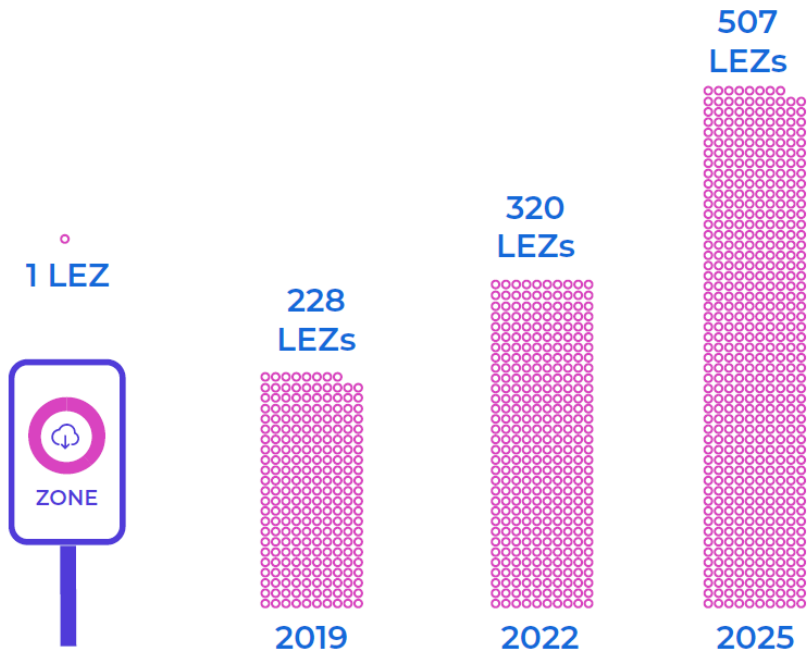

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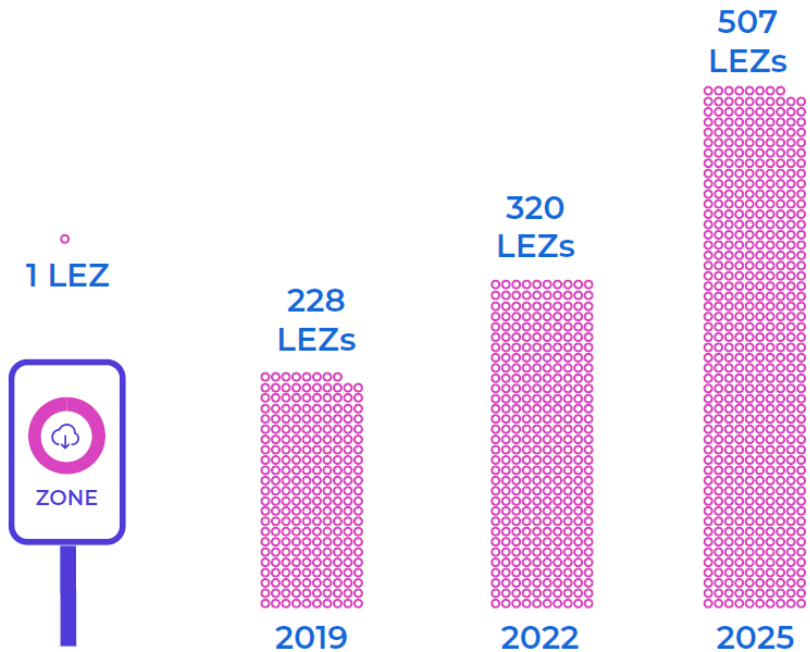

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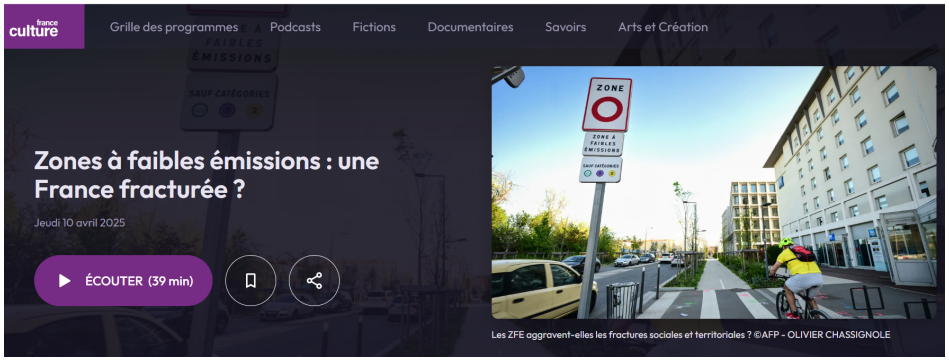

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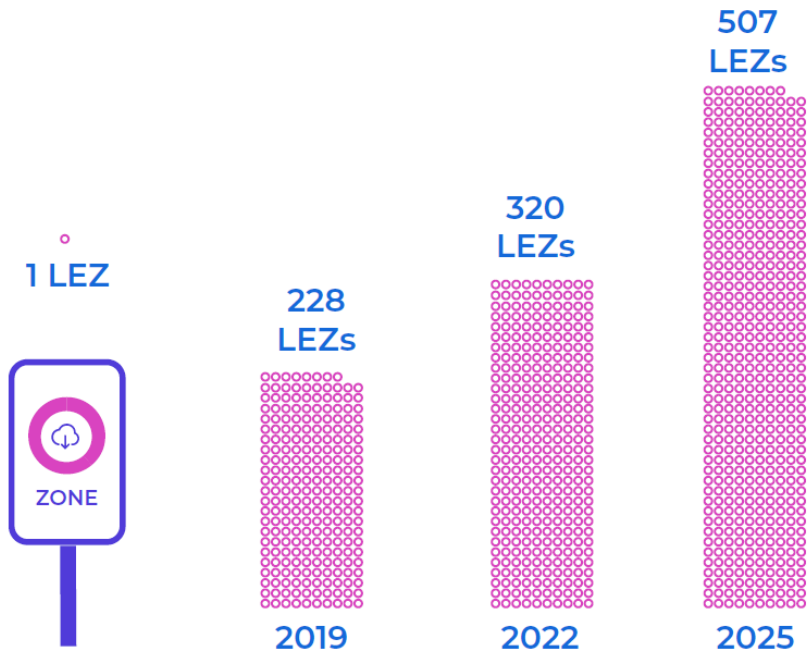

