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Equity in temporary street closures: The case of London's Covid-19 'School Streets' schemes

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A R T I C L E I N F O

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A B S T R A C T

School Streets are a street space reallocation scheme that has proliferated since the beginning of the Covid-19 pandemic in the UK, reducing motor traffic on streets outside many schools. Utilising a minimum-standards approach to equity, this paper examines the distribution of School Streets closures across social and environmental indicators of equity, and spatially across London's administrative geography. Using a multi-level regression analysis, we show that although School Streets have been equally distributed across several socio-demographic indicators, they are less likely to benefit schools in car-dominated areas of poor air quality, and their spatial distribution is highly unequal. This study presents an example of using environmental and spatial variables alongside more typical sociodemographic indicators in measuring the equity of school travel provision. For policymakers, the findings signal the need to implement complementary policies that can benefit schools with worse air quality, and to accelerate School Street implementation in slower districts.

1. Introduction

During the Covid-19 pandemic many cities have introduced temporary or emergency interventions to aid active travel, often reallocating road space from motor vehicles to pedestrians and cyclists (Honey-Rosés et al., 2020; Law et al., 2021). In the UK, 'School Streets' have been introduced relatively widely. School Streets refer to closures to motor traffic on the streets immediately outside schools at pick-up and drop-off times, often using temporary materials, volunteers, or automated traffic cameras[1] to enforce the closure (see Fig. 1 for an example). These are usually installed at schools on smaller, urban, residential streets,[2] typically at state-funded primary schools (ages 4–11). They aim to improve air quality, reduce road danger, and increase physical activity through uptake of active travel (e.g. walking, cycling, scooting).

Although School Streets were growing in number prior to the pandemic, with 70 installed in London between 2015 and March 2020, from our analysis a further 420 have been introduced since. With 18 % of all schools and 27 % of state-funded primary schools now having School Streets (including those implemented prior to March 2020), they are quickly becoming a familiar part of the city's urban environment. Internationally, cities that have installed similar measures have taken slightly different approaches to London,

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[1] The use of automatic cameras for School Streets has been mostly confined to London where different regulations allow their use. Their advantage is to enforce the closure without relying on volunteers, something that might benefit some schools over others.

[2] Hopkinson et al (2021: p43) estimate that a School Street may be feasible at up to 69% of primary schools in London, primarily those on quieter residential streets that can be fully closed temporarily to motor traffic without substantial impacts on wider motor traffic flows.

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Fig. 1. An example of a School Street in London. Source: Anna Goodman.

with New York schools using the street space for lessons during the day and in Barcelona schemes have mostly closed a single lane of traffic rather than the entire street.

This policy focus on schools is perhaps unsurprising given that an estimated quarter of London's peak time vehicle traffic is attributable to the 'school-run' (Transport for London, 2018), while nationally since 2013 motor-vehicle trips have overtaken walking as the most frequent mode of travel to school for primary-age pupils (Department for Transport, 2014). This has been accompanied by widespread declines in children's independent mobility (both nationally and internationally), with auto-centric built environments likely partially to blame (Marzi and Reimers, 2018). Given that schools are highly temporally concentrated 'trip attractors', trends towards automobile school travel present significant problems for road safety and air quality on the streets directly outside of schools. It is in this context that School Streets have become a key element of the London Mayor's goal of 60 % of all children walking to school by 2026 (Mayor of London, 2022).

Although there has been some research in the grey literature on the potential impacts of School Street schemes (Air Quality Consultants, 2021; Thomas, 2022), demonstrating potential air pollution and traffic benefits, analysis of their socio-spatial distribution has been more limited. Evidence of the equity and justice implications of other Covid-19 road space reallocation schemes is still emerging, with only a few studies to date (Aldred et al., 2021; Firth et al., 2021; Fischer and Winters, 2021). Existing work on the equity of wider road-safety interventions at school has presented a mixed picture, with both equitable and inequitable distributions found (Jones et al., 2005; Rothman et al., 2018). This paper contributes to this literature by investigating whether School Streets implemented in London during Covid-19 have been equitably distributed and are likely benefiting London's deprived and minority ethnic primary school pupils and the surrounding populations, as well as those most subjected to the negative effects of car dominance and resulting pollution.

In doing so, this research seeks to answer two questions:

(1) How does the (in)equitable distribution of School Streets vary depending on the dimension of equity (e.g. ethnicity, deprivation, local environment)?
(2) How do(es) a) the overall spatial distribution of School Streets, and b) the relationships between dimensions of equity and School Street presence vary across London's diverse geography?

We assess School Streets against a minimum standards approach to equitable policy prioritisation, measuring the extent to which schools most in need by measures of equity are treated first. Through this approach, we argue that alongside more typical social dimensions of equity, local-environmental and spatial dimensions must also be considered to ensure a fair distribution of School Streets in London. We find that the current distribution, although demonstrating *equality* on several measures, does not meet a minimum standards definition of *equity*, especially when considering these additional environmental and spatial dimensions.

2. Literature review

At its most basic level, transport equity is concerned with the distribution of both the benefits of transportation systems as well as the burdens or negative outcomes of these systems across society (Di Ciommo and Shiftan, 2017; Lee et al., 2017). This has been an area of significant international research – often focusing on the equity of transport accessibility. In London, for example, research has shown that although public transport accessibility varies substantially across the city's social demography, non-White and deprived Londoners are less likely to have access to a car or van (Transport for London, 2012) and are more likely to experience negative consequences related to their use (Edwards et al., 2006; Steinbach et al., 2007; Moorcroft et al., 2021). In spite of this attention, there is currently limited research on the equity of interventions to support active travel to school (Buttazzoni et al., 2018). After first considering theoretical engagements with the concept of transport equity, this literature review will examine the adjacent research on the equity of active travel interventions and the equity issues around children's transport and travel to school.

2.1. (Active) transport equity

The use of the concept of equity in transport research has several different dimensions. At the broadest level, most conceptualisations have focused on the moral or fair distribution of goods and burdens in society. Although some authors distinguish notions of justice from equity (Karner et al., 2020), for others, this distinction is less important with equity being the practical result of the application of a theory of justice such as utilitarianism or egalitarianism (Nahmias-Biran et al., 2017; Pereira et al., 2017). Here, any assessment of equity invokes a normative understanding of fairness, meaning that quite different distributive principles might be understood as 'equitable'. Indeed, varied dimensions of equity have also been invoked in the transport context. For example, the importance of spatial equity has been distinguished from the social equity of active travel interventions (Lee et al., 2017). This perspective considers the equity implications of an uneven spatial distribution of a transport intervention alongside its distribution across the socio-demographic composition. Due in part to the varied normative judgements involved, and differing domains of equity emphasised, there is no agreed upon method for measuring equity in transport (Lucas et al., 2019).

Nevertheless, there is growing research that assesses the equity of the distribution of active travel interventions (see Aldred et al., 2021 for an overview), and of Covid-19 related road space reallocation more specifically (Aldred et al., 2021; Firth et al., 2021; Fischer and Winters, 2021). Aldred et al (2021) found that London's pandemic Low Traffic Neighbourhood interventions were broadly equitably distributed on the city level, but with significant variation between borough authorities. Research on the equity of cycling infrastructure has generally reported poorer provision in lower-income areas (Flanagan et al., 2016; Hirsch et al., 2017; Parra et al., 2018; Braun et al., 2019). However, studies in Australia and Canada have shown more equitable distributions arising from investment in specific low-income areas (Pistoll and Goodman, 2014; Houde et al., 2018). For pedestrian infrastructure, research in the UK and Europe has found less favourable walking environments for higher-income residents (driven by lower densities) (Zandieh et al., 2017; Kenyon and Pearce, 2019), but also higher quality infrastructure (such as pavements and crossings) in wealthier city centres (Bartzokas-Tsiompras et al., 2020).

2.2. Children and transport equity

Transportation equity research has not only uncovered that in the UK, ethnic minorities and more economically deprived populations are most exposed to poor air quality (Mitchell and Dorling, 2003; Goodman et al., 2011; Fecht et al., 2015), but that children are also disproportionately affected, particularly on their journeys to school (Osborne et al., 2021). In both the UK and internationally, children from ethnic minority and deprived backgrounds are disproportionately exposed to air pollution (Jephcote and Chen, 2012; Gaffron and Niemeier, 2015) and most likely to be injured by road traffic (Nantulya and Reich, 2003; Hwang et al., 2017; Ferenchak and Marshall, 2019). These inequalities have also been found to exist in London[3] for both air quality and road traffic injuries (Edwards et al., 2006; Steinbach et al., 2007; Moorcroft et al., 2021).

The transport geography of school travel can also be highly inequitable. Research (often from North America) has shown that many recent policies intended to promote school choice or consolidate schools often increases school travel distance, disadvantaging children from deprived and minority communities with less family capacity for mobility (Talen, 2001; Andersson et al., 2012; Lee and Lubienski, 2017; Scott and Marshall, 2019; Fast, 2020; Bierbaum et al., 2021). This hostile school travel environment is compounded by a general decline in children's independent mobility and increasing car dependence (Marzi and Reimers, 2018). In accordance, calls emphasising a child's right to the city' or for cities to become more child-friendly have become more frequent (Whitzman et al., 2010; Mayor of London, 2019; Gill, 2021).

2.3. School travel interventions

Barriers to independent mobility are often embedded in the objective features of the built environments around schools as well subjective parental perceptions of safety (Mitra, 2013; Mitra et al., 2015; Rothman et al., 2015, 2018, 2021). These can be ameliorated by interventions aimed at improving road safety both at the school gates and along routes to school. In cities in the global north, these efforts have historically been dominated by traffic calming measures, improved pedestrian infrastructure (e.g., crossings) and the use of crossing guards. Such interventions have been effective in reducing the perception of danger (Rothman et al., 2015), and in one UK case study, addressing the inequitable distribution of objective danger for children (Jones et al., 2005).[4] However, other research has

[3] Although for air quality this picture is improving with the introduction of recent measures such as the Ultra Low Emissions Zone which introduced a charge for the most polluting vehicles.

[4] There is also some evidence that the benefits of active travel are greater for children from lower-socio economic backgrounds (Laverty et al., 2021).

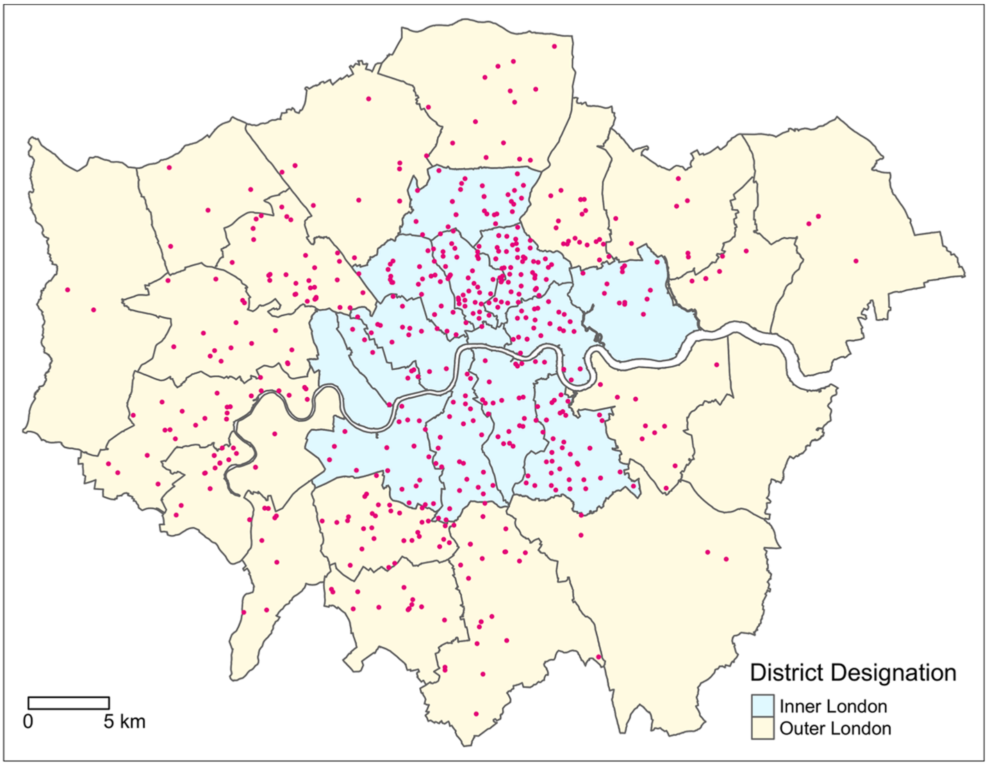

Fig. 2. A map showing the location of state-funded primary schools with School Streets (implemented between March 2020 and April 2022) across Greater London (April 2022). School Street Data Source: Thomas 2022, School Location Data Source: Department for Education.

found traffic calming measures around schools to be inequitably distributed (Rothman et al., 2018).

Traffic calming is one of several features of the built environment that have been found to impact active travel to school: high car-dominance/traffic levels (Giles-Corti et al., 2011; Larsen et al., 2016; Buliung et al., 2017), less dense road network densities (Mitra and Buliung, 2014; Ozbil et al., 2021), greater distances between home and school (Page et al., 2010; Waygood and Susilo, 2015; Yu and Zhu, 2015), and larger roads surrounding the school (Panter et al., 2010), are all often negatively associated with active travel to school. These characteristics are often also unevenly distributed within cities, leading to environmental inequities in the experience of active travel. Accordingly, the location of any equitable policy (e.g. School Streets) that aims to ameliorate the negative effects of car dominance on active travel to school should consider dimensions of the local built environment alongside social and spatial characteristics.

Most studies of transport equity outlined in this literature review have focussed on one single dimension of equity, looking at the distribution of benefits *or* burdens, typically in strictly social terms. There is also currently very limited research on the equity of interventions to support active travel to school. One recent study of School Streets in the UK found them to be more often implemented in more deprived schools (Hopkinson et al., 2021), and unevenly spread across London's boroughs. However, there are still several aspects of equity outlined in this review that merit attention in the context of School Streets, including the social equity of the benefits they provide, the environmental equity of the negatives they intend to ameliorate, and the spatial equity of their overall distribution in the city. The next section will outline in more detail how these different dimensions of equity will be measured in this paper.

Table 1
The breakdown of schools with School Streets (implemented since March 2020) by school type in Greater London.

School type	Total Schools	School Street Schools (n)	School Street Schools (%)
State-funded primary	1813	446	24.6
State-funded secondary	520	32	6.2
State-funded nursery	79	2	2.5
State-funded special school	153	3	2
Independent school	541	20	3.7
Non-maintained special school	4	0	0
Pupil referral unit	57	0	0

Table 2
A summary of the data used in this equity analysis.

