Access to education and clean air: Urban policies in Warsaw primary schooling

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mobil.TUM 2024
April 10th

Intro

In PL: Compulsory education (& access to it) and health protection are guaranteed for children.

But to assess the provision of these rights we need data that is not available:

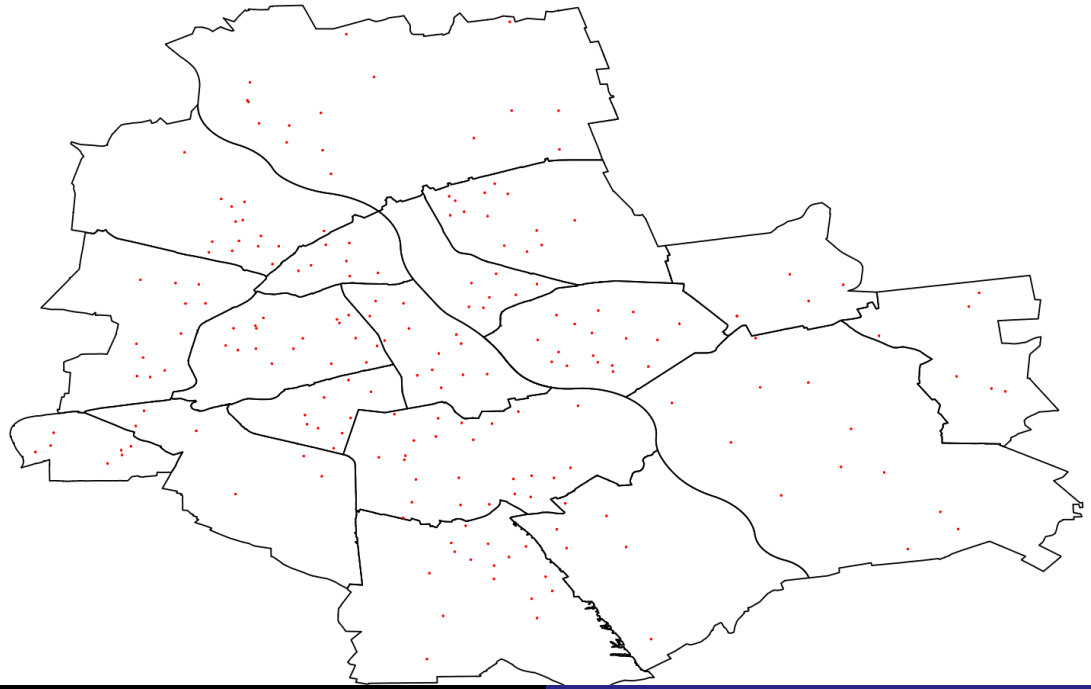
- no data on access to public education, no monitoring of possible inequalities
- no data on air quality around the schools

We are:

- developing a method of assigning each child in Warsaw at school age to a primary school based on several factors documented as relevant in the process
- modelling air quality in Warsaw, specifically in the locations of public primary schools

Primary education and air quality

- Warsaw has 2mln residents (46% living in the inner districts; 54% in the outer)
- There are 210 public primary schools; they are unevenly distributed; no official monitoring of school air quality
- Any legal regulations concerning air quality related to compulsory education were imposed by UE (no Polish regulations)
- Air quality monitoring is conducted with one official sensor (al. Niepodległości)



Primary education in Poland

- Compulsory primary education starts at age 7 and ends with a state exam after 8th grade
- Access to compulsory schooling must be provided by local authorities (municipalities)
  - in Warsaw: public transport services are for free to primary school students
- Parents can apply to an unlimited number of schools, regardless of their address, ranking them according to individual preferences
- The actual 'assignment' algorithm in not publicly known, but
  - admission rules prioritize firstly a so called "district school",
  - secondly other schools within a three-kilometre radius from a home address
  - whether older siblings are already enrolled in the school, and whether there are more than three children in the family
- No info on how long it takes children to get to school - there is no information at the municipality level of home and school addresses of pupils

Primary school choice in Warsaw

In Warsaw, about 76% of children in public primary education attend a district school. *Based on a representative sample of Varsovians.*

Table: Factors reported as relevant for the choice of an out-of-district primary school by parents of primary-school-age children in Warsaw

Factors relevant for the choice of school	Percentage
Education quality	35
Sibling in the school	13
Pre-school education was in that school	13
Closest to home	13
Not closest to home, but on the regular route	9
Not closest to home, but with the easiest commute	2
Other	16
N	154

Source: CoMobility Warsaw sample data, waves 1 and 2 (2022, 2023).
Note: Category "other" most frequently included: school having a sports class/profile or child having a disability.