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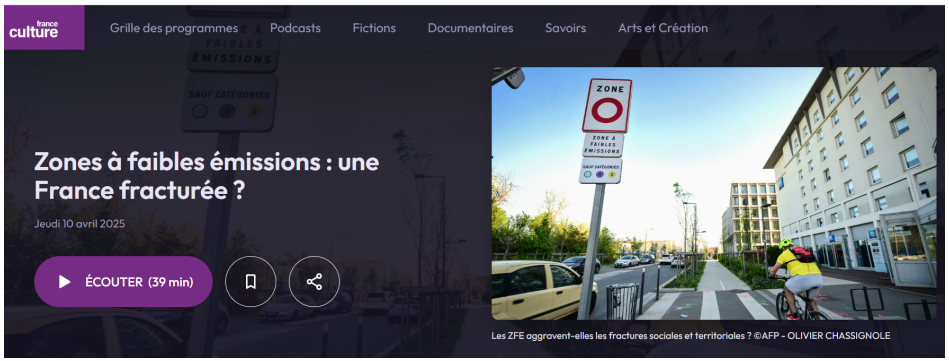

[FILM] ZFE : la bombe à retardement sociale - La contre-enquête de "40 millions d'automobilistes" à voir absolument !

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LEZs and inequalities

- Public and scientific debates around LEZs focus on inequality impacts:
  - **Environmental justice** impacts (Poulhès and Proulhac, 2021; Host et al., 2020; Moreno et al., 2022).

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  - **Transport justice** impacts:
    - Qualitative assessments: impact on shopping (Tarriño-Ortiz et al., 2022) or social relationships (De Vrij and Vanoutrive, 2022).
    - Geospatial analysis: identification of vulnerable households (Blandin et al., 2025).
    - Factors shaping unequal impacts (Charleux, 2014): vehicle ownership, job accessibility, and opportunities for modal shift.

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    - Geospatial analysis: identification of vulnerable households (Blandin et al., 2025).
    - Factors shaping unequal impacts (Charleux, 2014): vehicle ownership, job accessibility, and opportunities for modal shift.
- Research gap:
  - **Few quantitative studies** on LEZ justice impacts.
  - Focus on vehicle ownership; **limited systemic perspective**.

This study

- Quantitative assessment of LEZ impacts on transport justice in 8 French cities.
  - Outcome of interest: **job accessibility** (spatial accessibility indicators).
  - Computed using **ex-ante data**.
  - Estimates effects by **occupational category**.

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  - Outcome of interest: **job accessibility** (spatial accessibility indicators).
  - Computed using **ex-ante data**.
  - Estimates effects by **occupational category**.
- Analyses underlying factors explaining transport injustice:
  - **Counterfactual decomposition of differences across occupational categories**, considering the distribution of workers, jobs, and the transport system.