Equity dimension	Variable	Geographical level	Year	Source	Categories
Socioeconomic	% of pupils eligible for Free School Meals[1]	School	2020–2021	Department for Education (2022)	NA
	Index of Multiple Deprivation rank and Score	LSOA	2019	Ministry of Housing, Communities and Local Government (2020)	NA
Ethnicity	% of pupils in each ethnic group	School	2020–2021	Department for Education (2022)	White Black/Black British Asian/Asian British Mixed/Multiple Other
	% of population in each ethnic group	LSOA	2011[2]	ONS (2013a)	White Black/Black British Asian/Asian British Mixed/Multiple Other
Local environment	Road classification (% of road length of total road length in area around a school)	School buffer: a) within 500 m; b) within 1000 m; c) within 75th percentile of students' travel distances	2021	OS Mastermap Highways	A/B road or motorway Local or minor road Restricted/Access road
	Ratio of main roads to minor roads (% of total road length within 500 m of school that are A/B or motorway roads divided by % that are local/minor roads)	School buffer: within 500 m of school	2021	OS Mastermap Highways	NA
	Air pollution: modelled NOx levels from motor vehicles	School	2020	Breathe London (2020)	NA
Geographical distribution	Geographical location	School	2022	ONS (2013b)	Inner London Outer London London borough
Other variables[3]	Population density (persons per hectare)	LSOA	2021 (based on projected population)		NA
	% of population with degree-level qualifications	LSOA	2011	Office for National Statistics (2013a)	NA

[1] Research has shown that FSM eligibility is a suitable proxy for socioeconomic disadvantage (Ilie, Sutherland and Vignoles, 2017) and, with some caveats, for family income (Hobbs and Vignoles, 2010).
[2] We use the 2011 variable at LSOA level because more recent ethnicity projections are only available at the much wider geographical scale of local authority borough.
[3] These variables are not part of the main bivariate analysis, although population density is controlled for in two of the logistic regression models. This is because, while it is not considered a key dimension of equity, it is a key determinant of School Street location and not doing so would threaten the internal validity of the research.

Table 3
A summary of the variables used to create the equity index.

Equity dimension	Variable	Direction
Socioeconomic	% of pupils eligible for FSM IMD score	+ +
Ethnicity	% of pupils in White ethnic group % of LSOA population in White ethnic group	– –
Local environment	Ratio of main roads to minor roads NOx levels from motor vehicles	+ +

3. Methods and data

3.1. Measuring transport equity for School Streets

Although there is no agreed upon definition or measurement of equity in transport (Lucas et al., 2019), research on the theory of transport equity has increasingly drawn upon John Rawls' theory of egalitarianism, as well Sen's capabilities approach (Martens, 2012; Pereira et al., 2017; Verlinghieri and Schwanen, 2020). These approaches share a common perspective which holds that an *un*equal policy is only fair if it benefits those more disadvantaged in society. The distributive principle that underpins this could be broadly described as a minimum standards or sufficiency approach, where policy efforts are prioritised first and foremost on those defined as most disadvantaged and most in need (Martens and Bastiaanssen, 2019). We utilise the minimum standards approach in this paper to help understand the extent to which an incomplete policy (School Streets) has been prioritised to serve schools and local areas most in need before others.

Given the current inequities in transport identified in the literature review, an equitable School Streets policy, according to a minimum standards approach, would initially have prioritised these improvements for low income and ethnic minority Londoners for whom transport options are most limited. However, School Streets also seek to ameliorate the environmental disbenefits of motor

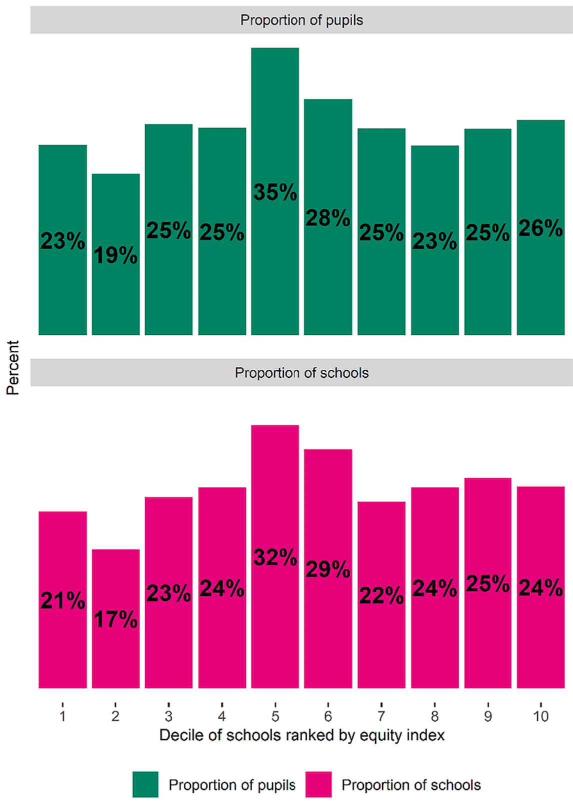

Fig. 3. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by equity index.

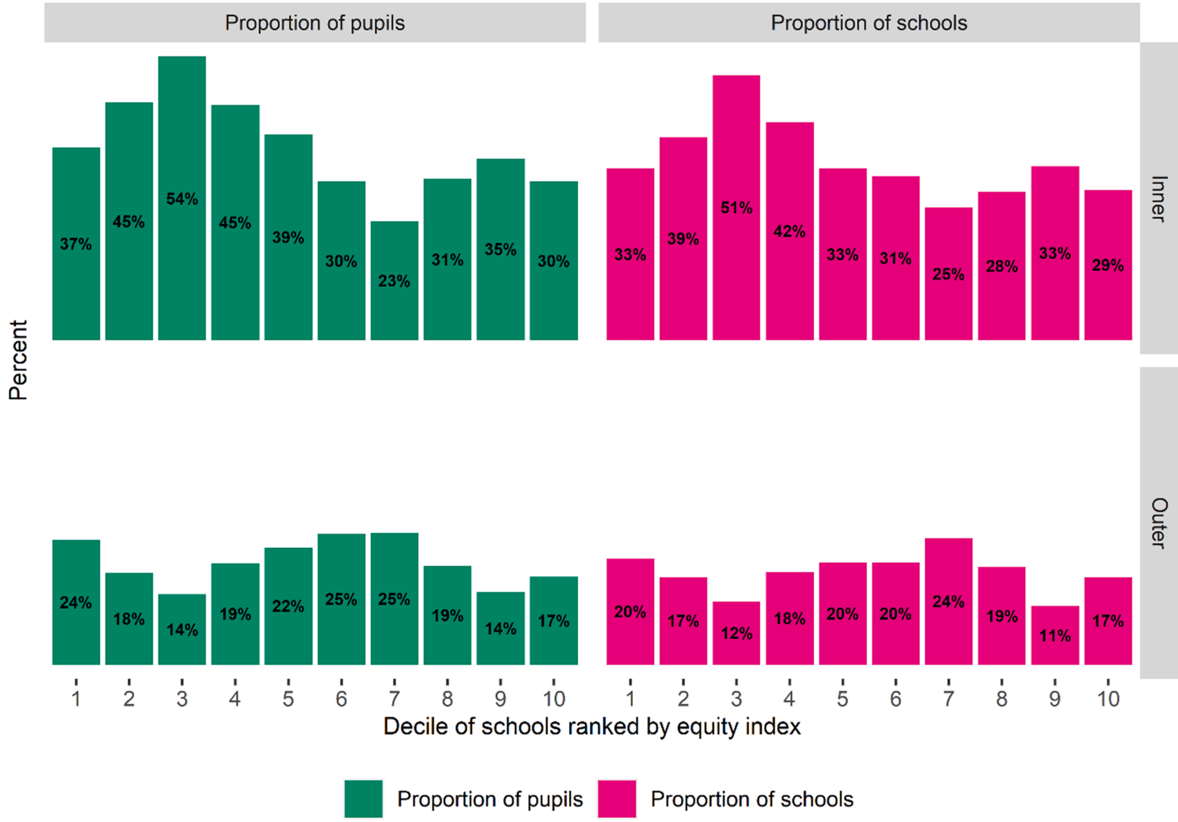

Fig. 4. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by equity index (inner and outer London).

traffic. Thus, a focus on the social equity of its benefits as transport infrastructure may not represent a fair distribution in terms of the children most affected by air pollution and road danger. A prioritisation of School Streets along minimum standards should also attend to whether the policy is equitably distributed across the schools in the most car-dominated and most polluted areas. Lastly, the equity of School Streets across London's administrative geography should be considered. Some of the schools most in need in terms of social and environmental equity exist in all of London's district authorities. However, not all have embraced School Streets policies, potentially opening spatial inequities in provision.

From this perspective, we would expect an equitable distribution of School Streets to favour schools with higher proportions of non-White pupils, pupils from economically deprived households and in more car-dominated, polluted local areas, irrespective of London's administrative geography. This section will examine in more detail how these different variables will be measured and analysed.

3.2. Identifying School Streets

Two different organisations have maintained databases of School Street locations in London and have been made available for this study. Between the two databases there were some discrepancies. Manual research has been conducted to check these and to complete the validation and produce a harmonised dataset of School Street measures. Given the frequency with which School Streets have been installed and difficulties in obtaining up to date data from districts, a small number of sites may have been missed. However, given the large number of sites recorded, this database is considered sufficiently accurate (see Fig. 2 for the final distribution).

The validated list of School Streets was matched by postcode and Unique Reference Number (URN: an id number for all schools in the UK) to the dataset of all schools in London. As a single School Street measure can serve multiple schools, and some schools are split into multiple institutions with different URNs, all schools with the same postal code were deemed to have the same School Street status. The dataset and analysis that follows only includes School Streets that had commenced after March 2020 because this analysis is primarily concerned with the measures installed as part of the Covid-19 pandemic. In addition, the analysis has been restricted to state-funded primary schools since the vast majority - some 89 % - of School Streets have been implemented in this school type (see Table 1).

3.3. Data and variables

School Streets impact on both the pupils themselves and on those that live nearby. Therefore, this research considers both the

Table 4
Distribution of School Streets (state primary) by inner and outer London.

	Overall			Borough-level		
	Non- School Street schools (n)	Schools with a School Street schools (n)	Schools with a School Street (%)	Median count: School Streets per borough	Mean count: School Streets per borough	Mean percentage: schools with School Streets per borough
London	1319	420	24.2	11.0	12.7	24.3
Inner London	438	230	34.4	17.5	16.4	31.2
Outer London	881	190	17.7	10.0	10.0	19.2

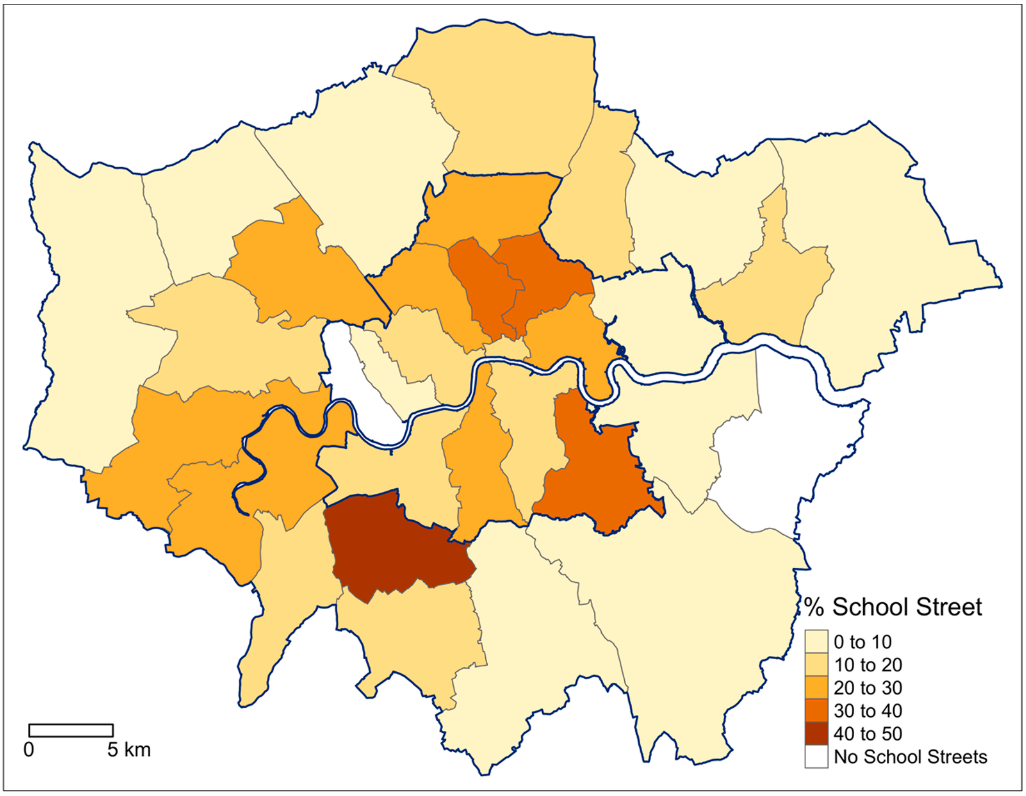

Fig. 5. A map showing the proportion of state primary schools with School Streets (implemented post-March 2020) across Greater London boroughs (April 2022).

Table 5
Total and percent of pupils eligible for FSM by school status.

School status	Total pupils	Total pupils eligible for FSM	Percent of pupils eligible for FSM
Non-School Street	513,540	110,892	21.6
School Street	175,682	40,912	23.3

characteristics of the school population as well as the surrounding area. At the school-level, we have obtained publicly available sociodemographic data for the student body of each primary school in London. For the area-level data, a lookup file has been used (Office for National Statistics, 2022) to locate each primary school in London within a Lower Super Output Area (LSOA).[5] LSOAs have been used as this is the finest geographical scale, with an average of 1718 residents (mid-2020 estimate, (Office for National Statistics, 2021) in Greater London, at which there is data available on variables such as the Index of Multiple Deprivation (IMD). Most LSOA-level data come from the most recent UK census in 2011 (Office for National Statistics, 2013a). Where possible, more recent datasets are used (see Table 2 for more details).

While we use widely established variables - deprivation and ethnicity – to measure social equity, we omit any consideration of gender and physical disability. Although both measures are highly relevant to any study of the impacts of School Streets, there is no significant gender variation between state-funded primary schools or LSOAs in London. On physical disability, we do not have access to school-level data to conduct any analysis.

A measure of car dominance of the local environment has been created for each school based on local road characteristics. A straight-line[6] buffer has been mapped from the centre-point of each school of different distances: 1) 500 m; 2) 1000 m and 3) a unique value for each school calculated as the median of the 75th percentile of travel to school distances of all pupils across the years 2010–2016 (Greater London, 2018). In cases of missing data, the median 75th percentile has been used from the corresponding district. Each buffer area for each school has then been intersected with road data (Ordnance Survey, 2021) to calculate the proportion of the

[5] For more details on how LSOAs fit into the UKs census geography, please consult the Office for National Statistics overview: https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeography.