Data

We develop a complex system of data from several sources:

- assigning children to schools:
  - addresses of all households in Warsaw with a child aged 7, i.e. subject to compulsory education, in 2019 provided by the City of Warsaw;
  - addresses of all 210 public primary schools in Warsaw;
  - average scores from the 2019 final primary school exam for each public school in Warsaw;
- access to school:
  - all possible public transport connections (bus, tram, train, underground) from any home address to any school address in Warsaw;
  - road network for private car travel from any home address to any school address in Warsaw;
- air quality (average annual concentrations and number of exceedances above the recommended thresholds of NO2 and PM2.5) for each public school in Warsaw in 2019

Primary school assignment

We use the *a prori* place of living addresses of all 11 023 children of pre-school age in Warsaw provided by the city council to predict the choice of primary school.

We run the algorithm based on the actual factors relevant to the public school enrollment process in Warsaw:

- proximity of schools
- the school's capacity
- final exam results of school
- assumption that all children from the same household are assigned to the same school

Because air quality is unavailable for particular areas in Warsaw, it cannot be taken into account in the school selection by parents and, hence, is exogenous to the selection algorithm.

Best school algorithm

The *Best School* algorithm assumes that, in total, for 80% of households, all the children are assigned to the closest school **which still has the capacity to accept them**.

For remaining 20% cases, it assigns **by default the best school within the range 7km** * from the given household that still has the capacity to accept all kids from the shared household**.

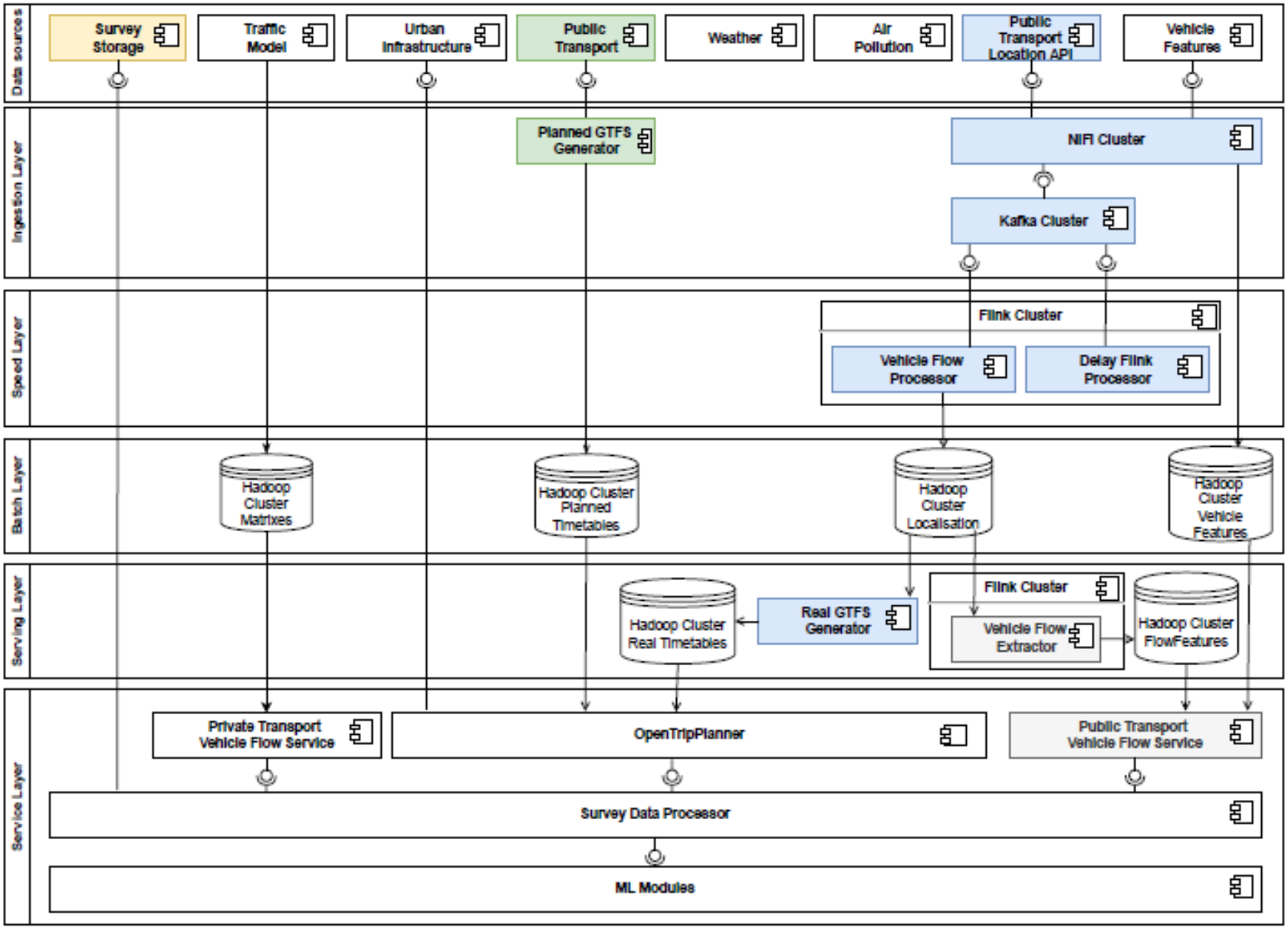
For each algorithm, we ran 5 assignments to verify how this randomness may impact the results.