Outline

Context

2015
First french LEZ in Paris

↓

2019
Loi d'Orientation des Mobilités
Creates the legal framework around LEZs

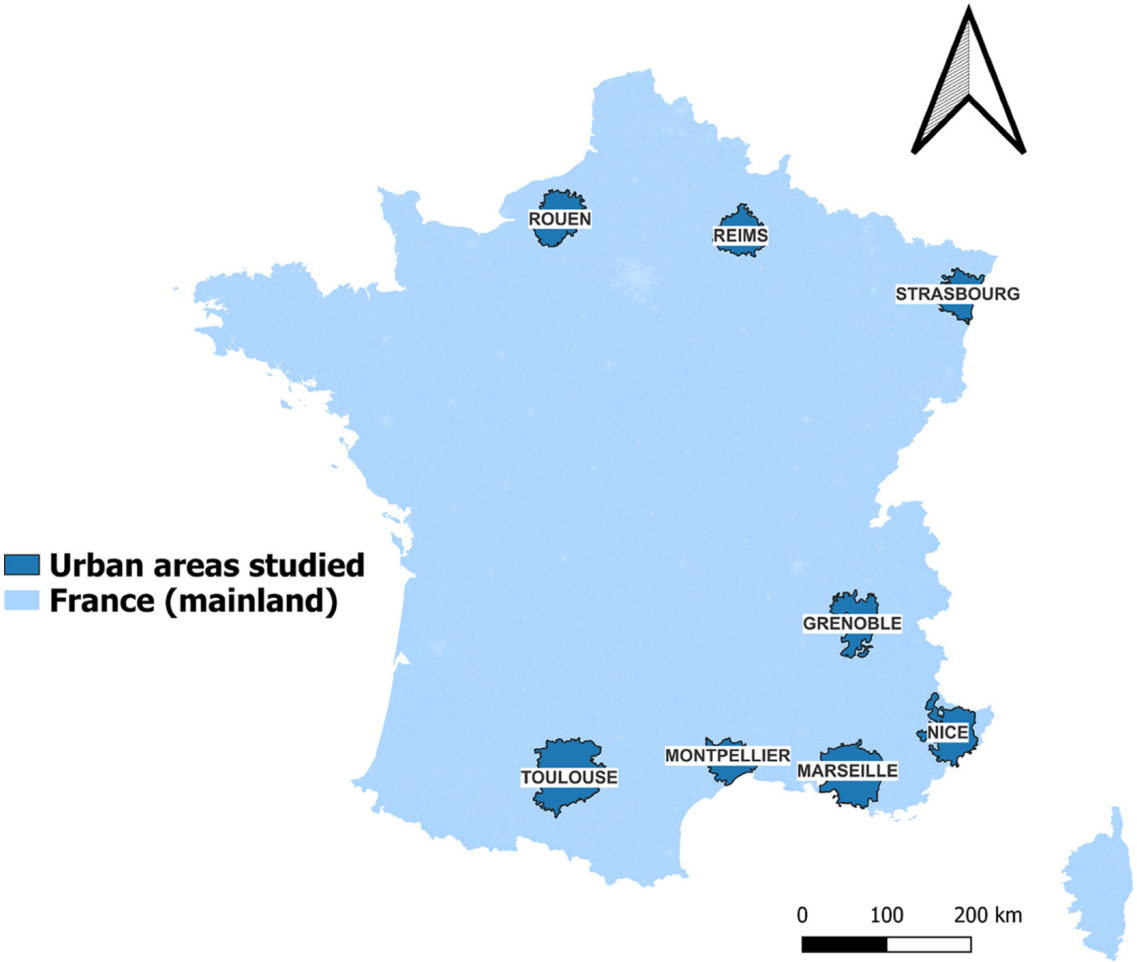
↓

2021
Loi Climat et Résilience
Makes LEZs mandatory for cities
$>$ 150,000 inhabitants with poor air quality
Minimal perimeter and implementation calendar

↓

2025
Debate around the cancellation of LEZs

City sample



- 8 mid-size French cities covering 8.5 million inhabitants.
- In the process of implementing a LEZ.
- Paris excluded due to much more advanced LEZ implementation.

LEZ implementation

	Population	Median income	LEZ area	Crit'air 3 vehicle ban
Marseille	2,189,779	22,050€	19.5km^2	Sept. 2024*
Toulouse	1,425,256	23,660€	71km^2	Jan. 2024*
Nice	1,091,877	22,050€	2.7km^2	*
Strasbourg	945,215	22,990€	340km^2	Jan. 2025
Rouen	865,281	21,780€	86km^2	Jan. 2025*
Montpellier	814,267	21,600€	198km^2	Jan. 2025
Grenoble	753,307	23,950€	270km^2	Jan. 2025
Reims	406,238	21,910€	3.4km^2	Jan. 2029

** indicates that the measure has been suspended because the air quality is good enough.*

Outline

Job accessibility

Job accessibility of a worker of occupational category g living in location i is computed as:

$$A_i^g = \sum_j d_j^g \max_{m \in \{P,A,C\}} f(t_{ij}^m) \tag{1}$$

with d_j^g the share of jobs of category g in location j and t_{ij}^m the transportation time between i and j using transportation mode $m \in \{P, A, C\}$ corresponding to public transport, active transportation modes, and private cars respectively.

f is the transport time decay function, assumed as being an exponential function such that $f(t_{ij}^m) = e^{-\beta t_{ij}^m}$.

Average accessibility per occupational category

Denoting n_i^g the share of workers of category g living in i:

$$A_g = \sum_i \sum_j n_i^g d_j^g \max_{m \in \{P,A,C\}} f(t_{ij}^m) \tag{2}$$

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Accessibility losses due to LEZs

Denoting s_i^g the share of polluting vehicles among workers of category g living in i:

$$A_g^{LEZ} - A_g = \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum n_i^g d_j^g s_i^g [\max_{m \in \{P,A\}} f(t_{ij}^m) - \max_{m \in \{P,A,C\}} f(t_{ij}^m)] \tag{3}$$

Job accessibility losses decomposition

Difference of job accessibility losses due to the LEZ between occupational categories g and g':

$$(A_g^{LEZ} - A_g) - (A_{g'}^{LEZ} - A_{g'}) = POLL_{g,g'} + AM_{g,g'} + PT_{g,g'}^{POP} + LEZ_{g,g'}^{POP} + PT_{g,g'}^{JOB} + LEZ_{g,g'}^{JOB}$$

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- $POLL_{g,g'}$: impact of the diff. in **polluting vehicles** ownership.

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- $AM_{g,g'}$: impact of the diff. in the possibility of **active transport** modes.

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- $LEZ_{g,g'}^{POP}$: impact of the diff. in **shares of workers living in the LEZ**.

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- $LEZ_{g,g'}^{POP}$: impact of the diff. in **shares of workers living in the LEZ**.
- $PT_{g,g'}^{JOB}$: impact of the diff. in **public transport availability near jobs**.
- $LEZ_{g,g'}^{JOB}$: impact of the diff. between the **shares of jobs in the LEZ**.

▸ See details

Outline

Urban boundaries and socioeconomic data

- **Urban boundaries**: OECD Functional Urban areas.
- **Socioeconomic data**:
  - Workers' spatial distributions: 2017 census (IRIS level).
  - Jobs' spatial distributions : 2018 'Emploi - Population Active' INSEE survey (zip code level).