[6] An alternative would have been population-weighted buffers but there was also uncertainty that this would more accurately map on to the school catchment areas.

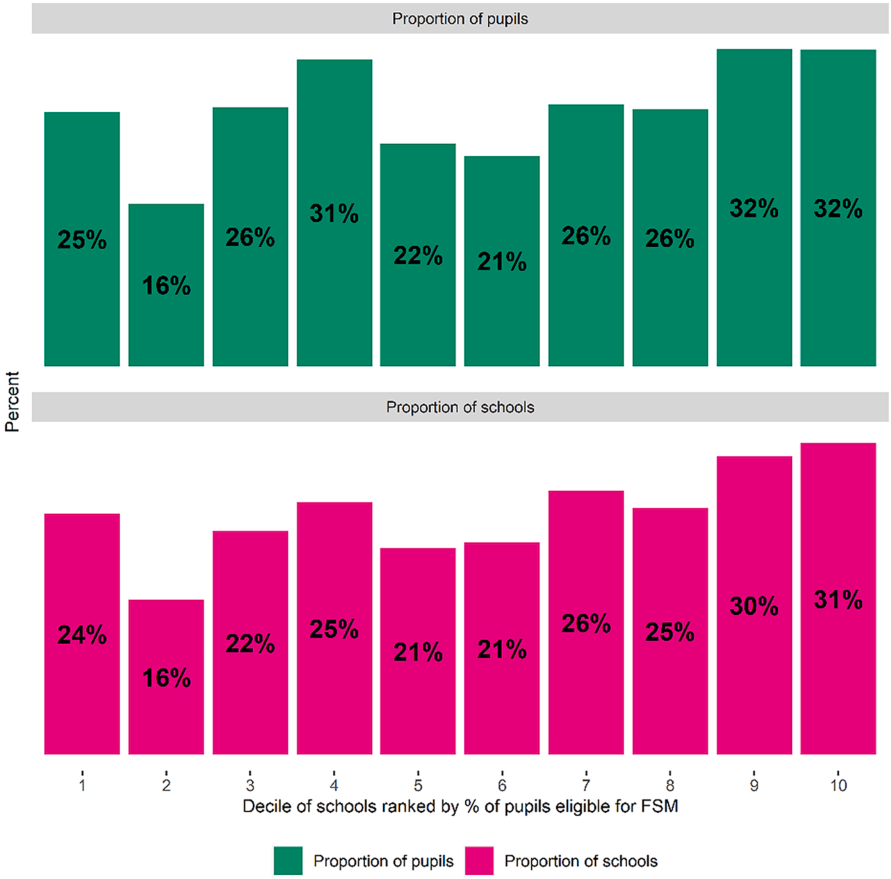

Fig. 6. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by percent of pupils eligible for FSM.

Table 6
Total and percent of pupils eligible for FSM by school status and geography.

Geography	School status	Total pupils	Total pupils eligible for FSM	Percent of pupils eligible for FSM
Inner London	Non-School Street	143,043	41,690	29.1
	School Street	84,040	24,737	29.4
Outer London	Non-School Street	370,497	69,202	18.7
	School Street	91,642	16,175	17.7

Table 7
Summary statistics of IMD score by School Street status.

School status	n	min	Q0.25	mean	median	Q0.75	max	sd
School Street school	420	3.3	14.5	23.2	23	31	53.3	11
Non-School Street school	1318	2.8	12.7	22	21.5	30.2	64.7	11.1

total road length within 500 m, 1000 m and the 75th distance percentile by road type. Schools with more car dominated local environments are those which have a higher proportion of ‘A roads, B roads and motorways’. In the statistical models, a ‘ratio of main roads to minor roads’ has been calculated - that is, the proportion of road lengths that are ‘A/B or motorway’ divided by the proportion that are ‘local or minor roads’.

3.4. A composite index of equity

Schools have been ranked according to a composite index of equity that incorporates both social (socioeconomic and ethnicity) and environmental dimensions. The variables used to create the overall index are shown in Table 3.

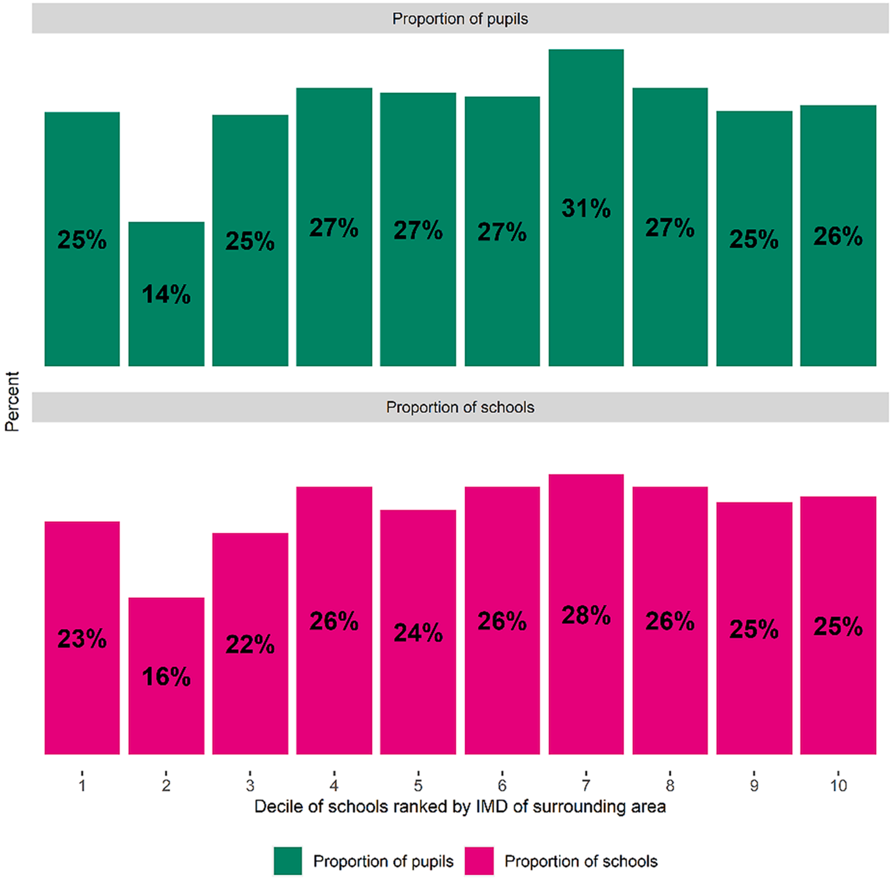

Fig. 7. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by IMD score of surrounding area.

As the variables are ‘substitutable’ - that is, a low value in one indicator can be offset by a high value in another - an additive aggregation method using the arithmetic mean was deemed most appropriate (Mazziotta and Pareto, 2013). The final composite variable (C) was therefore created by summing the standardised z-score values (z) for each variable:

$$C = z_1 + z_2 + \dots z_p$$

where $z = \frac{x - \bar{x}}{SD}$.

Due to the different variances of the variables, without standardisation one variable could have a greater impact on the composite index than another (Song et al., 2013). As we have no prior belief regarding the importance of the different indicators or dimensions in measuring equity, weights have not been utilised – all variables contribute equally to the composite index. In Table 3, for each variable, where the direction is positive (e.g. % of pupils eligible for FSM), this implies that a higher value of the variable contributes to an increase in the overall score. A negative direction (e.g. % of White pupils) implies that a higher value contributes to a decrease in the score. Overall, if a school has a high index score, under an equitable policy distribution it would be more likely to have a School Street.

3.5. Statistical modelling

For both primary schools and their surrounding areas, relationships between sociodemographic, economic, and environmental characteristics and the presence of a School Street are examined through regression models. As the outcome in all models is a dichotomous variable (1: School Street; 0: no School Street), binomial logistic regression models predict the probability that a school has or does not have a School Street scheme. To examine both the additional district-level association with School Street provision as well as the extent to which school and area-level factors remain significant after accounting for district, a multi-level random intercept model has also been executed, in which the school and area-level characteristics (level 1) are nested within the district (level 2).

To avoid unreliable or indeterminate regression coefficients (and therefore, spurious findings), variables are excluded from the models where there is evidence of multicollinearity - as detected by a variance inflation factor (VIF) of greater than five (Harris and Jarvis, 2011). As there was evidence of non-linearity between three independent variables (NOx levels, ratio of main to minor roads and population density) and the logit of the outcome, a Generalized Additive Model (GAM) has also been performed with smoothed

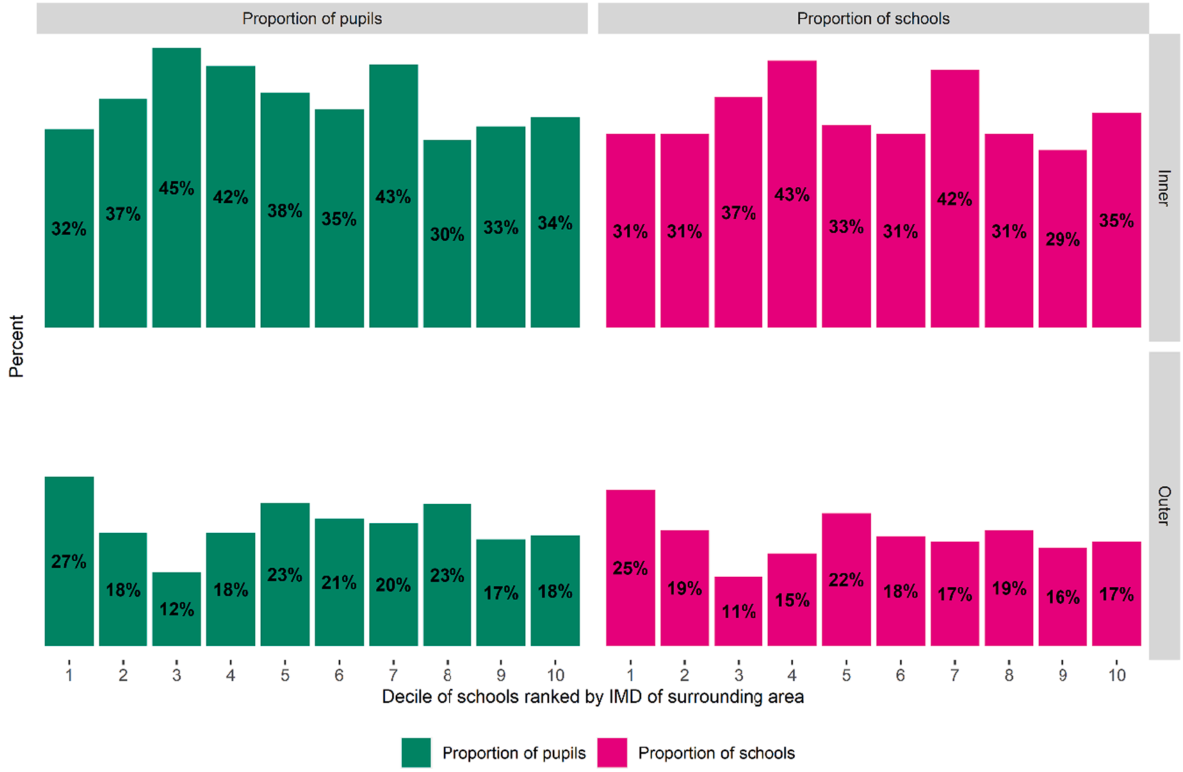

Fig. 8. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by IMD score of surrounding area (inner and outer London).

Table 8
Distribution of pupils by ethnicity across schools with School Streets and without School Streets in Greater London.

	Non-School Street		School Street	
Ethnic group	Total pupils	Percent of pupils	Total pupils	Percent of pupils
Asian/Asian British	124,463	23.8	39,752	21.5
Black/Black British	85,961	16.4	34,541	18.7
Mixed or multiple	60,348	11.5	23,936	13
Other	30,168	5.8	11,153	6
White	222,476	42.5	75,309	40.8
Total	523,416		184,691	

Table 9
Distribution of ethnic groups across state primary school LSOAs with and without School Streets by inner/outer London.

	% White	% Mixed/Multiple ethnic groups	% Asian/Asian British	% Black/African/Caribbean/Black British	% Other ethnic group
All LSOAs					
London	60.7	4.9	17.9	13.1	3.4
Inner	58.0	5.9	15.5	16.6	4.1
Outer	62.5	4.3	19.5	10.8	2.9
School LSOAs with School Streets					
London	58.8	5.5	16.7	15.4	3.6
Inner	56.6	6.1	14.7	18.7	3.9
Outer	61.7	4.7	19.2	11.2	3.2
School LSOAs without School Streets					
London	61.4	4.8	17.8	12.6	3.4
Inner	57.8	5.7	16.4	15.9	4.3
Outer	63.6	4.3	18.6	10.7	2.9

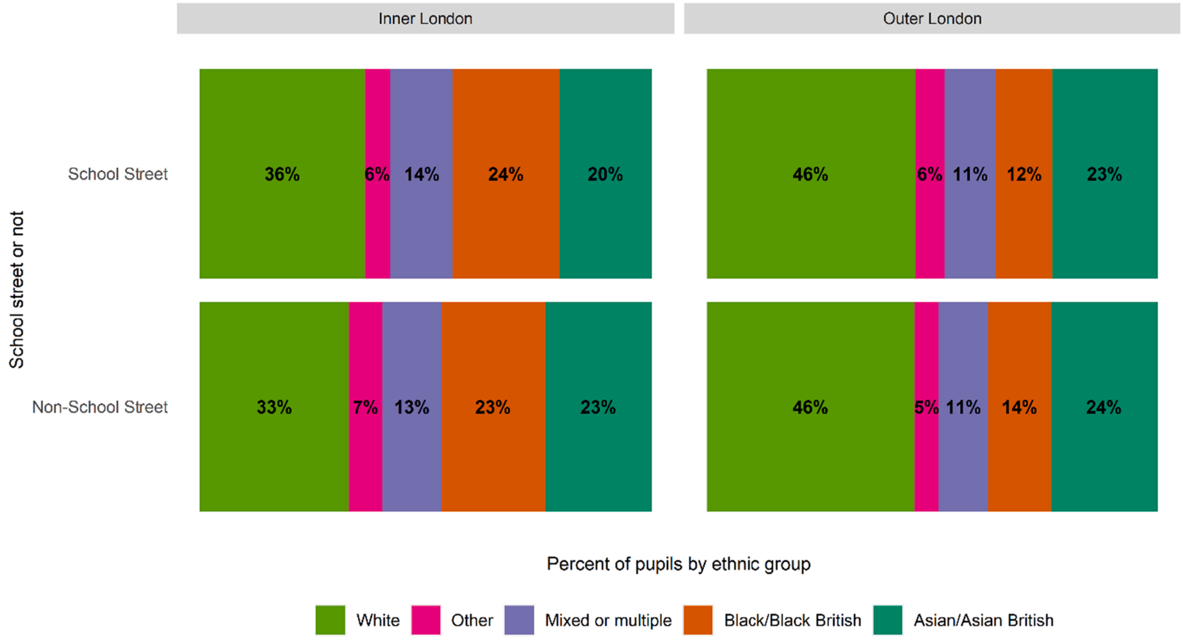

Fig. 9. Distribution of pupils by ethnicity across schools with School Streets and without School Streets in Greater London (inner and outer London).