* We earlier checked that the range of 7 km is sufficient to ensure that there will always be a school to assign children, unlike in case of lower values of the range.
** Due to limited capacity of the schools, the proportion of children assigned to out-of-district schools exceeds the lower bound of 20% assumed in the algorithm, reaching the share (about a quarter) similar to the one observed in the survey data

Computing travel times

- Based on the Open Trip Planner which is loaded with all public transport schedules and live geolocation data of vehicles, it allows for the inclusion of actual bus, tram, and train deviations from the schedule.
- We compute travel times to school during the morning peak of 8 am.
- Travel by public transport is calculated for door-to-door, including walking, waiting, and tranfer
- Travel by car doesn't include walking, parking, maneuvering not traffic jams, but the estimated car speed was limited to the average speed of 23 km/h (when the city speed limit is 50 km/h)

Information system for computing travel times

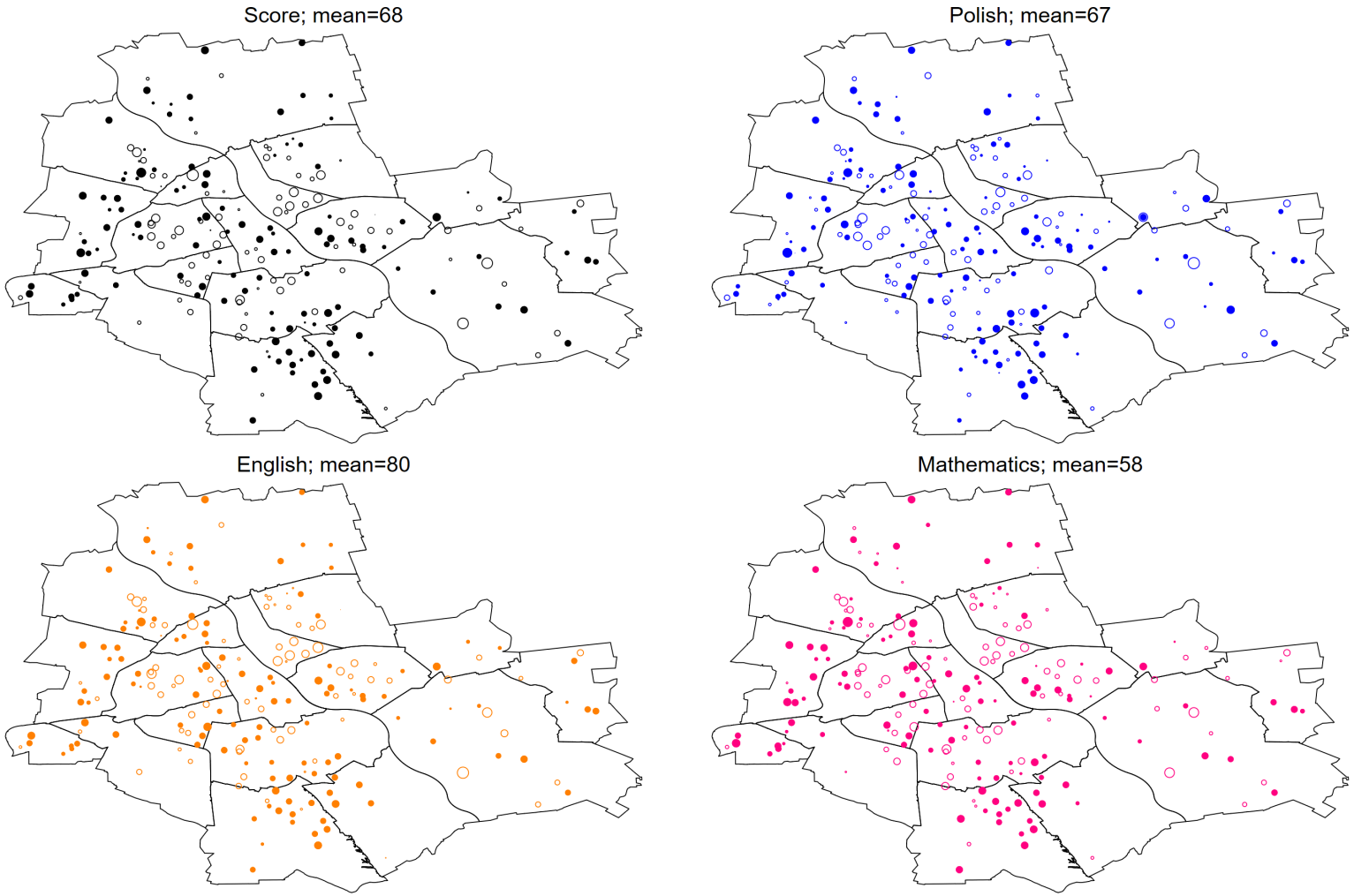


NILU environmental model

- The study uses surface ambient concentrations of PM2.5 and NO2 for the Warsaw area at 1km by 1km horizontal resolution.
- These concentrations were produced with the Weather Research and Forecasting Model (WRF) to produce the 2019 meteorological fields for the EPISODE Air Quality (AQ) urban dispersion model. The emissions are from the Polish Institute for Environmental Protection.
- The model takes into account:
  - car and public transport traffic in morning peak hours
  - other emission sources
  - background pollution
  - weather conditions
  - chemical processes
  - atmospheric physics processes

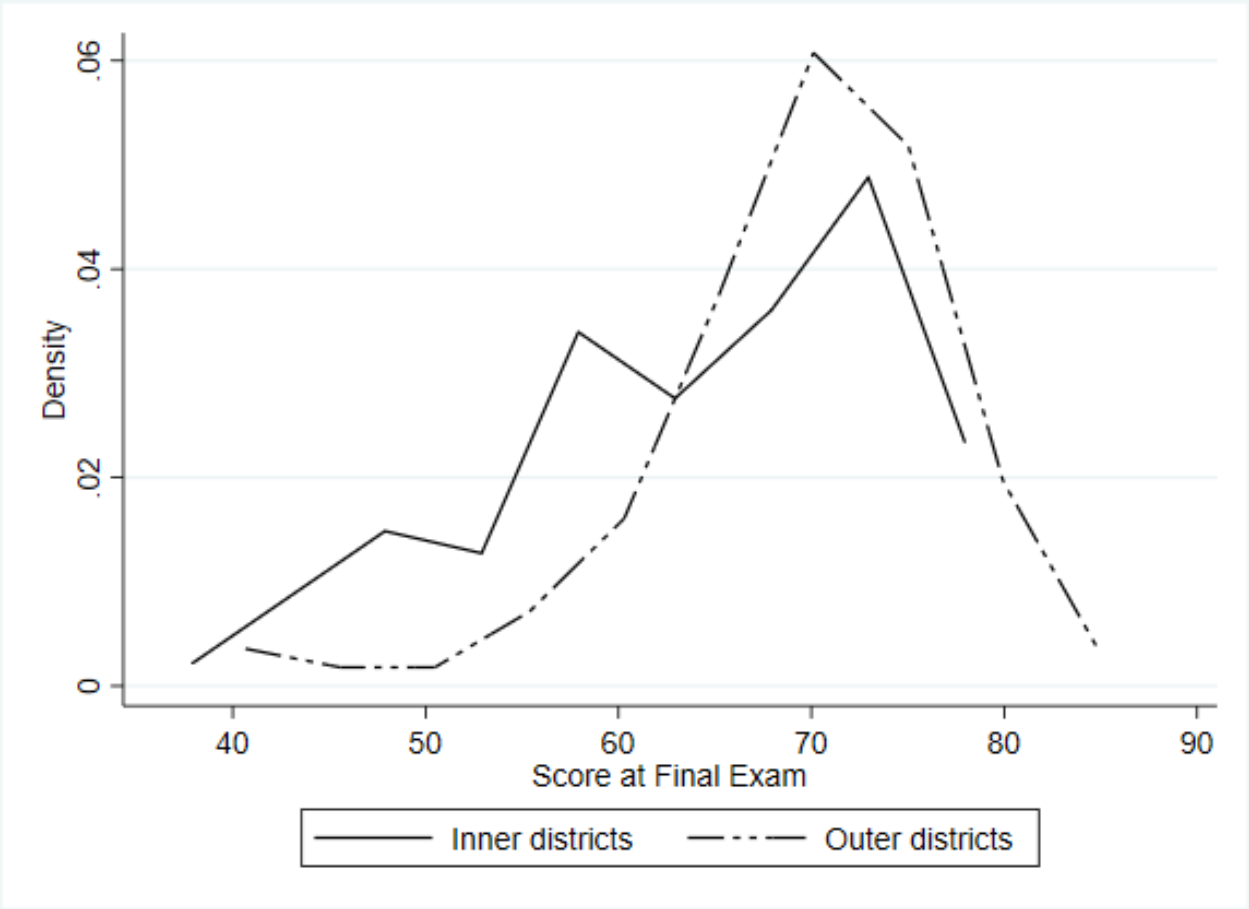
Variation in final exam results in Warsaw