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Category	Avg. income	Share of workers
CSP1 – Farmers	29,310€	1.6%
CSP2 – Executive directors		6.8%
CSP3 – Managers	39,860€	21.7%
CSP4 – Intermediate occuptions	27,000€	24.6%
CSP5 – Sales, services workers	21,480€	26.0%
CSP6 – Blue-collar workers	20,310€	18.9%

Table: Occupational categories

Polluting vehicles ownership

- Vehicles of categories **NC, Crit'Air 5, Crit'Air 4, and Crit'Air 3 considered as polluting** vehicles.
- **Share of polluting vehicles per location and occupational category** estimated using two sources:
  - Data on the share of polluting vehicles per zip code in 2022, but without any information on the distribution per occupational category.
  - 'Mobilité des personnes' 2019 data on the share of polluting vehicles per occupational category, but at the NUTS2 level only.
  - Identification of the potential distributions of polluting vehicles by minimizing the difference with these two databases.

▸ See details

Transport times

- **Private cars**: *osmnx* package.
- **Walking**: geographic distance between cells, assuming a 4km/h speed.
- **Public transport**: GTFS data provided by local transport companies. Transport times computed using the *r5py* package.

City	GTFS
Reims	CITURA, Fluo Grand Est
Strasbourg	CTS
Nice	Lignes d'Azur
Marseille	RTM
Montpellier	TAM, Transp'Or
Toulouse	Tisséo
Rouen	Astuce
Grenoble	TAG, TPV, TouGo

Table: Public transport data sources

Outline

Accessibility losses from the LEZ

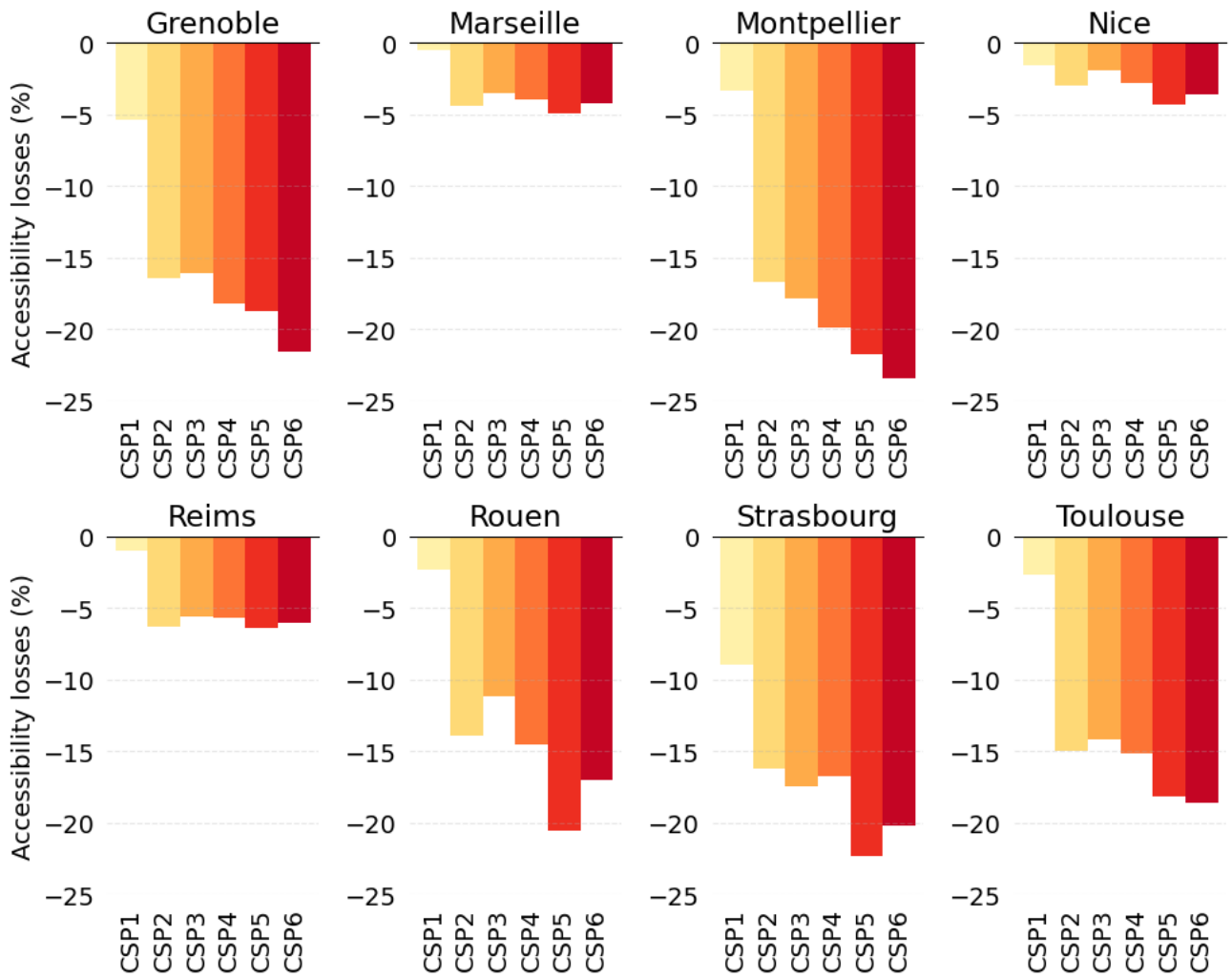


Figure: Accessibility losses from the LEZ, by city and occupational group.