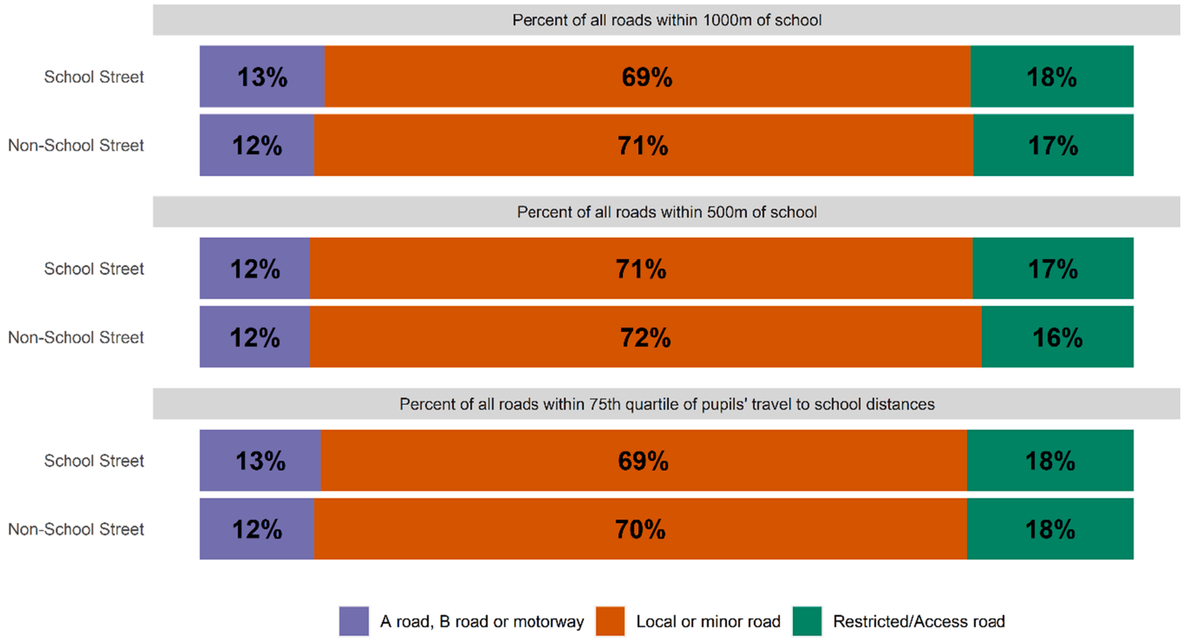

Fig. 10. Proportion of roads in the local environment surrounding a school by road classification and School Street/non-School Street school.

Table 10
Summary statistics of NOx air pollution values (μg/m3) from motor vehicles by School status.

School status	n	min	Q0.25	mean	median	Q0.75	max	sd
School Street school	417	6.4	12.5	17.2	14.4	16.5	122.7	11.9
Non-School Street school	1314	5.5	11.4	20.3	14	18.5	148.9	17.7

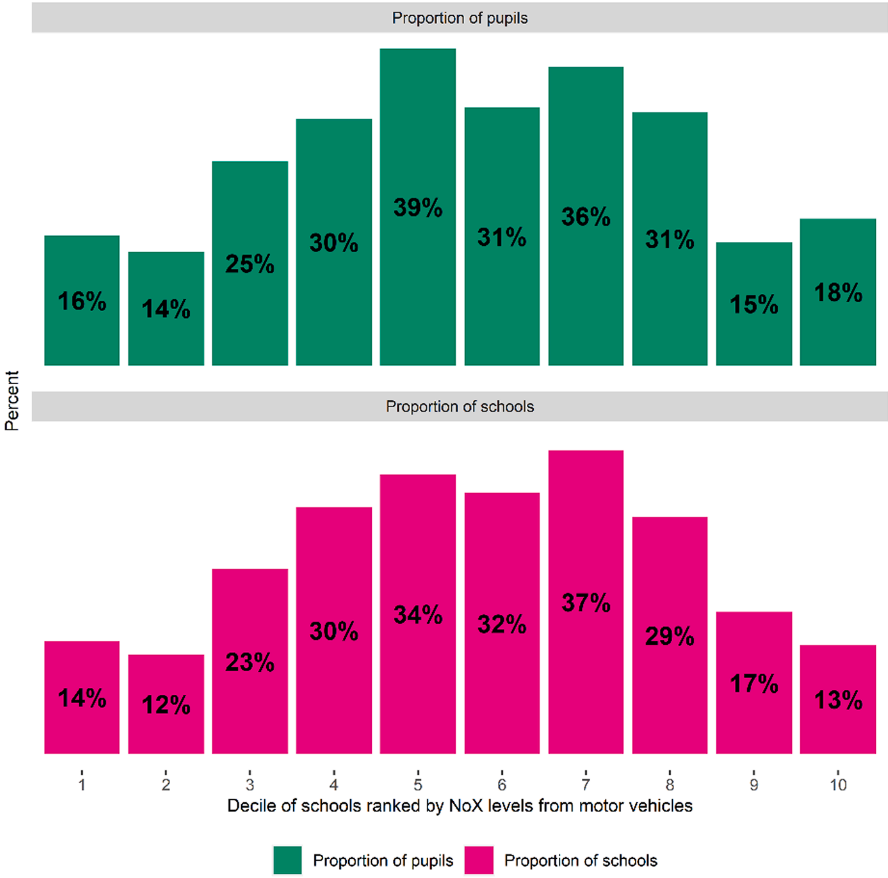

Fig. 11. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by NOx level from motor vehicles.

terms for these variables. Full details of the model diagnostics can be found in the supplementary material and the outputs from the additional GAM models are in Appendix F (see Fig. 23).

4. Results

4.1. Overall equity: A composite index of equity

In Fig. 3, all state primary schools have been ranked into deciles, such that the higher the composite index score, the higher the decile it falls into. An equitable distribution would have a higher proportion of schools/pupils attending schools with School Streets in the highest deciles. However, Fig. 3 shows little evidence of any increase or decrease in School Street proportions in the highest deciles with the highest index scores. Rather, a higher proportion of School Streets are found at schools in the centre of the index distribution, in what might be termed the most “average” schools on these measures.

Fig. 4 shows that the distribution of School Streets is more inequitable across inner London schools than those in outer London. Generally, in inner London there are higher proportions of schools and pupils in schools with lower equity index scores. At the most extreme, some 54 % of pupils in the third decile of schools attend a school with a School Street compared to only 23 % in the seventh decile of schools. In outer London, while there is some variation between deciles, on the whole School Streets appear somewhat equally but not equitably distributed.

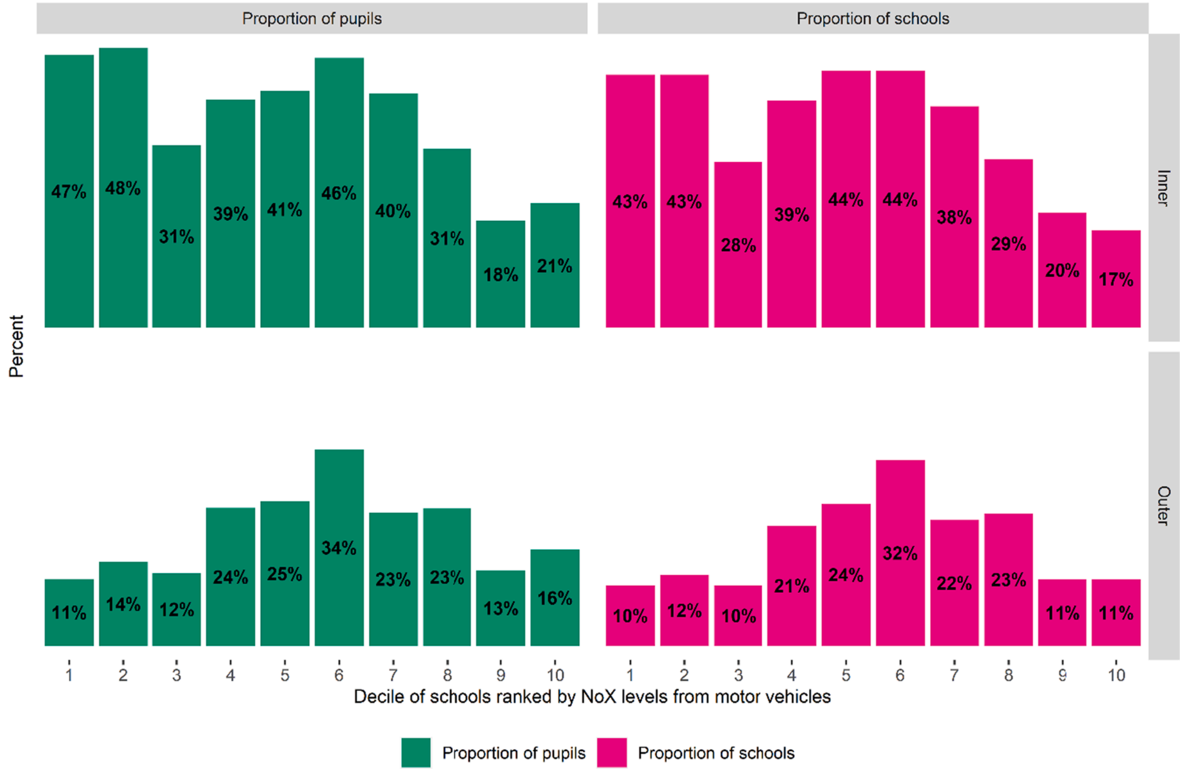

Fig. 12. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by NOx level from motor vehicles (inner and outer London).

Table 11
Regression summaries from three models predicting School Street presence at state-funded primary schools in Greater London.

	Dependent variable:		
	School Street (1) or not (0)		
	School-level only (1)	With local area variables (2)	Multilevel model with fixed effects (L2 = Borough (3)
Free school meals (% eligible)	**0.011* (0.005)**	0.006 (0.006)	0.004 (0.008)
Asian/Asian British (% pupils)	0.003 (0.003)	−0.002 (0.004)	0.004 (0.005)
Black/Black British (% pupils)	0.002 (0.004)	**−0.014* (0.006)**	−0.012 (0.007)
Mixed/Multiple ethnicity (% pupils)	**0.031* (0.012)**	0.023 (0.013)	0.012 (0.016)
Black/Black British (% of LSOA pop)		**0.033*** (0.009)**	**0.027* (0.011)**
IMD score		**−0.021* (0.008)**	**−0.034*** (0.010)**
Ratio of main roads to minor roads		−0.341 (0.315)	**−1.130** (0.381)**
NOx level from motor vehicles		**−0.017*** (0.005)**	**−0.021*** (0.005)**
Population density		**0.008*** (0.001)**	**0.005*** (0.001)**
Intercept	−1.881*** (0.218)	−1.663*** (0.246)	−0.972* (0.404)
Observations	1,739	1,728	1,728
Log Likelihood	−952.251	−904.503	−811.480
Akaike Inf. Crit.	1,914.502	1,829.006	1,644.960
Bayesian Inf. Crit.			1,704.962

Note: *p < 0.05**p < 0.01***p < 0.001.

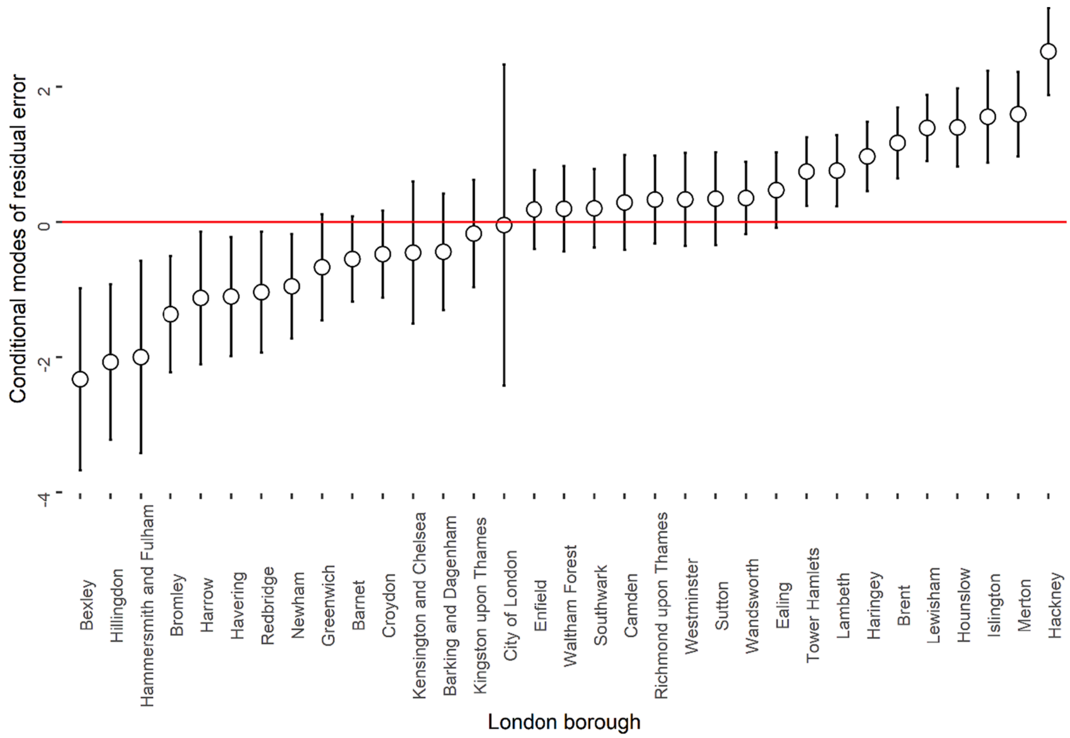

Fig. 13. Confidence intervals of residual error for London's district boroughs.