Schools vary in terms of average result in the final school exam, but the differences is not correlated with specific city districts.

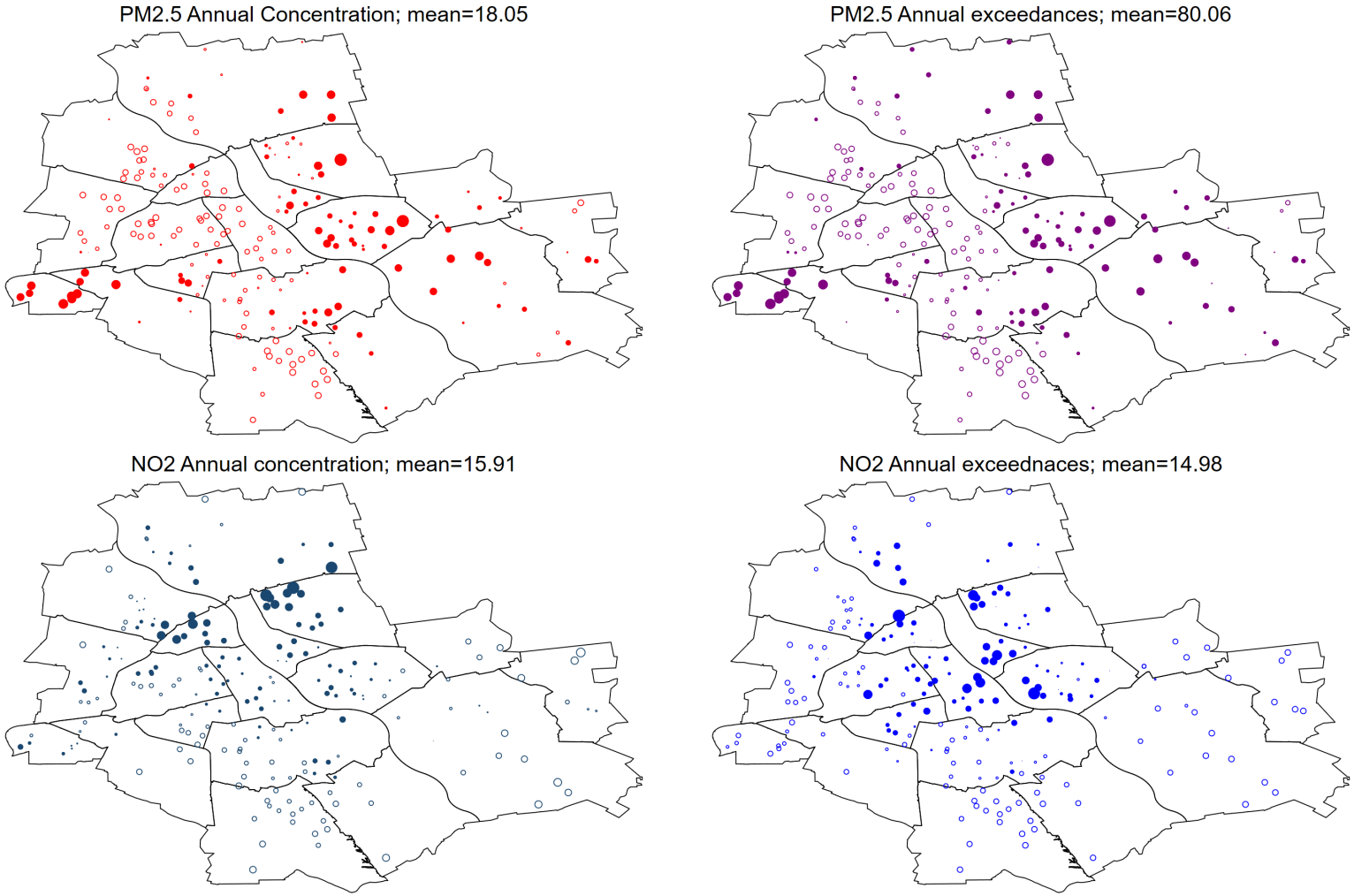


Inequalities in exam results in Warsaw

Average exam score was better in the schools in outer than inner Warsaw districts. The main driver was the Mathematics exam.