Descriptive statistics - Mean over the 8 cities

	Polluting vehicles ownership	Share of workers living in the LEZ	Share of jobs in the LEZ
CSP1	37.3%	2.6%	3.9%
CSP2	31.1%	14.2%	27.8%
CSP3	25.0%	24.3%	45.9%
CSP4	28.7%	19.2%	39.1%
CSP5	35.2%	18.4%	34.8%
CSP6	37.4%	15.6%	29.4%

In total, over the 8 functional urban areas:

- **570,000 workers** living in the LEZs.
- **1,4M jobs** in the LEZs.
- **970,000 workers** owning polluting vehicles. ▸ See details

Counterfactual decomposition

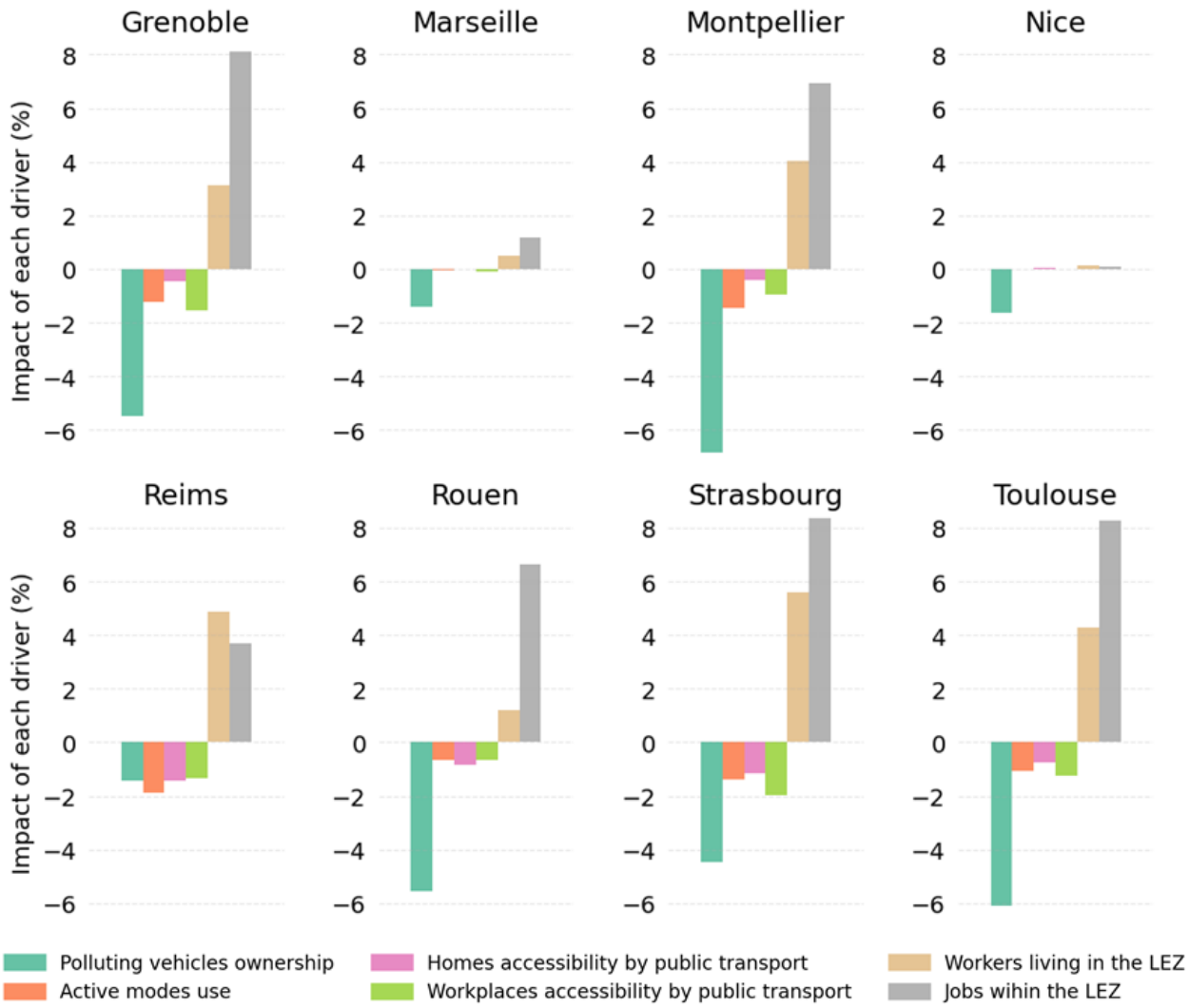
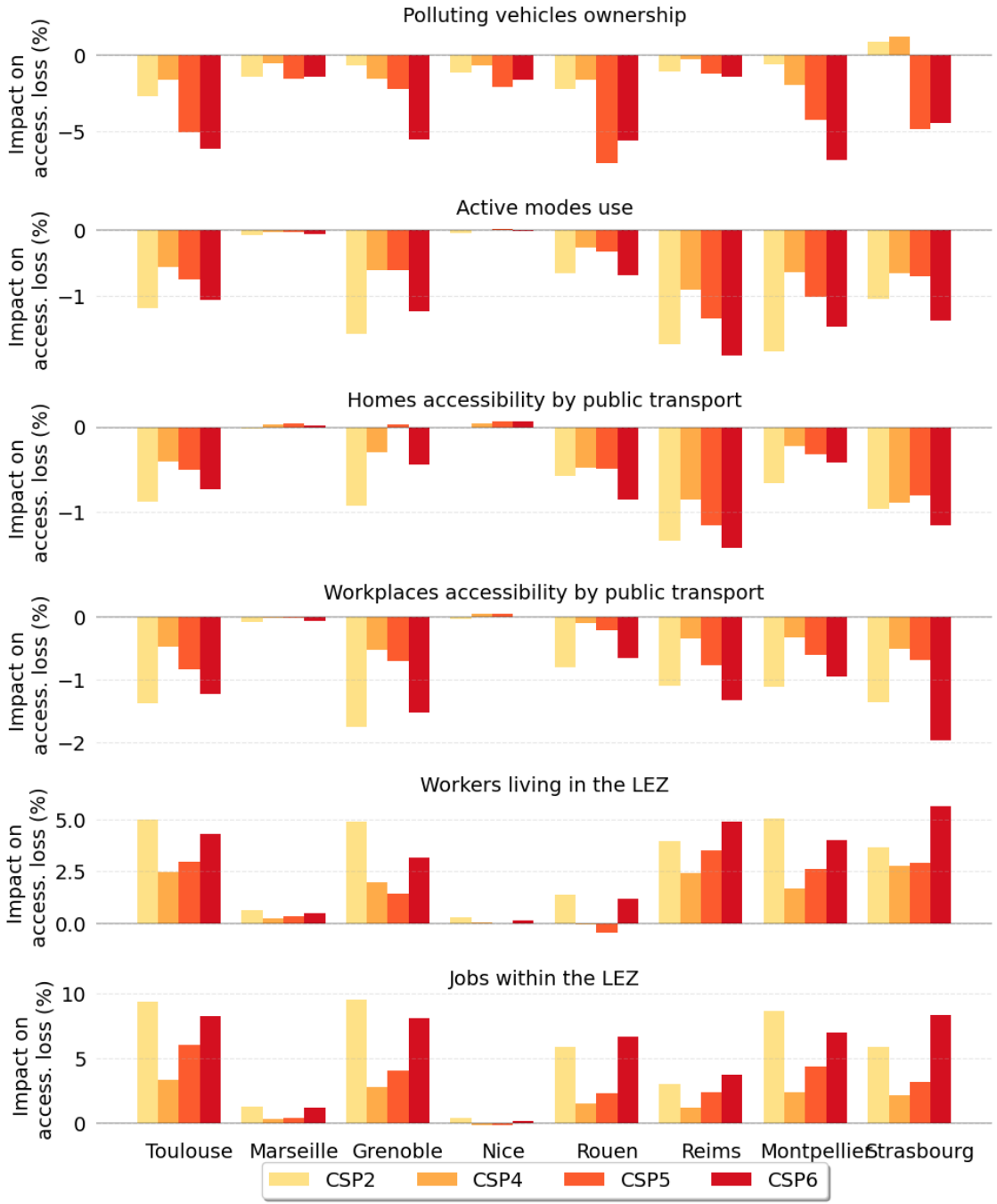