4.2. Spatial equity: District borough distribution

There is a clear geographical inequity in the spatial distribution of School Streets: 34.4 % of all inner London state-funded primary schools have School Streets in comparison to only 17.7 % for outer London where many boroughs are under-served (see Table 4). This fits closely with the strong positive relationship between School Streets and population density of the surrounding area (see Fig. 15, Appendix A). While some 30 out of 33 London boroughs have a School Street,[7] there is a significant concentration in the north-east of inner London in boroughs such as Hackney and Islington with other boroughs such as Hammersmith and Fulham and Bexley having no School Streets (Fig. 5).

There are currently 420 state-funded primary schools with School Streets implemented since March 2020. Based on the overall equity index, we have identified the 420 schools that *would have* received a School Street intervention if this policy had been implemented equitably according to the minimum standards approach. There is huge geographical variation here: in some boroughs (Hackney – 74 %, Lewisham 47 %, Brent, 45 %), a significant proportion of these most 'at need' schools have received School Streets (see Table 14, Appendix A). In others, the opposite is the case: in Newham for instance, only 6 School Streets have been implemented compared to a predicted 38 under an equitable Greater London distribution (see Table 13, Appendix A).

4.3. Socioeconomic equity

4.3.1. School-level deprivation (Free School Meals)

The proportion of students at School Street schools that are eligible for FSM in 2020–21 was 24.3 % - slightly higher than the 21.5 % at schools without a School Street. The implication is that, across Greater London, the student body of schools with School Streets is likely to reflect higher levels of socioeconomic deprivation than that at non-School Street Schools (Table 5).

The graphs in Fig. 6 rank schools into deciles by the proportion of pupils eligible for FSM, from the lowest 10 % (least deprived) of schools in the first decile to the highest 10 % (most deprived) in the tenth decile. Broadly, the distribution is equitable: with increasing proportions of pupils eligible for FSM, the proportion of schools that have a School Street and proportion of pupils attending a school with a School Street both increase. Indeed, some 31 % of schools in the top 10 % most deprived schools have a School Street – the highest figure at any decile.

This equitability of School Street distribution by FSM eligibility is driven by trends in inner London (see Table 6). The pattern is much more mixed when we consider each borough district as a separate entity. In fact, in only 6 of 22 districts, the proportion of pupils

[7] For analysis at the borough-level, boroughs are excluded if: a) they have fewer than five School Street interventions or; b) either fewer than 10% of the total state primary pupils attend a school with a School Street or fewer than 10% of the state primary schools have School Streets implemented.

eligible for FSM is higher at School Street schools than non-School Street schools. This shows quite how significantly the data is skewed by a) a small number of districts that simultaneously have higher levels of FSM eligibility overall; b) significantly higher eligibility at School Street schools; c) a greater proportion of pupils at School Street schools. It also indicates that while School Streets overall are more likely to be introduced at schools with more deprived student bodies, for most local districts this is not the case.

4.3.2. Area-level deprivation (Index of Multiple Deprivation)

The IMD ranks every LSOA in England by level of deprivation, using a score summarising several different variables. Table 7 presents the IMD score distribution across School Street and non-School Street school areas. Overall, on both median and mean values, the average IMD score is slightly higher in areas around School Street schools, implying a somewhat equitable distribution on this measure. However, we have also ranked each school into deciles based on the IMD score of the surrounding LSOA ranging from 1 (least deprived: lowest 10 % of scores) to 10 (most deprived: highest 10 % of scores). Overall, across London, there was a somewhat equal (rather than equitable) distribution of School Streets by deprivation in the surrounding area. In all but one decile, the proportion of schools that had School Streets is between 22 % and 28 %. An equitable distribution would have more clearly increasing proportions of School Street schools and pupils with increasing levels of area-level deprivation (Fig. 7 and 8).

While IMD encompasses educational levels, we also tested the bivariate association between the proportion of the population with degree-level qualifications and the presence of a School Street, finding a clear positive relationship: School Streets are disproportionately located in areas with more highly qualified populations (see Fig. 17, Appendix B).

4.4. Ethnic equity

It is somewhat unclear whether the distribution of pupils by ethnic group by School Street and non-School Street schools across Greater London is equitable. On the one hand, a slightly higher proportion of pupils at School Street schools are Black/Black British or have a Mixed ethnicity or multiple ethnicities and overall the non-White population at School Street schools is slightly higher (59.2 %) than at non-School Street schools (57.5 %). In contrast, 21.5 % of School Street school pupils are Asian/Asian British compared to 23.8 % at non-School Street schools. The equitability of the policy in this case depends on the ethnic group being considered (Table 8 and 9).

As with deprivation, the somewhat equal distribution of School Street schools by ethnic group is matched across inner and outer London, as can be seen in Fig. 9. However, at schools in inner London with School Streets there was a slightly higher proportion of White pupils and slightly lower proportion of Asian/Asian British than at non-School Street schools. There was significantly more variance by the more defined geography of London's districts, as shown by Fig. 19 in Appendix C. In some London districts, an inequitable distribution is evident. In Greenwich for example, only 13 % of pupils at schools with School Streets are Black/Black British compared to 32 % of pupils at schools without School Streets implemented. In Ealing, only 21 % of pupils at School Street schools are Asian/Asian British and some 40 % are White compared to 35 % and 27 % respectively at non-School Street schools.

In terms of the ethnic make-up of the areas surrounding School Streets, there is some evidence of a more equitable distribution: in both inner and outer London, there is a lower proportion of White residents and a higher proportion of Black/Black British residents in areas surrounding School Street Schools than non-School Street Schools. The relatively high levels of Black/Black British residents are particularly evident in inner London School Street areas. However, the opposite is true with Asian residents, where there is an under-representation in both inner and outer London areas.

4.5. Environmental equity

This section considers the distribution of School Streets according to three measures: 1) the characteristics of roads nearby to the school 2) modelled air pollution from motor vehicles at the school site.

4.5.1. Characteristics of the roads surrounding schools

Overall, across Greater London, there is an equal but not equitable distribution of School Street interventions according to how car-dominated the immediate local environment is. For example, within 500 m of the school, 71 % of the total road length is classified as 'local or minor' at School Street schools compared to 72 % at schools without School Streets (Fig. 10). The equivalent percentages for 'A roads, B roads and motorways' is 12 % at both School Street and non-School Street schools. The distribution by inner and outer London is also remarkably similar, though there is fairly significant geographical variation across London's boroughs (see Fig. 21, Appendix D).

4.5.2. Air pollution

Given the equal (but not equitable) distribution of School Streets by the car dominance of the local environment, it is unsurprising that the distribution of air pollution levels from motor vehicles is quite similar (see Table 10). The proportion of School Streets does not appear to be higher or lower in the most or least polluted schools (see Fig. 11). However, the proportion of School Streets is much higher at schools closer to the centre of the distribution, favouring schools with levels of air pollution closer to the average across all schools. For example, in schools in the fifth decile, 39 % of pupils attend a school with a School Street compared to just 16 % in the schools with lowest levels of air pollution and 18 % in schools with the higher levels of air pollution. Just 13 % of schools that have the poorest air quality have School Streets. The School Streets policy is not effectively reaching schools where children are likely to be most exposed to air pollution from motor vehicles.

The distribution of School Streets is significantly more inequitable by air pollution in inner London than outer London. A much higher proportion of School Streets have been implemented at schools in inner London with the lowest levels of air pollution than those with the highest. For example, some 43 % of the least polluted 10 % of schools have a School Street compared to just 17 % of the most polluted 10 % of school in inner London (see Fig. 12).

4.6. Summary of models

Three separate logistic regression models have been executed to predict a binary outcome: the presence of a School Street at each school. Model 1 uses only school-level explanatory variables; Model 2 uses school and local area variables; Model 3 is a multi-level random intercept model with district as the level 2 grouping variable. The model summaries are presented in Table 11. Versions of these models with normalised explanatory variables as well as a GAM version of Model 2 with smoothed terms (see Section 3.5) have also been executed. The model summaries can be found in Appendix F.

Although in Model 1 the proportion of students eligible for FSM and in Model 2 the proportion of Black/Black British pupils are positive and negative predictors respectively, after accounting for district in Model 3, there are no statistically significant predictors at the school-level. The implication is that, after accounting for local area characteristics and the specific borough district of each school, there is little evidence of school ethnic makeup, deprivation or attainment determining the presence of a School Street.

After accounting for the relationship between districts and School Streets in Model 3, IMD is a statistically significant negative predictor, implying that the higher the level of deprivation in the area surrounding the school, the lower the probability of a School Street. This is *precisely the opposite* of what we would expect to see under an equitable distribution by deprivation. In contrast, the proportion of Black/Black British residents in the surrounding area has a positive association with School Streets, in line with the findings in Section 4.4.

The environmental variables present evidence of an inequitable policy: overall, there was a statistically significant negative association between air pollution from motor vehicles (NOx levels) outside a school and the presence of School Streets. Similarly, the more car dominated the area around a school (the ratio of main to minor roads), the lower the probability of a School Street being present. These two findings are broadly confirmed in the GAM models: although the partial effects plots (see Fig. 23, Appendix F) present the road ratio variable as having a non-monotonic relationship with the outcome, there is not sufficient confidence to confirm anything other than the probability of a School Street is significantly lower in the most compared to the least car dominated school areas. While School Streets are disproportionately being implemented in more densely populated parts of London, it is evident that – after controlling for demographics, population density and borough – they are still less likely to be implemented in car-dominated, polluted environments where they may be of most benefit.

Overall, the variance of 1.29 for the district-level random effect indicates that there is substantial within-school variance that is explained by the differences across borough districts. This district-level geographical inequality in the distribution of School Streets is exemplified most clearly by the plot of the conditional modes of residual error for each borough in Fig. 13. This shows the borough-level (L2) residuals and their associated standard errors to explore the variation in School Streets interventions across local authorities in London. The residuals in this plot can be understood as the estimated borough-level effect on the probability of their schools having a School Street. Where the confidence intervals cross the x-axis – as is the case for many district boroughs (e.g., Enfield), there is no statistically significant effect. However, there are positive effects associated with some boroughs, most notably Hackney. At the other end of the spectrum, there is a negative effect associated with a school being in Hillingdon, Hammersmith and Fulham, Bexley, Bromley, Newham and Redbridge.

To further demonstrate the effect of this geographical inequality in distribution, the multi-level model has then been used to predict the probability for a random group of the same schools (keeping their school and area-level characteristics) that it would have a School Street if it were (hypothetically) located in Hackney (most positive association), Richmond upon Thames (neutral) and Hillingdon (most negative). Taking one example from the table (see Table 22, Appendix E) – Perivale Primary School: if it were located in Hillingdon, the predicted probability of a School Street is 0.05; in Richmond upon Thames it is 0.38; and in Hackney it is 0.84. This is clear evidence of the way in which the district-level implementation of School Streets has resulted in substantial geographical inequalities in access to School Streets.

5. Discussion

5.1. Overview

In assessing the equity of School Street measures, we have employed a minimum standards approach, based on school and area-level measures of socioeconomic deprivation, ethnicity, the local road network, and air quality. Combining these variables into one index score, we find clearer evidence of a broadly equal rather than equitable distribution of School Streets. From a minimum standards approach to equity, schools that should be prioritised are those with high levels of pollution, car dominance, deprivation, and a non-White population. This research finds that these schools are no more or less likely to have a School Street intervention than schools that would be considered less of a priority. When this same comparison is made between inner and outer London, School Streets in inner London appear to be more inequitably distributed than those in outer London. We also find an uneven spatial distribution of School Streets across London's geography that is not accounted for solely by demographic or local area characteristics. Of the 420 School Streets that have been installed since the pandemic, only 103 of these are at schools deemed a priority by our definition of minimum standards (see Appendix A Table 14).

Our first research question asks how the equity of School Streets varies by different indicators – socioeconomics, ethnicity, and local environment. While overall the analysis has shown more evidence of equality than equity in School Streets distribution, this varies significantly across the different indicators considered. Perhaps the most notable findings are in relation to the local environment, where rates of School Street provision are lower at both the most and least polluted School-areas in London. In inner London, School Street provision is generally lower at schools with higher levels of air pollution from motor vehicles. Consistent with this finding, air quality is also a statistically significant negative predictor of School Street provision in the regression models. This is perhaps surprising given that the local road characteristics – a proxy for car dominance – of School Streets and non-School Street schools are very similar. However, when the effects of districts on School Street variance is accounted for, the ratio of main to minor roads becomes a significant negative predictor. This reveals that once the uneven spatial School Street provision by districts is accounted for, School Streets are more likely to be implemented at schools in less car-dominated local environments.

At the school-level, there is agreement with the findings of Hopkinson et al (2021) - that School Streets tend towards more deprived schools (by FSM). Pupils from more deprived households are somewhat more likely to benefit from School Streets, implying a more equitable distribution at this level. In contrast, there is more tentative evidence of inequitable effects on the local area population, where, after accounting for other characteristics, more deprived areas are less likely to receive a School Street intervention. This repeats the complex picture found in the literature review, with both Covid-19 road reallocation schemes, as well as wider active travel infrastructure reporting contrasting findings on the equitability of interventions in terms of deprivation.

For ethnicity, there is limited evidence of significant differences between student bodies at School Street and non-School Street schools and little evidence of a particularly equitable distribution, reflected in the non-significance of pupil-level ethnicity in the regression analysis. At the area-level, there is some evidence that School Streets favour Black/Black British residents, with the category remaining a significant positive predictor even once the effect of district areas is accounted for in the multi-level model. This supports findings in Aldred et al (2021) that Low Traffic Neighbourhood measures installed in London during the initial stages of the pandemic also favoured Black residents, with Asian residents under-represented – a tendency also present in our descriptive findings. This is a positive finding in relation to ethnic equity, given that research has found Black children are over-represented in London's road traffic injury statistics (Steinbach et al., 2007).

Overall, the inequitable distribution of School Streets in relation to air pollution and to some extent the car dominance of local environments is perhaps the clearest finding of this research. By ameliorating air pollution and supporting children and carers' active mobilities, School Streets have the potential to attend to existing transport inequities. However, ensuring that they are also distributed equitably is central to the effectiveness on the policy writ-large both in terms of fairness but also the more prosaic scheme goals of facilitating children's safe and unpolluted active travel. Targeting, whether through School Streets or through complementary measures at city- or street-level, the schools most in need of mitigation against the effects of automobile dominance, as well as on socio-demographic groups most disadvantaged by transport goods and burdens, will likely see the greatest population benefit while attending to issues of transport justice.

Studies of transport equity have tended to focus on the relationship between socio-demographic variables either in relation to access to transport infrastructure or to environmental exposure of its negative effects (Lucas and Jones, 2012). However, the environmental context of car dominance and its effects on air quality is also a key element of equity when assessing interventions targeted at children's active transport. When assessing these variables, we have found the equity of the local environment to be at least as significant as many socio-demographic indicators.