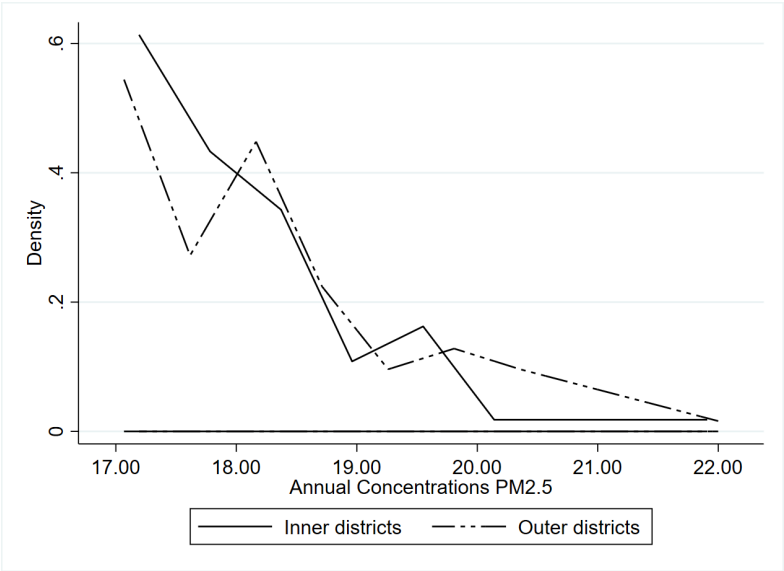
Results: Air quality in Warsaw primary schools

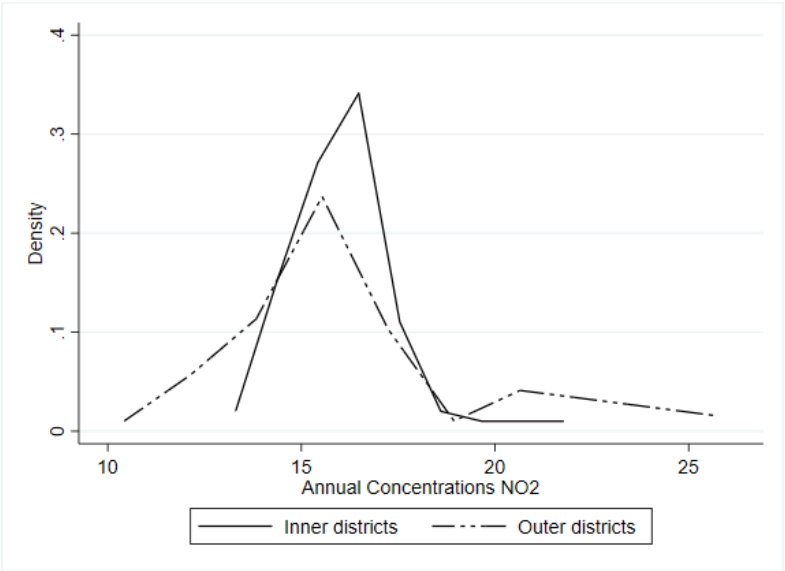


Note: Circle size = diff. from the mean value. Empty = smaller than the mean; coloured = larger than the mean. Concentrations = 2019 annual avrg. expressed in μg per 1m3. Annual exceed. = number of days during the year when the concentrations exceeded the WHO daily limits of 25 and 50 μg per 1m3 for PM2.5 and N02.

Results: Air quality - inner/outer districs

We observe significantly lower variation and higher values in terms on NO2 concentrations in the schools localized in inner than outer districts.