Figure: Impact of different drivers on the differences in LEZ impacts between CSP3 (high-income) and CSP6 (low-income), in % of CSP6 pre-LEZ accessibility.



Impact of different drivers on the accessibility losses of each occupational group, compared with CSP3 *(in % of the pre-LEZ accessibility of each occupational group)*.

Outline

Discussion

- **Anti-redistributive impacts of the LEZs** in 6 cities out of 8.
  - Except for Reims and Marseille (smaller LEZs perimeter, fewer low-income workers living within the LEZs, small difference in polluting vehicle ownerships between occupational categories).
  - Even when LEZs' impacts are evenly distributed, it remains more difficult for low-income households to adapt by buying a new car.

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  - Even when LEZs' impacts are evenly distributed, it remains more difficult for low-income households to adapt by buying a new car.
- **Key driver: polluting vehicles ownership, but urban forms and policy designs also play a role.**
  - Polluting vehicle ownership, commuting distances, and access to public transport play against unskilled workers.
  - Spatial distribution of jobs plays against skilled workers.

Discussion

- **Public policies can play on these 3 drivers**.
  - Targeted subsidies for new cars.
  - Targeted exemptions.
  - Targeted public transport development, employment subcenters development, social housing and targeted housing subsidies.

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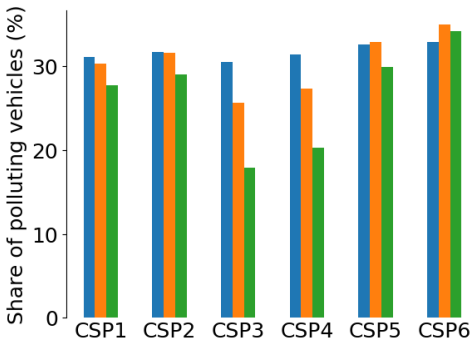
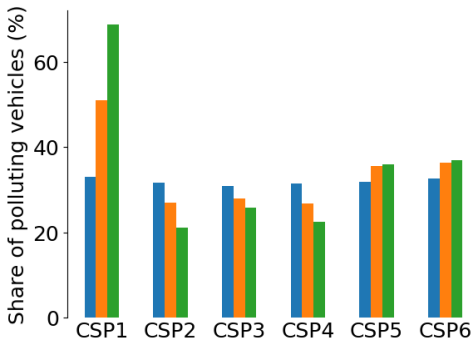
- **Refinements for further research:**
  - More complex accessibility measure (e.g. with competition for jobs).
  - Improve the transport model (e.g. with congestion or active mobility).
  - Dynamic analysis to model longer-term equilibrium effects (gentrification near public transport stations, changes in job distribution,...).