5.2. Barriers and potential solutions to achieving School Street equity

There are two primary barriers to achieving an equitable distribution of School Streets in London. The first is that temporary closures are not a suitable intervention at all schools, with authorities unable or unwilling to close the most highly trafficked roads for a School Street. Although the least polluted schools in London also have lower-levels of School Streets, and with perhaps as many as 42 %[8] of state primary schools likely suitable and still without School Streets, we can still expect the air quality and car dominance inequity observed here to be in part attributable to the most polluted and most main-road heavy schools being less suitable for School Streets. A limitation of this research is that we cannot define a measure of school suitability[9] and assess the extent to which suitability drives the overall findings of equity on different dimensions. It also reflects a limitation with School Streets measures as they are currently construed, and it may have long-term equity implications for the policy at the very least in terms of supporting the active mobility of all children.

Possible solutions to this issue of suitability may include expanding the scope of measures used to improve the streets at schools so that more schools can be treated. In Barcelona for example, for schools on busier streets, single lanes, parking spaces or non-essential sections of the main vehicle lanes have been reclaimed and protected from motor traffic to provide space for informal play. In addition, improved crossing facilities may attend to road danger issues, and the use of vegetated green screens have shown some evidence of limiting air pollution at schools (Tremper and Green, 2018). In addition, transport authorities could be bolder with regards to the streets they consider suitable for a temporary School Street closure, including some less essential 'B' class roads in London.

The second critical barrier to achieving equitable distribution in part addresses our second research question asking at which geographies the distribution of School Streets is (in)equitable. This analysis has shown that the distribution of School Streets across

[8] Calculated from estimates on eligibility in Hopkinson et al. (2021).

[9] While it is possible to identify the road classification of the main entrance of most primary schools, any measure of suitability would need to consider how many other school entrances there are, if they are located on minor roads and the variation in traffic levels even within school roads that are classified as 'A', 'B' or 'local or minor'.

London is spatially uneven, with some districts having much more extensive School Street policies than others. It is clear from the multi-level model that these district-level effects are not simply attributable to sociodemographic differences at school or area-level.

This discrepancy is likely in part a consequence of the UK's multi-level governance approach to transport policy, with local governments holding considerable power over key domains (Marsden and Rye, 2010). In London, this tendency intersects with what has been called 'ungovernability' of global city-regions – the process whereby fragmented local policy dynamics thwart regional efforts to develop metropolitan areas as a whole (O'Brien et al., 2019). As compared with other global cities, London's local regional governments have significant power over certain policy areas with different local priorities often dictating city-wide spatial patterns of provision. Policy efforts could therefore be directed not only towards achieving a more equitable distribution of School Streets within each district, but also towards addressing issues in local government capabilities and resources that might mitigate these between-district discrepancies. Providing funding for specific schools identified as in-need within non-participating districts may help. City-wide efforts to improve air quality such as London's recently expanded Ultra Low Emissions Zone will also go some way to help air quality issues at many schools in districts currently under-served by School Street policies.

6. Conclusion

By the minimum standards approach to equity used in this paper, School Streets appear to be equitably distributed *only* in terms of the deprivation of London's school population as well as for some ethnic groups. Some areas in London have significantly more extensive School Street schemes than others and School Streets are under-represented at schools with the highest levels of air pollution from motor vehicles in London.

This finding demonstrates the importance of considering the wider environmental context in an analysis of equity. Who is doing the travelling matters in studies of transport infrastructure equity. For interventions that support the mobility of children, air pollution is a key dimension of equity, as children are more exposed to air pollution at an area level, and it is more damaging to their health. Existing research has reported the inequity of children's' exposure to air pollution and road danger. Less, however, is known about the (in) equity of measures to ameliorate these effects. This paper contributes to this growing research, focusing on a novel and promising urban intervention and extending a conception of equity beyond a focus on socio-demographic indicators.

These findings should be of interest to policy makers introducing active travel infrastructure at schools or assessing the outcomes of Covid-19 road space reallocation schemes. This paper proposes that more flexible typologies of School Street-style interventions suitable for busier roads may be needed to better serve a wider range of schools, and to alleviate some of the air-quality based inequity found here. Furthermore, research and policy development may help to better understand and address the under-participation found in several of London's districts and improve equality across London's administrative geography.

Measures like School Streets have the potential to address the wider inequities in transport systems that undervalue the mobility of children and mobilities of care. However, as interventions in urban space they too must be distributed equitably. This research finds promising signs but by some measures there is work still to be done. Further research on the topic should seek to measure the benefits of London's School Streets. The equity of this policy could then be assessed not only in terms of the distribution of investment but also in terms of its actual outcome.

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CRediT authorship contribution statement

Asa Thomas: Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Jamie Furlong:** Conceptualization, Methodology, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Rachel Aldred:** Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. District borough distribution

Tables 12-15.
Figs. 14 and 15.

Table 12
The distribution of School Street and non-School Street state primary schools across Greater London's boroughs (April 2022).

Local Authority	Schools				Pupils			
	Counts		Percentages		Counts		Percentages	
	Non-School Street	School Street	Non-School Street	School Street	Non-School Street	School Street	Non-School Street	School Street
Barking and Dagenham	38	5	88.37	11.63	21,424	3,575	85.7	14.3
Barnet	80	10	88.89	11.11	27,060	3,766	87.78	12.22
Bexley	59	0	100	0	22,935	0	100	0
Brent	33	25	56.9	43.1	14,588	10,964	57.09	42.91
Bromley	73	4	94.81	5.19	26,515	1,484	94.7	5.3
Camden	27	11	71.05	28.95	6,799	3,358	66.94	33.06
City of London	1	0	100	0	270	0	100	0
Croydon	64	11	85.33	14.67	22,103	4,981	81.61	18.39
Ealing	52	16	76.47	23.53	23,392	7,935	74.67	25.33
Enfield	54	14	79.41	20.59	23,761	7,546	75.9	24.1
Greenwich	53	6	89.83	10.17	21,649	2,735	88.78	11.22
Hackney	11	39	22	78	3,375	12,745	20.94	79.06
Hammersmith and Fulham	36	0	100	0	9,928	0	100	0
Haringey	38	24	61.29	38.71	12,422	8,705	58.8	41.2
Harrow	38	3	92.68	7.32	20,141	1,755	91.98	8.02
Havering	56	4	93.33	6.67	22,021	1,751	92.63	7.37
Hillingdon	67	1	98.53	1.47	28,624	616	97.89	2.11
Hounslow	27	21	56.25	43.75	12,281	10,471	53.98	46.02
Islington	14	19	42.42	57.58	4,678	5,146	47.62	52.38
Kensington and Chelsea	23	3	88.46	11.54	5,593	924	85.82	14.18
Kingston upon Thames	27	7	79.41	20.59	10,195	3,420	74.88	25.12
Lambeth	37	23	61.67	38.33	11,663	9,444	55.26	44.74
Lewisham	32	33	49.23	50.77	9,946	14,168	41.25	58.75
Merton	18	23	43.9	56.1	7,050	9,345	43	57
Newham	57	6	90.48	9.52	29,190	3,946	88.09	11.91
Redbridge	45	4	91.84	8.16	25,759	2,114	92.42	7.58
Richmond upon Thames	33	12	73.33	26.67	12,698	4,614	73.35	26.65
Southwark	50	16	75.76	24.24	15,163	5,409	73.71	26.29
Sutton	29	11	72.5	27.5	12,932	6,082	68.01	31.99
Tower Hamlets	44	24	64.71	35.29	15,427	10,036	60.59	39.41
Waltham Forest	35	13	72.92	27.08	15,369	8,488	64.42	35.58
Wandsworth	42	20	67.74	32.26	12,652	7,168	63.83	36.17
Westminster	26	12	68.42	31.58	5,937	2,991	66.5	33.5

Table 13
The difference between the counts and proportions of actual School Street schools and an equitable distribution of the same number of School Street schools in different district boroughs (based on the Index of Equity).

District	Actual School Street Schools				Predicted School Street Schools				Difference	
	Count		Percent		Count		Percent		Percentage point	
	Schools	Pupils	Schools	Pupils	Schools	Pupils	Schools	Pupils	Schools	Pupils
Merton	23	9345	56.1	57	6	1762	14.63	10.75	41.47	46.25
Lewisham	33	14,168	50.77	58.75	15	4520	23.08	18.74	27.69	40.01
Sutton	11	6082	27.5	31.99	0	0	0	0	27.5	31.99
Hackney	39	12,745	78	79.06	23	7746	46	48.05	32	31.01
Waltham Forest	13	8488	27.08	35.58	5	1838	10.42	7.7	16.66	27.88
Richmond upon Thames	12	4614	26.67	26.65	0	0	0	0	26.67	26.65
Wandsworth	20	7168	32.26	36.17	9	2153	14.52	10.86	17.74	25.31
Hounslow	21	10,471	43.75	46.02	11	4799	22.92	21.09	20.83	24.93
Kingston upon Thames	7	3420	20.59	25.12	2	944	5.88	6.93	14.71	18.19
Islington	19	5146	57.58	52.38	13	3459	39.39	35.21	18.19	17.17
Haringey	24	8705	38.71	41.2	17	5756	27.42	27.24	11.29	13.96
Brent	25	10,964	43.1	42.91	20	8393	34.48	32.85	8.62	10.06
Enfield	14	7546	20.59	24.1	10	4766	14.71	15.22	5.88	8.88
Lambeth	23	9444	38.33	44.74	24	7652	40	36.25	−1.67	8.49
Havering	4	1751	6.67	7.37	0	0	0	0	6.67	7.37
Barnet	10	3766	11.11	12.22	4	1500	4.44	4.87	6.67	7.35

(continued on next page)

Table 13 (*continued*)

District	Actual School Street Schools				Predicted School Street Schools				Difference	
	Count		Percent		Count		Percent		Percentage point	
	Schools	Pupils	Schools	Pupils	Schools	Pupils	Schools	Pupils	Schools	Pupils
Harrow	3	1755	7.32	8.02	1	420	2.44	1.92	4.88	6.1
Bromley	4	1484	5.19	5.3	0	0	0	0	5.19	5.3
Barking and Dagenham	5	3575	11.63	14.3	5	2711	11.63	10.84	0	3.46
Hillingdon	1	616	1.47	2.11	3	1056	4.41	3.61	−2.94	−1.5
Greenwich	6	2735	10.17	11.22	8	3425	13.56	14.05	−3.39	−2.83
Bexley	0	0	0	0	3	979	5.08	4.27	−5.08	−4.27
Ealing	16	7935	23.53	25.33	26	9446	38.24	30.15	−14.71	−4.82
Westminster	12	2991	31.58	33.5	15	3691	39.47	41.34	−7.89	−7.84
Camden	11	3358	28.95	33.06	15	4275	39.47	42.09	−10.52	−9.03
Redbridge	4	2114	8.16	7.58	8	4890	16.33	17.54	−8.17	−9.96
Croydon	11	4981	14.67	18.39	23	8014	30.67	29.59	−16	−11.2
Southwark	16	5409	24.24	26.29	39	10,811	59.09	52.55	−34.85	−26.26
Hammersmith and Fulham	0	0	0	0	11	2814	30.56	28.34	−30.56	−28.34
Kensington and Chelsea	3	924	11.54	14.18	12	3149	46.15	48.32	−34.61	−34.14
Tower Hamlets	24	10,036	35.29	39.41	53	20,195	77.94	79.31	−42.65	−39.9
Newham	6	3946	9.52	11.91	38	20,734	60.32	62.57	−50.8	−50.66
City of London	0	0	0	0	1	270	100	100	−100	−100

Table 14
The counts and proportions of predicted schools with School Streets (according to an equitable distribution) that are actual schools with School Streets in different district boroughs.

District	Predicted School Street Schools		Predicted Schools That Are Actual School Street Schools			
	Counts		Counts		Percentage	
	Schools	Pupils	Schools	Pupils	Schools	Pupils
Hackney	23	7746	17	5300	73.91	68.42
Lewisham	15	4520	7	2480	46.67	54.87
Brent	20	8393	9	4130	45	49.21
Waltham Forest	5	1838	2	879	40	47.82
Tower Hamlets	53	20,195	18	7795	33.96	38.6
Enfield	10	4766	3	1740	30	36.51
Islington	13	3459	5	1038	38.46	30.01
Camden	15	4275	4	1257	26.67	29.4
Southwark	39	10,811	10	2993	25.64	27.68
Lambeth	24	7652	7	2105	29.17	27.51
Westminster	15	3691	3	929	20	25.17
Haringey	17	5756	4	1354	23.53	23.52
Hounslow	11	4799	2	648	18.18	13.5
Ealing	26	9446	4	1251	15.38	13.24
Merton	6	1762	1	225	16.67	12.77
Croydon	23	8014	2	936	8.7	11.68
Newham	38	20,734	4	2417	10.53	11.66
Wandsworth	9	2153	1	198	11.11	9.2
Barking and Dagenham	5	2711	0	0	0	0
Barnet	4	1500	0	0	0	0
Bexley	3	979	0	0	0	0
City of London	1	270	0	0	0	0
Greenwich	8	3425	0	0	0	0
Hammersmith and Fulham	11	2814	0	0	0	0
Harrow	1	420	0	0	0	0
Hillingdon	3	1056	0	0	0	0
Kensington and Chelsea	12	3149	0	0	0	0
Kingston upon Thames	2	944	0	0	0	0
Redbridge	8	4890	0	0	0	0

Table 15
Summary statistics: population density by school status.

School status	n	min	Q0.25	mean	median	Q0.75	max	sd
School Street school	420	6.1	67.4	114.2	105.4	152.8	442.2	61.3
Non-School Street school	1318	1.2	47.7	88.1	75.4	117.7	363.1	57.1

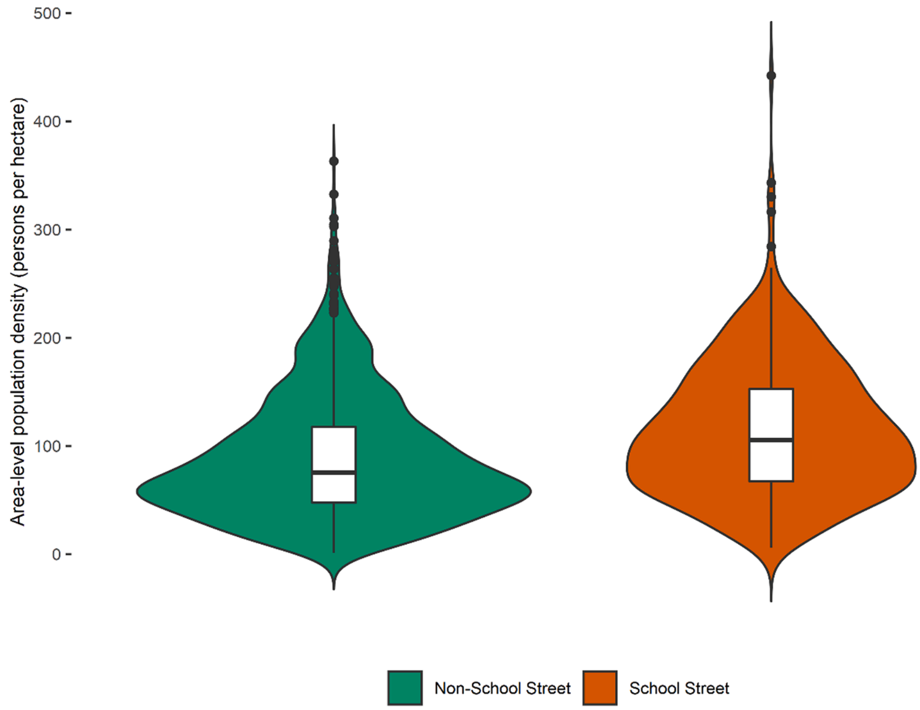

Fig. 14. The distribution of population density in LSOAs surrounding School Street and non-School Street schools.