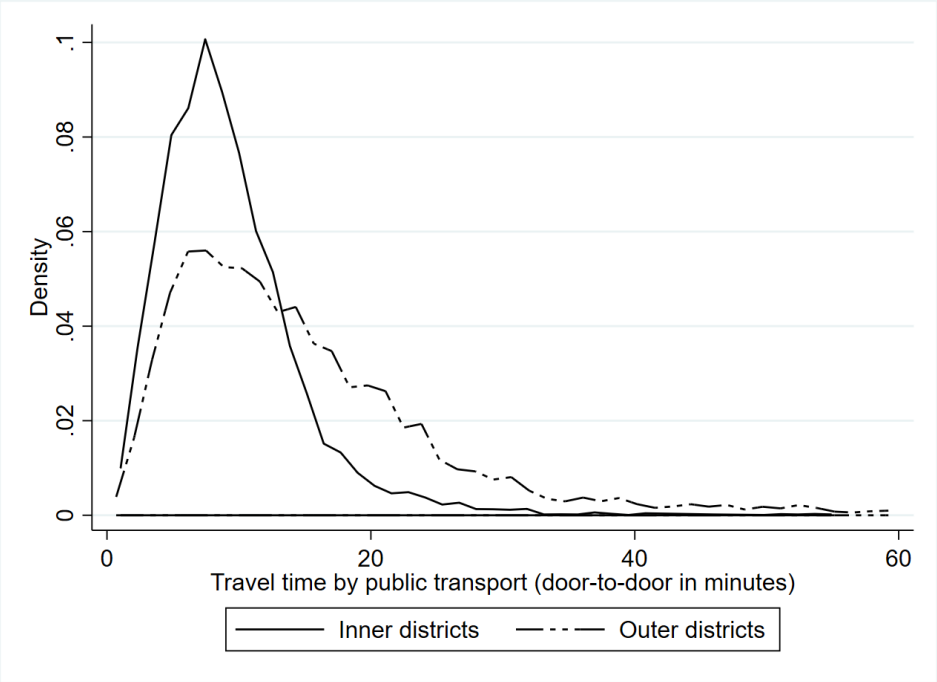


We find little evidence of the correlation between outdoor air quality and school performance, which distinguishes Warsaw from other cities where similar analyses were conducted.

Travel times to school by public transport

- 13 minutes on average, with a substantial standard deviation of 10 minutes, suggestive of good yet significantly varied school access in Warsaw
- 90% of children could reach their preferred school in 20 minutes by public transport; the same distance takes 10 minutes by car (but excluding parking and walking!)

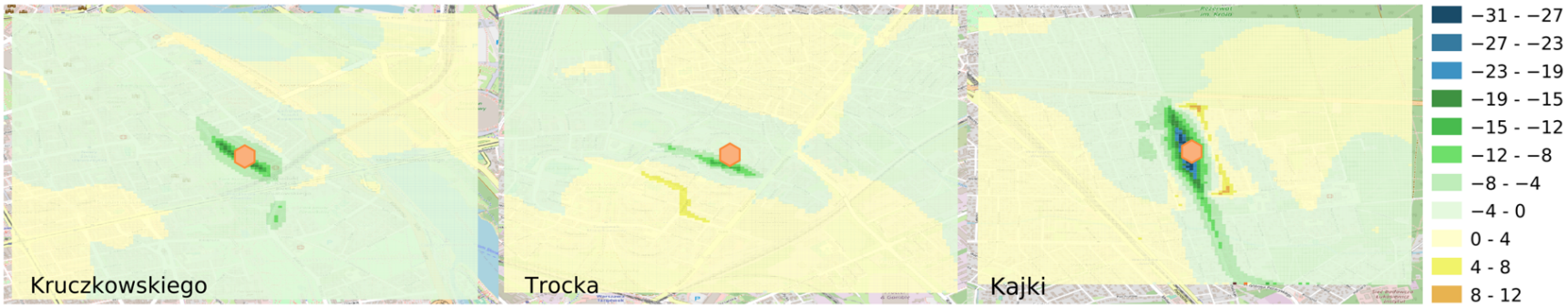
Travel times - inner/outer districts



- In the inner districts, the average travel time is 9 min. 20 sec. In the outer districts - 15 min. 30 sec. (66% more).
- 90% of children living in the inner districts could reach their preferred school in 15 minutes, while in the outer- 28 minutes.

NOx simulation: no car traffic at the school street

- School street closure would have only local positive effects on AQ: without overall reduction of private car traffic, the negative external effects are substantial



Conclusions

- Free and low-emission public transport in Warsaw performs very well on average.
- 90% of children can get to their school by free public transport in up to 20 minutes, while 10min by car (not accounting for walking and parking).
- Air quality is equally poor in Warsaw schools, though differences in NO_2 and $PM_{2.5}$ occur.
- The average number of days with $PM_{2.5}$ levels at school exceeding the WHO recommended threshold is 80 per year, similar to the entire city.
- We find significant inequalities in the school's access and outdoor AQ between inner and outer city districts.
- School street interventions would have only local positive effects on AQ: without overall reduction of private car traffic, the negative external effects are substantial.