Appendix

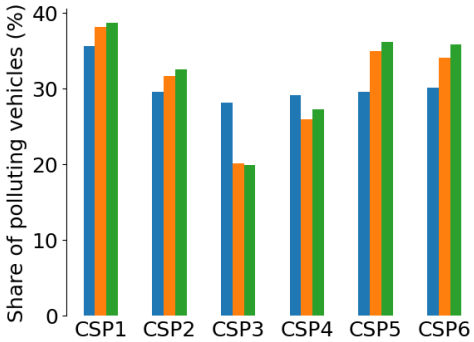
Comparison between the different databases and this study's estimates for the share of polluting vehicles



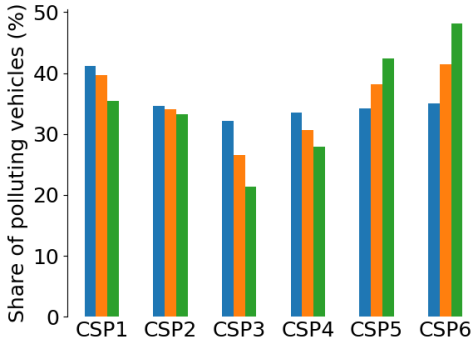
(a) Reims



(b) Strasbourg



(c) Nice



(d) Toulouse

Data at the zip code level | This study's estimate | Data at the NUTS2 level

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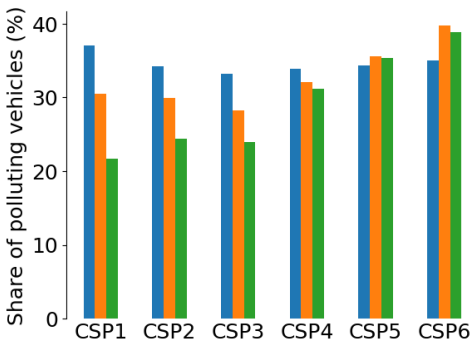
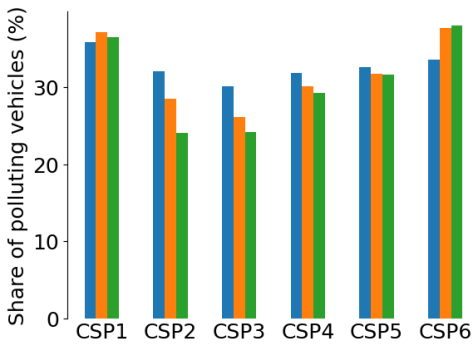
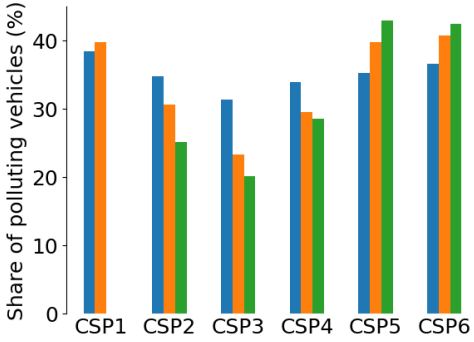


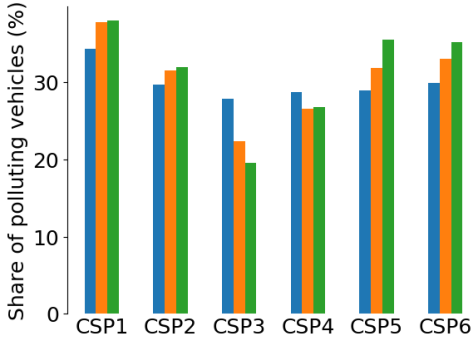
(a) Montpellier



(b) Grenoble



(c) Rouen



(d) Marseille

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Back to main

Job accessibility losses decomposition

$$A_g^{LEZ} - A_g = \sum\sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} n_i^g \, d_j^g \, s_i^{g'} \left[\max_{m \in \{P,A\}} f(t_{ij}^m) - \max_{m \in \{P,A,C\}} f(t_{ij}^m) \right] + POL_{g,g'}$$

with

$$POL_{g,g'} = \sum\sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} n_i^g \, d_j^g \, (s_i^g - s_i^{g'}) \left[\max_{m \in \{P,A\}} f(t_{ij}^m) - \max_{m \in \{P,A,C\}} f(t_{ij}^m) \right]$$

corresponding to the impact of the difference in polluting vehicles' ownership between occupational categories.

Job accessibility losses decomposition

Similarly, further decomposition accounts for the differences in spatial distributions of the workers of g and g':

$$
\begin{aligned}
&\mathrm{A}_g^{LEZ} - A_g = \\
&\sum\sum_{\substack{(i\in LEZ, j)\\(i\notin LEZ, j\in LEZ)}} n_i^{g'} d_j^g s_i^{g'} [\max_{m\in\{P,A\}} f(t_{ij}^m) - \max_{m\in\{P,A,C\}} f(t_{ij}^m)] + \\
&\sum\sum_{\substack{(i\in LEZ, j)\\(i\notin LEZ, j\in LEZ)}} (n_i^g - n_i^{g'}) d_j^g s_i^{g'} [\max_{m\in\{P,A\}} f(t_{ij}^m) - \max_{m\in\{P,A,C\}} f(t_{ij}^m)] \\
&+ \mathrm{POL}_{g,g'}
\end{aligned}
$$

Job accessibility losses decomposition

Further decomposition accounts for the differences in spatial distributions of jobs of categories g and g':

$$
\begin{aligned}
&\mathrm{A}_g^{LEZ} - A_g = (A_{g'}^{LEZ} - A_{g'}) + \\
&\sum\sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} n_i^{g'} (d_j^g - d_j^{g'}) s_i^{g'} \left[\max_{m \in \{P,A\}} f(t_{ij}^m) - \max_{m \in \{P,A,C\}} f(t_{ij}^m) \right] + \\
&\sum\sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} (n_i^g - n_i^{g'}) d_j^g s_i^{g'} \left[\max_{m \in \{P,A\}} f(t_{ij}^m) - \max_{m \in \{P,A,C\}} f(t_{ij}^m) \right] \\
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\end{aligned}
$$