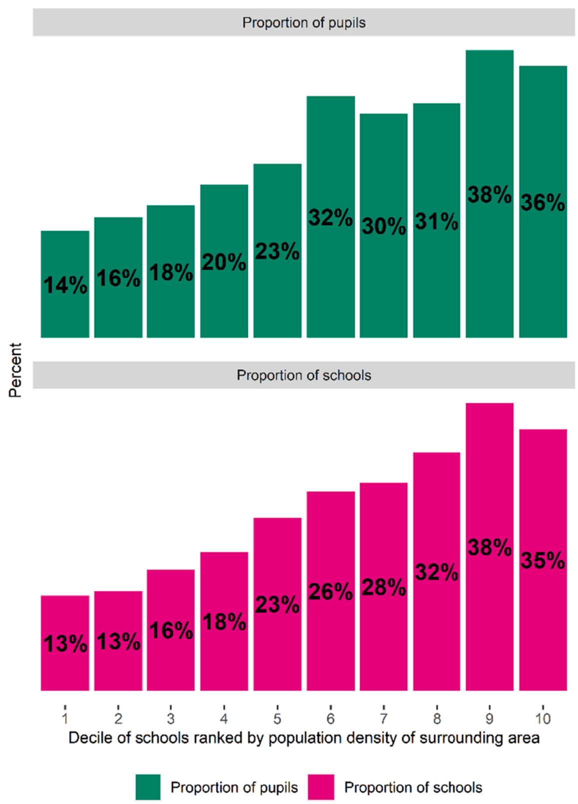

Fig. 15. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by population density of the surrounding LSOA.

Appendix B. Socioeconomic equity

Tables 16 and 17.
Figs. 16 and 17.

Table 16
Total and proportion of pupils eligible for FSM by school status (inner and outer London).

Geography	School status	Total pupils	Total pupils eligible for FSM	Percent of pupils eligible for FSM
Inner London	Non-School Street	143,043	41,690	29.1
Inner London	School Street	84,040	24,737	29.4
Outer London	Non-School Street	370,497	69,202	18.7
Outer London	School Street	91,642	16,175	17.7

Table 17
Total and proportion of pupils eligible for FSM by school status and district borough.

District borough	Non-School Street			School Street		
	Pupils	Pupils eligible for FSM	Percent pupils eligible for FSM	Pupils	Pupils eligible for FSM	Percent pupils eligible for FSM
Barking and Dagenham	21,424	4,951	23.1	3,575	693	19.4
Barnet	27,060	4,496	16.6	3,766	874	23.2
Brent	14,588	2,332	16	10,964	1,875	17.1
Camden	6,799	2,478	36.4	3,358	1,297	38.6
Croydon	22,103	6,395	28.9	4,981	1,170	23.5
Ealing	23,392	5,126	21.9	7,935	1,625	20.5
Enfield	23,761	5,521	23.2	7,546	1,828	24.2
Greenwich	21,649	5,540	25.6	2,735	451	16.5
Hackney	3,375	1,039	30.8	12,745	4,760	37.3
Haringey	12,422	2,578	20.8	8,705	1,948	22.4
Hounslow	12,281	2,375	19.3	10,471	2,052	19.6
Islington	4,678	1,844	39.4	5,146	1,884	36.6
Kingston upon Thames	10,195	1,406	13.8	3,420	322	9.4
Lambeth	11,663	4,066	34.9	9,444	2,741	29
Lewisham	9,946	2,236	22.5	14,168	2,980	21
Merton	7,050	1,676	23.8	9,345	1,724	18.4
Newham	29,190	7,581	26	3,946	948	24
Richmond upon Thames	12,698	1,409	11.1	4,614	437	9.5
Southwark	15,163	4,910	32.4	5,409	1,940	35.9
Sutton	12,932	2,395	18.5	6,082	687	11.3
Tower Hamlets	15,427	5,325	34.5	10,036	3,712	37
Waltham Forest	15,369	3,179	20.7	8,488	1,572	18.5
Wandsworth	12,652	2,925	23.1	7,168	1,619	22.6
Westminster	5,937	2,019	34	2,991	729	24.4
Total	351,754	83,802		167,038	39,868	

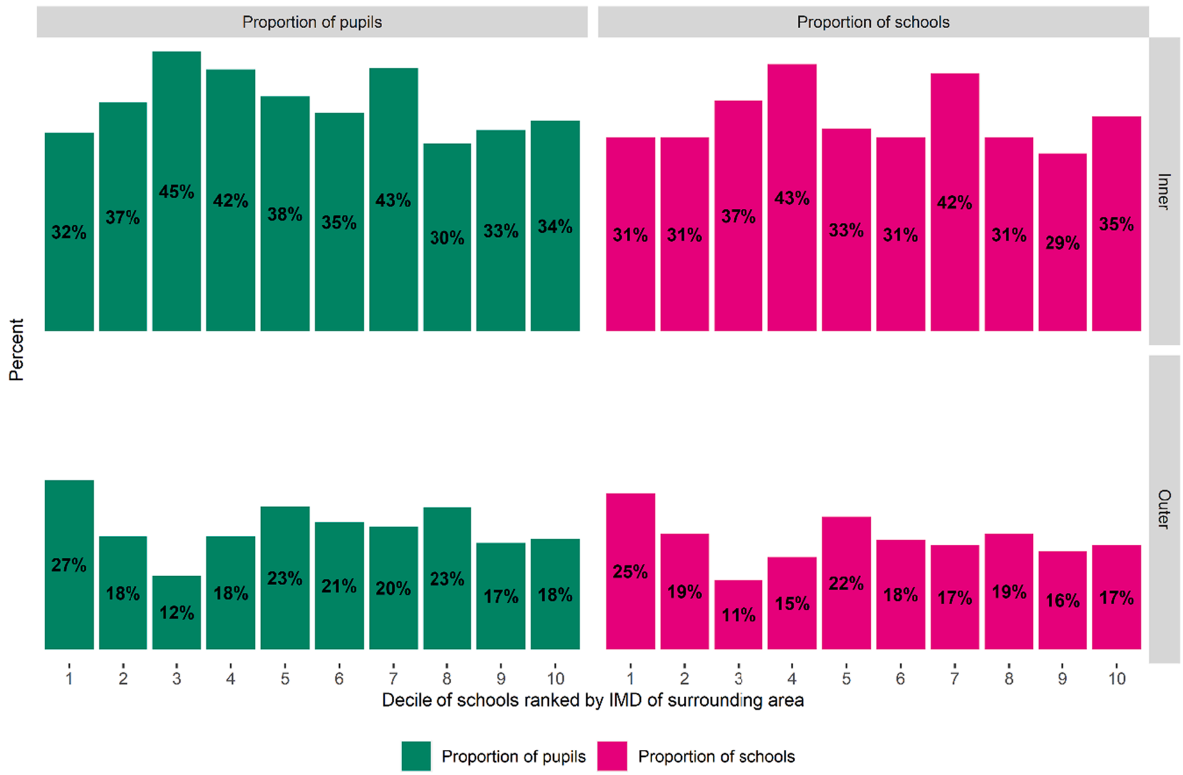

Fig. 16. The proportion of pupils attending a school with a School Street and the proportion of schools with a School Street by decile of school ranked by IMD score of surrounding area (inner and outer London).

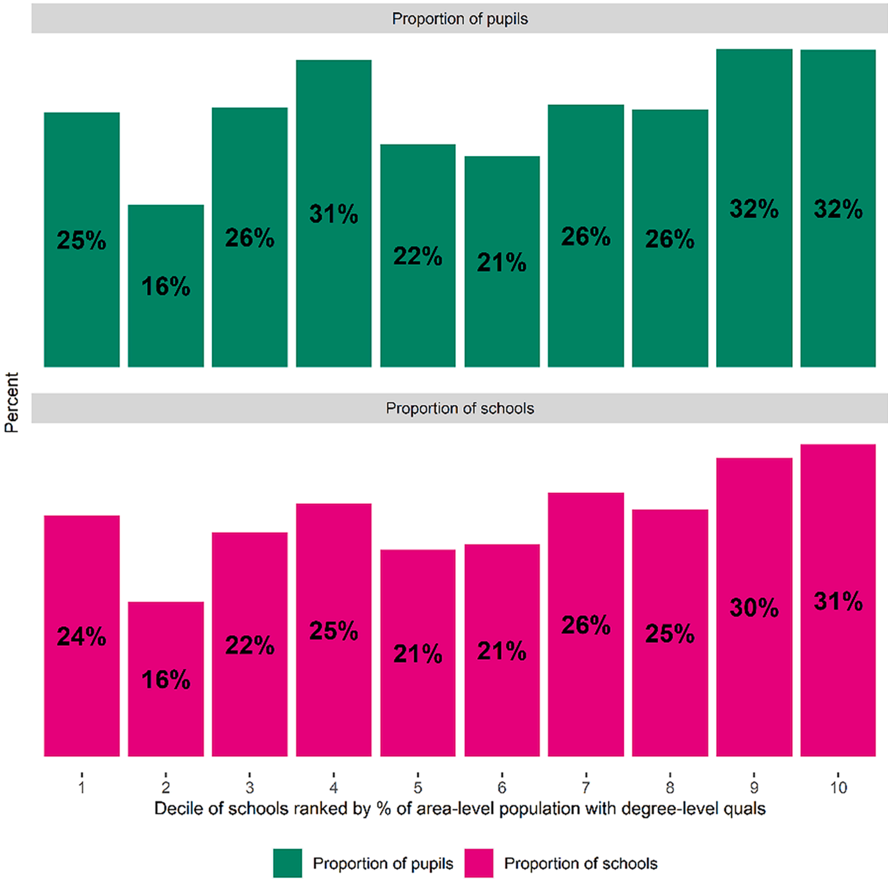

Fig. 17. Proportion of population with degree-level qualifications in LSOA around School Street and non-School Street schools.

Appendix C. Ethnic equity

Table 18.
Figs. 18 and 19.

Table 18
Breakdown of pupils by ethnic group by school status (inner and outer London).

Geography	School status	Count of pupils					Percent of pupils				
		White	Mixed or multiple	Asian/ Asian British	Black/ Black British	Other	White	Mixed or multiple	Asian/ Asian British	Black/ Black British	Other
Inner London	Non-School Street	46,092	18,266	32,862	32,412	10,341	32.93	13.05	23.48	23.16	7.39
	School Street	30,041	11,559	16,761	19,429	4,599	36.46	14.03	20.34	23.58	5.58
Outer London	Non-School Street	168,011	39,829	86,996	50,557	19,085	46.1	10.93	23.87	13.87	5.24
	School Street	41,602	10,221	21,095	11,243	5,778	46.26	11.36	23.45	12.5	6.42

Fig. 18. Breakdown of pupils by ethnic group by school status.

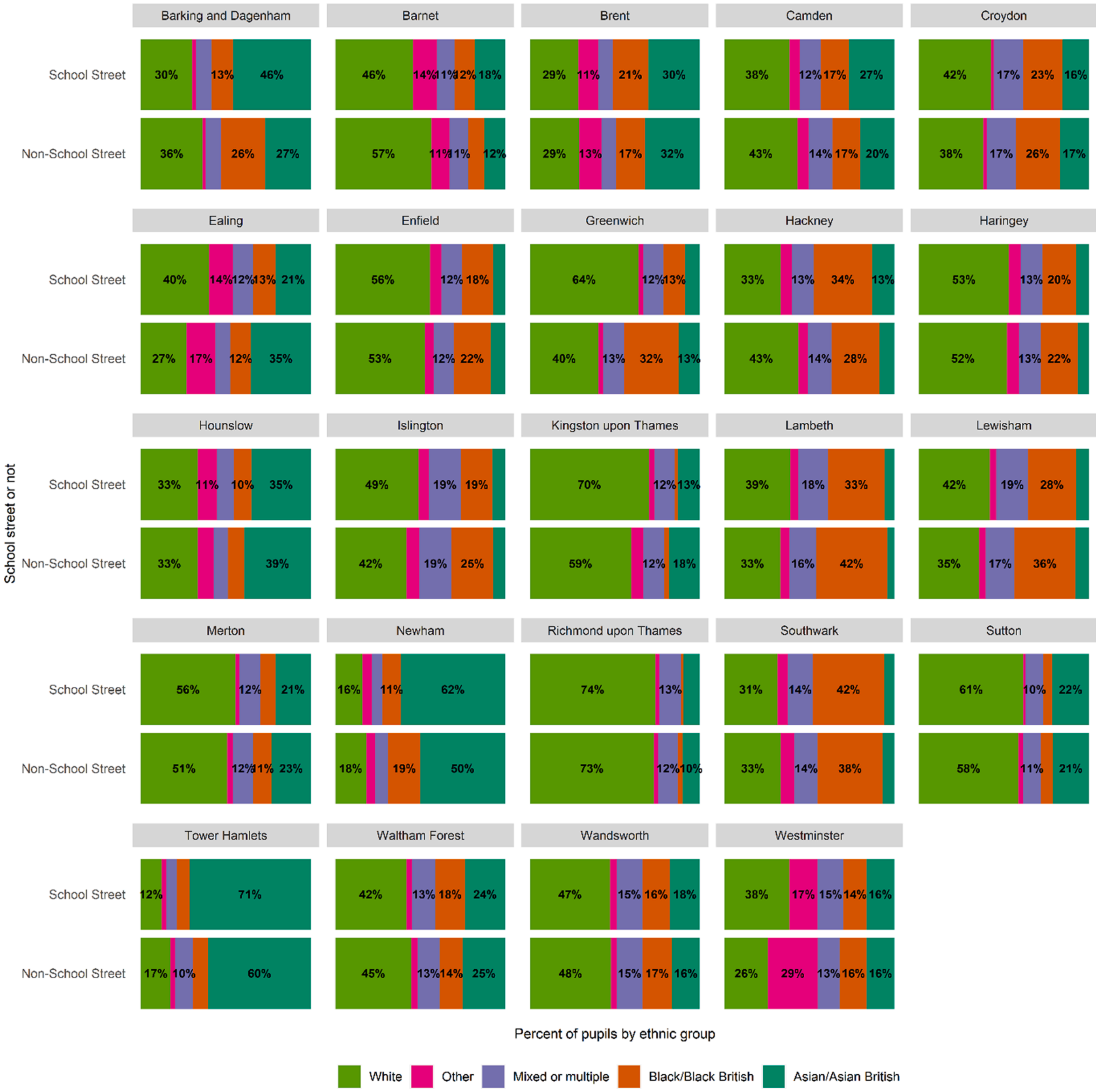

Fig. 19. Breakdown of pupils by ethnic group by school status and district borough.