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Scope of the analysis

We limit the analysis to Warsaw households with children entering free public primary education to examine access to public services (7yo going to the first grade)

Non-public education has a separate, non-unified recruitment process. Thus, it is excluded from the analysis despite

- increasing proportion of primary education students in non-public education (almost 20% in 2022/23)
- larger distances and hence presumably greater prevalence of private car commutes
- private services of private school buses with door-to-door commute

Modeling air quality - WRF

- We used the WRF model version 4.1.5 with initial and boundary conditions from the 6-hourly 0.25°× 0.25°National Centers for Environmental Prediction (NCEP) Final (FNL) operational global analysis and forecast data (National Centers for Environmental Prediction, National Weather Service, NOAA, U.S. Department of Commerce, 2015). WRF (Skamarock et al., 2019) is a three-dimensional, non-hydrostatic mesoscale numerical model designed to serve both operational forecasting and atmospheric research needs.
- WRF is freely available, and it is continuously developed with contributions by developers from the research community, with new versions released regularly. It includes the recent advances in physics, numerics, and data assimilation.

Modeling air quality - EPISODE

- The AQ urban dispersion model EPISODE v10.0 is used to estimate air concentrations and relies on emissions, meteorological fields, and boundary concentrations as input data. For the present study, the boundary conditions come from background AQ stations. EPISODE is a model developed specifically to answer questions regarding air quality legislative compliance and policy development
- For the reference simulation for Greater Warsaw, we used EPISODE v10.0 without sub- grid calculations, grid-representative output and simplified chemistry as NO2 photochemistry using the photostationary steady-state approximation. We use for this study the annual concentration averages and daily and hourly breaches to health safety thresholds recommended by the WHO.

Air pollution consequences for health

The adverse effects of pollutants are more pronounced for kids because of:

- higher breathing frequency
- being in the development stage of bodies and brains
- pollution concentration peaks being near the ground

High concentrations of NO_2 and $PM_{2.5}$ increase the risk of:

- lung diseases in adult life (Salvi 2007; Perera 2017)
- morbidity and mortality related to lung function (Sin et al. 2005, Salvi 2007, Asri et al. 2021) also in areas with relatively low pollution (Schultz et al. 2016)
- negative dermatological consequences (Wang et al. 2021, Yong et al. 2022).

Being highly exposed to greenspace (associated with reduced indoor and outdoor air pollution (Dadvand et al. 2015)) during childhood decreases the risk of obesity (Dadvand et al. 2019, Islam et al. 2020) as it is associated with greater physical activity.

Air pollution consequences for cognitive functions

There is a high association between (traffic-related) air pollution and:

- general cognition including working memory
- reasoning
- inattentiveness (Suglia et al. 2008, Sunyer et al. 2015, Gartland et al. 2022)

Exposure to increased air contamination is strongly linked to:

- poorer performance in cognitive tasks (including working memory and attention tasks) (Calderon-Garciduenas et al. 2008, Naveed and Khayyam 2022)
- diminished growth of working memory (Alvarez et al. 2017)
- lower productivity
- impaired decision-making (Lu 2020).

Air quality in house and public school addresses of Warsaw first graders, 2019

The school with the least days of $PM_{2.5}$ exceedances noted 62 such days (2 months) and with the most - 112 (3.7 months)

	School		Home		
	Mean	St. Dev	Mean	St. Dev	
Concentration					
NO_2	15.9134	2.252372	15.84172	2.439284	
$PM_{2.5}$	18.265	1.075868	18.43019	1.216419	**
Exceedances					
$PM_{2.5}$	79.79808	9.902793	81.33403	10.87183	**

Note: Concentrations in (μgm per $1m^3$). $**-p < 0.05$

Best *versus* Closest School

To remove the effect of the household sequence in the assignment to school, we repeat the algorithm 5 times using separate random household sequences.

The algorithm performs sufficiently well in the **Best school** option; the average final exam score for the examined children is larger than in the **Closest school** option.

Table: Ranges of average test scores and air qualities in primary schools in Warsaw depending on the school assignment algorithm.

	Air quality		Test score	
	Mean	St. dev.	Mean	St. dev.
Closest	(18.527, 18.529)	(1.192, 1.193)	(31.027, 31.03)	(3.578, 3.6)
Best	(18.416, 18.483)	(1.136, 1.163)	(32.126, 32.336)	(3.982,4.203)

Source: Authors' own analysis based on Warsaw city council and IOŚ-PIB data, 2019. *Note*: Air quality is measured as annual average PM2.5 concentration (μgm per 1m^3).

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