Job accessibility losses decomposition

Then, the change in transport times are decomposed:

$$\max_{m\in\{P,A\}} f(t_{ij}^m) - \max_{m\in\{P,A,C\}} f(t_{ij}^m) = (\max_{m\in\{P,A\}} f(t_{ij}^m) - f(t_{ij}^C))\mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)}$$
$$= (f(t_{ij}^P) - f(t_{ij}^C))\mathbb{1}_{t_{ij}^C \leq t_{ij}^P \leq t_{ij}^A} + (f(t_{ij}^P) - f(t_{ij}^A))\mathbb{1}_{t_{ij}^C \leq t_{ij}^A \leq t_{ij}^P}$$
$$= - f(t_{ij}^C)\mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)} + (f(t_{ij}^P) - f(t_{ij}^A))\mathbb{1}_{t_{ij}^C \leq t_{ij}^P \leq t_{ij}^A} + f(t_{ij}^A)\mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)}$$

Job accessibility losses decomposition

Combined with the previous equation, this leads to:

$$
\begin{aligned}
(A_g^{LEZ} - A_g) =& (A_{g'}^{LEZ} - A_{g'}) \\
&+ PT_{g,g'}^{POP} + LEZ_{g,g'}^{POP} + PT_{g,g'}^{JOB} + LEZ_{g,g'}^{JOB} + POL_{g,g'} \\
&+ \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum (n_i^g - n_i^{g'}) d_j^g s_i^{g'} f(t_{ij}^A) \mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)} \\
&+ \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum (d_i^g - d_i^{g'}) n_i^{g'} s_i^{g'} f(t_{ij}^A) \mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)}
\end{aligned}
$$

Job accessibility losses decomposition

With:

$$PT^{POP}_{g,g'} = \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum (n_i^g - n_i^{g'}) d_j^g s_i^{g'} [f(t_{ij}^P) - f(t_{ij}^A)] \mathbb{1}_{t_{ij}^C \leq t_{ij}^P \leq t_{ij}^A}$$

$$LEZ^{POP}_{g,g'} = - \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum (n_i^g - n_i^{g'}) d_j^g s_i^{g'} f(t_{ij}^C) \mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)}$$

$$PT^{JOB}_{g,g'} = \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum (d_j^g - d_j^{g'}) n_i^{g'} s_i^{g'} [f(t_{ij}^P) - f(t_{ij}^A)] \mathbb{1}_{t_{ij}^C \leq t_{ij}^P \leq t_{ij}^A}$$

$$LEZ^{JOB}_{g,g'} = - \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum (d_j^g - d_j^{g'}) n_i^{g'} s_i^{g'} f(t_{ij}^C) \mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)}$$

Job accessibility losses decomposition

Therefore, by rearranging the last two terms:

$$(A_g^{LEZ} - A_g) - (A_{g'}^{LEZ} - A_{g'}) = POLL_{g,g'} + AM_{g,g'} + PT_{g,g'}^{POP} + LEZ_{g,g'}^{POP} + PT_{g,g'}^{JOB} + LEZ_{g,g'}^{JOB}$$

with:

$$AM_{g,g'} = \sum_{\substack{(i \in LEZ, j) \\ (i \notin LEZ, j \in LEZ)}} \sum n_i^g d_j^g s_i^{g'} f(t_{ij}^A) \mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)} - n_i^{g'} d_i^{g'} s_i^{g'} f(t_{ij}^A) \mathbb{1}_{t_{ij}^C \leq min(t_{ij}^P, t_{ij}^A)}$$

Back to main

Share of workers of each category living in the LEZ

	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6
Marseille	0.06%	2.83%	4.49%	3.38%	3.79%	3.16%
Grenoble	4.97%	27.54%	41.14%	33.21%	35.25%	28.85%
Montpellier	4.97%	26.30%	43.75%	36.54%	33.15%	29.02%
Nice	0.33%	1.88%	2.70%	2.60%	2.90%	2.51%
Rouen	1.80%	19.65%	35.76%	24.71%	22.93%	15.64%
Reims	1.15%	7.76%	17.66%	10.45%	8.25%	5.59%
Strasbourg	8.56%	34.16%	47.03%	36.20%	35.54%	27.18%
Toulouse	1.59%	13.05%	22.54%	17.47%	17.74%	15.31%

Share of each category working in the LEZ

	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6
Marseille	1.46%	12.18%	16.44%	15.40%	14.96%	12.08%
Grenoble	6.92%	48.44%	75.65%	65.76%	62.07%	51.25%
Montpellier	6.30%	44.46%	73.75%	63.48%	56.57%	48.08%
Nice	3.92%	10.17%	11.69%	12.86%	12.84%	11.26%
Rouen	3.77%	36.30%	56.74%	49.60%	46.61%	32.27%
Reims	1.16%	17.98%	26.17%	22.66%	20.35%	16.45%
Strasbourg	9.74%	50.81%	70.56%	62.38%	58.99%	43.43%
Toulouse	3.25%	34.45%	55.67%	45.37%	39.29%	34.90%

Share of workers of each category owning polluting vehicles (Crit'Air 3, 4, 5, NC)

	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6
Marseille	37.8%	31.5%	22.4%	26.5%	31.9%	33.0%
Grenoble	37.1%	28.5%	26.1%	30.1%	31.8%	37.7%
Montpellier	30.5%	29.9%	28.2%	32.0%	35.5%	39.7%
Nice	38.1%	31.6%	20.1%	25.9%	34.9%	34.0%
Rouen	39.7%	30.6%	23.2%	29.5%	39.7%	40.7%
Reims	30.3%	31.6%	25.7%	27.4%	32.9%	35.0%
Strasbourg	51.0%	27.1%	27.9%	26.8%	35.6%	36.3%
Toulouse	39.7%	34.0%	26.5%	30.7%	38.1%	41.5%

Back to main

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