Appendix D. Environmental equity

Tables 19-21.
Figs. 20-22.

Table 19
Road classification of roads in surrounding area of School Street and non-School Street schools.

School status	Road class	Within 500 m of school		Within 1000 m of school		Within 75th percentile of travel to school distance	
		Road length (m)	Percent of road length	Road length (m)	Percent of road length	Road length (m)	Percent of road length
Non-School Street	A road, B road or motorway	1,106,657	11.7	4,088,185	12.2	7,646,277	12.2
	Local or minor road	6,782,323	71.9	23,702,758	70.5	43,948,468	70.0
	Restricted/Access road	1,538,174	16.3	5,808,063	17.3	11,231,580	17.9
School Street	A road, B road or motorway	366,235	11.8	1,483,370	13.3	2,059,989	12.9
	Local or minor road	2,204,525	70.9	7,694,238	69.1	11,041,012	69.2
	Restricted/Access road	538,145	17.3	1,950,727	17.5	2,856,954	17.9

Table 20
Road classification of roads within 500 m of School Street and non-School Street schools (inner and outer London).

Geography	School status	Road class	Within 500 m of school	
			Road length (m)	Percent of road length
Inner London	Non-School Street	A road, B road or motorway	529,861	10.1
		Local or minor road	2,445,794	70.2
		Restricted/Access road	510,145	14.7
	School Street	A road, B road or motorway	234,342	8.8
		Local or minor road	1,251,941	71.2
		Restricted/Access road	271,763	15.5
Outer London	Non-School Street	A road, B road or motorway	576,796	10
		Local or minor road	4,336,529	73
		Restricted/Access road	1,028,029	17.5
	School Street	A road, B road or motorway	131,893	8.9
		Local or minor road	952,584	70.5
		Restricted/Access road	266,382	19.8

Table 21
Distribution of NOx levels from motor vehicles by school status (inner and outer London).

Geography	School status	n	min	Q0.25	mean	median	Q0.75	max	sd
Inner London	School Street school	229	10.7	13.7	17.6	15.5	17.2	72.2	9.4
	Non-School Street school	435	10.9	14.3	23.5	16.2	20.2	148.9	19.7
Outer London	School Street school	188	6.4	11.3	16.6	12.8	15	122.7	14.5
	Non-School Street school	879	5.5	10.6	18.6	12.4	16.4	131.1	16.3

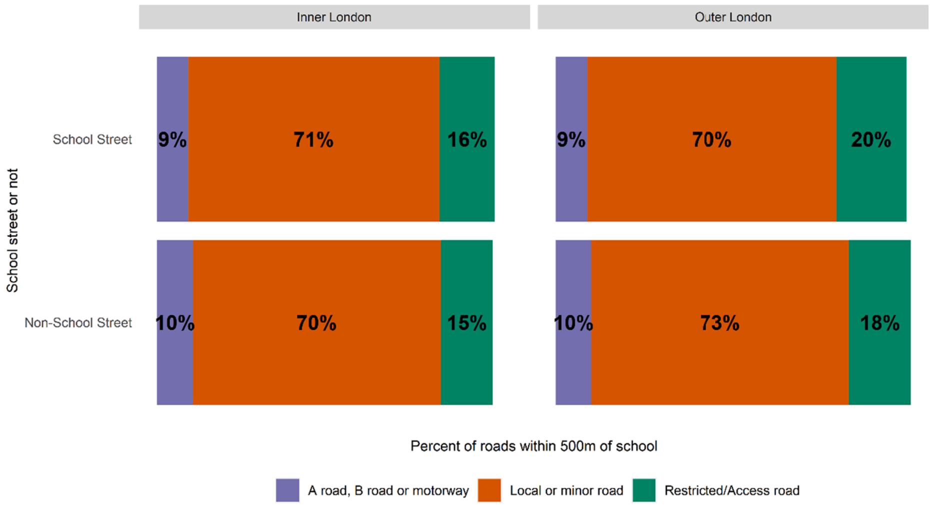

Fig. 20. Road classification of roads within 500 m of School Street and non-School Street schools (inner and outer London).

Fig. 21. Road classification of roads within 500 m of School Street and non-School Street schools by district boroughs.

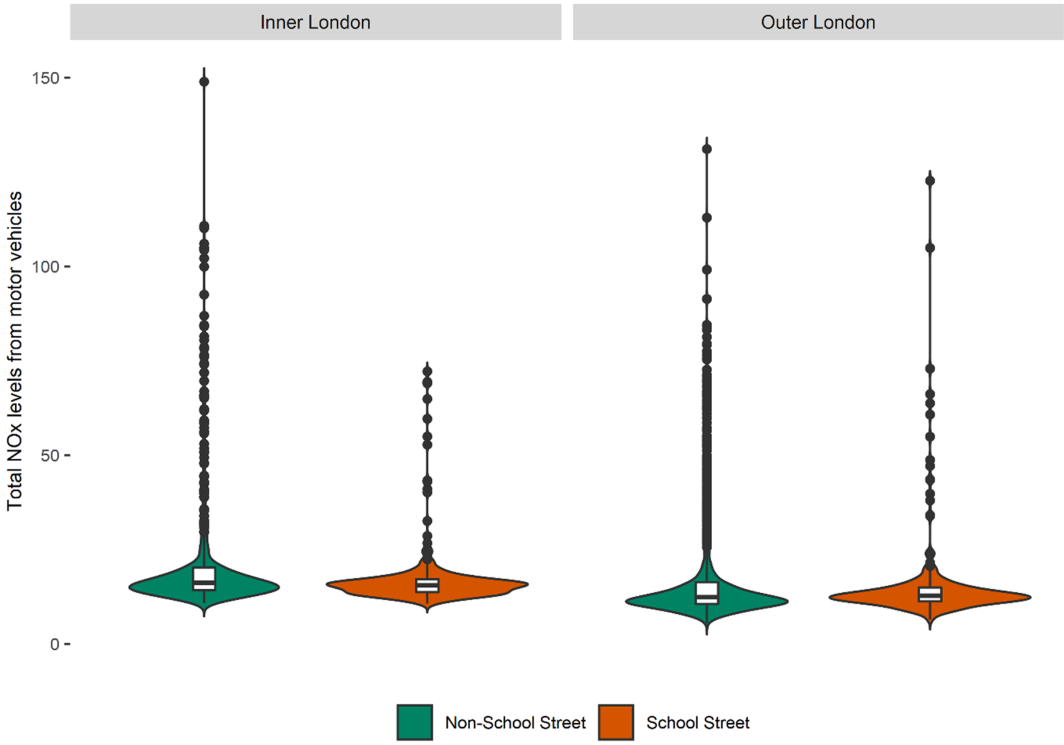

Fig. 22. Distribution of NOx levels from motor vehicles by school status.

Appendix E. Model predictions

Table 22.

Table 22
Predicted probability of schools having a School Street based on their hypothetical location in different district boroughs.

	Pupils (%)			LSOA (%)		LSOA		Local env.		Model probabilities		
School	FSM	Asian / Asian British	Black / Black British	Mixed or multiple	Black / Black British	IMD Score	Pop density	Road ratio	NOx level	Richmond upon Thames	Hackney	Hillingdon
Barnehurst Junior School	11	7	5	7	4	11	49	0	10	0.28	0.77	0.03
Coldfall Primary School	9	7	4	17	12	26	60	0	11	0.29	0.78	0.03
Cooper's Lane Primary School	19	11	19	18	20	28	51	0	12	0.29	0.78	0.03
Deansbrook Junior School	27	23	16	8	9	9	73	0	12	0.36	0.83	0.05
Gonville Academy	21	56	25	8	29	22	70	0	12	0.36	0.83	0.04
Martin Primary School	15	11	6	19	4	8	44	0	17	0.28	0.77	0.03
Northbury Primary School	20	51	23	8	28	32	125	0	20	0.32	0.81	0.04
Our Lady Immaculate Catholic Primary School	6	21	7	10	1	8	34	0	14	0.26	0.75	0.03
Perivale Primary School	23	47	7	8	8	13	76	0	13	0.38	0.84	0.05
St Joseph's Catholic Primary School	7	8	34	10	3	12	34	1	11	0.14	0.59	0.01

Appendix F. Additional models

Tables 23 and 24.
Fig. 23.

Table 23
Regression summary of models using normalised explanatory variables.

	Dependent variable:		
	School Street or not		
	School-level only	With local area variables	Multilevel model with fixed effects (L2 = Borough
	(1)	(2)	(3)
Free school meals	0.733* (0.345)	0.415 (0.408)	0.283 (0.499)
Ethnicity: Asian/Asian British	0.245 (0.336)	−0.193 (0.351)	0.381 (0.490)
Ethnicity: Black/Black British	0.183 (0.409)	−1.251* (0.581)	−1.100 (0.679)
Ethnicity: Mixed/Multiple	1.054* (0.414)	0.773 (0.428)	0.416 (0.524)
LSOA ethnicity: Black/Black British		1.858*** (0.514)	1.519* (0.623)
Index of Multiple Deprivation score		−1.289* (0.514)	−2.085*** (0.629)
Ratio of main roads to quiet roads		−0.746 (0.689)	−2.471** (0.834)
NOx level from motor vehicles		−2.388*** (0.675)	−3.018*** (0.745)
Population density		3.326*** (0.475)	2.089*** (0.628)
Intercept	−1.880*** (0.219)	−1.800*** (0.235)	−1.174** (0.392)
Observations	1,728	1,728	1,728
Log Likelihood	−945.945	−904.503	−811.480
Akaike Inf. Crit.	1,901.890	1,829.006	1,644.960
Bayesian Inf. Crit.			1,704.962

Note: *$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 24
GAM model summary.

Parametric coefficients				
	Estimate	Std. Error	p-value	Significance
(Intercept)	−1.042	0.168	0.00	***
FSM	0.009	0.006	0.15	
Black / Black British (school)	−0.017	0.006	0.01	**
Asian / Asian British (school)	−0.005	0.003	0.12	
IMD score	−0.023	0.008	0.01	**
Black / Black British (LSOA)	0.033	0.009	0.00	***
Approximate significance of smooth terms				
	EDF	Chi.sq	p-value	Significance
Population density	4.003	52.494	0.00	***
Ratio of main roads to minor roads	1.891	6.689	0.03	*
NOx level	1	14.534	0.00	***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1				
R-sq.(adj) = 0.0609 Deviance explained = 6.45 %				

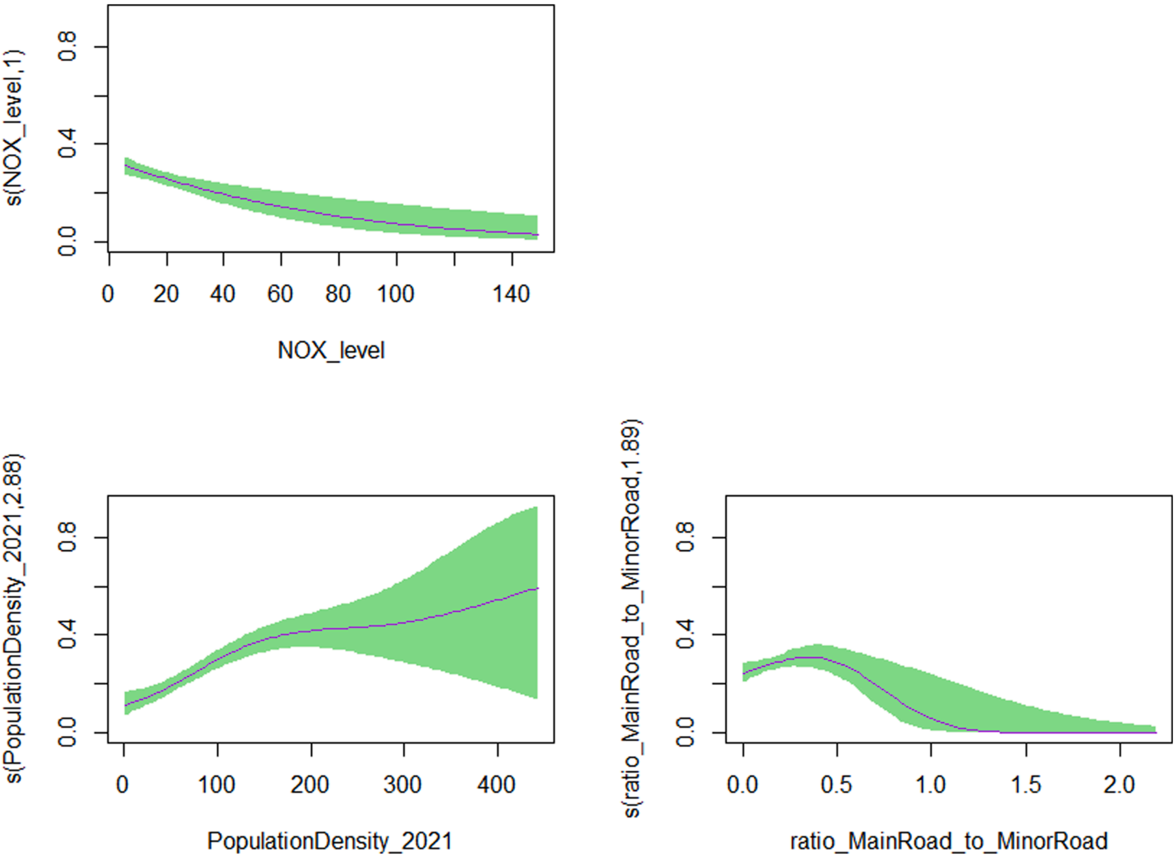

Fig. 23. Partial effects plots from the GAM model.

Appendix G. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2022.103402.

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Glossary

DfE: Department for Education
FSM: Free School Meals
GAM: Generalised Additive Model
IMD: Index of Multiple Deprivation
LSOA: Lower Super Output Area
LTN: Low Traffic Neighbourhood
ONS: Office for National Statistics
URN: Unique Reference Number
VIF: Variance Inflation Factor