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The modelled impact of Low Traffic Neighbourhoods (LTNs) on air pollution: findings from 5 schemes in London

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Abstract

Low traffic neighbourhoods (LTNs) are area-wide schemes that remove through motor traffic from residential streets. These schemes are controversial, and one focus for this controversy has been the potential for traffic diversion to increase air pollution on surrounding 'boundary roads'. In this study we estimate the air pollution changes and associated health impacts attributed to the implementation of five LTNs in London, UK. We did so by implementing a full-chain model covering changes in traffic-related emissions, air pollution, small-area level exposures, and health impacts across select outcomes. Model inputs included observed before-and-after changes in traffic volumes, traffic speeds and congestion. Inside LTNs, we found an average change of $-0.157 \mu\text{g}/\text{m}^3$ for NO_2 (equivalent to -0.87% in relative terms), and $-0.0276 \mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$ (-0.33% in relative terms). In areas containing boundary roads, we found a mixture of positive and negative changes, with net effects near zero. Contrary to concerns, there was no evidence that air quality deteriorated on LTN boundary roads on average. There was no evidence that the average improvement in air quality varied by area-level ethnic diversity or deprivation, but there was evidence that areas with the highest baseline pollution saw the smallest benefits. Overall, across LTNs and their surrounding areas, we estimated that the air quality improvements due to the LTNs translated into a -0.01% relative change in the number of deaths per year (-0.05% inside LTNs), and a -0.02% to -0.04% change in new cases of childhood asthma (-0.08% to -0.19% inside LTNs). We conclude that LTNs typically improve air quality in London but, at the current modest scale of implementation, their effect is small.

Keywords: air pollution; low traffic neighbourhood; transport policy; motor vehicle restrictions; mortality; asthma

Highlights

- We estimated the impacts of 5 low traffic neighbourhoods (LTNs) in London, UK
- Inside LTNs, pollution fell by 0.87% in relative terms for NO₂ and by 0.33% for PM_{2.5}
- Boundary roads saw mixed changes, but – contrary to concerns – no pollution increase on average.
- We estimate that the number of deaths fell 0.01% area-wide, or 0.05% inside LTNs.
- We conclude that LTNs improve local air quality but, at the current modest scale of implementation, the effect is small.

INTRODUCTION

Air pollution is a major threat to human health. It caused 8.1 million deaths in 2021, which makes it the second most important risk factor for death globally after high blood pressure (Health Effects Institute, 2024). In the UK, air pollution remains the most significant environmental threat to health, with the equivalent of 30,000 UK deaths in 2025 being attributed to toxic air exposure (Royal College of Physicians, 2025). Road transport is a major contributor to the harmful pollutants that directly affect human health, accounting for 49% of nitrogen oxides (NO_x), 26% of PM_{2.5}, and 20% of PM₁₀ emissions in the UK in 2023 (Department for Transport, 2025).

Low traffic neighbourhoods (LTNs) are area-wide traffic reduction schemes that restrict motor vehicle movements in residential streets. They do this by using bollards, planters, or cameras ('modal filters') to prevent motor traffic from cutting through residential streets, while retaining motor vehicle access to all homes. Surrounding the LTN areas are 'boundary roads', which do not receive traffic restrictions. Boundary roads are typically main roads, and may experience traffic displacement if traffic that used to travel through the LTN now uses the boundary roads instead.

LTNs aim to achieve modal shift away from cars, by making driving less convenient (a 'stick') and making walking and cycling safer and more pleasant (a 'carrot'). LTNs are similar to schemes such as superblocks in Barcelona (Nieuwenhuijsen et al., 2024), and more than 100 have now been rolled out in London (Furlong et al., 2025b). Evidence as to the health impacts of LTNs includes clear evidence of a benefit in terms of reductions in road traffic injuries (Furlong et al., 2025b, Furlong et al., 2025c); mixed evidence in terms of impacts on active travel (Aldred et al., 2024, Aldred and Goodman, 2021, Xiao et al., 2023); and evidence of a benefit in terms of reductions in noise (Leach et al., 2024). In the present study, we complement this work by extending the evidence base on how LTNs may affect health via changes in air pollution. In doing so, we also complement a wider body of literature that studies how urban transportation policies affect air pollution (Khreis et al., 2023, Jafari et al., 2021), across policies ranging from car-free spaces, days and events (Glazener et al., 2022) to urban design interventions that seek to achieve mode shift towards active modes (Glazener and Khreis, 2019). A systematic review of peer-reviewed articles published between 2000 and 2020

identified 376 unique articles covering 58 unique policy interventions targeted at reducing traffic-related emissions and air pollution in urban areas (Khreis et al., 2023). This review found that behavioural and land-use policies (like LTNs) were the least studied broad category of interventions. It further found that a mere 3% of included studies addressed all elements of the full-chain—traffic emissions, traffic-related air pollution, exposures, and human health. Our study therefore adds to a very limited evidence base that examines the ‘full chain’ from changes in traffic through to health outcomes in relation to an intervention with behavioural and land-use elements.

In common with other schemes to restrict traffic, LTNs have been controversial (Cooke et al., 2021, Gössling et al., 2024), and the potential for increased traffic and pollution on ‘boundary roads’ has been one particular focus for this controversy (Verlinghieri et al., 2025). For example, analyses of an LTN in Birmingham found that while there were positive views about the scheme overall, there were increased tensions in the community between people living inside LTNs and those living on the boundaries (Whelan et al., 2024, Pritchett et al., 2024). Concern over the potential for increased traffic on boundary roads is also sometimes combined with claims that LTNs will disadvantage ethnic minorities, poorer residents, or residents living on roads that are already more polluted (Pritchett et al., 2024, Larrington-Spencer and Sherriff, 2025, Belcher et al., 2022).

The local air pollution impacts of an LTN depend on the relative frequency of two types of change in driving behaviour:

- 1) Traffic evaporation: some trips stop being made by motor vehicle. This change is expected to reduce air pollution both inside the LTN and on boundary roads. Traffic evaporation is expected to decrease total pollution emissions and subsequent concentrations.
- 2) Traffic displacement: some trips continue to be made by motor vehicle but shift the driving route from ‘through the LTN’ to ‘on boundary roads’. This change is expected to reduce air pollution inside the LTN but increase overall emissions on boundary roads (although the increase may not be distributed evenly across boundary roads). Traffic displacement is most likely to increase total emissions because the alternative routes are often more circuitous. This increase in emissions will be exacerbated if the boundary roads also become more congested, as congested ‘stop-start’ traffic emits more pollution.

From a theoretical perspective, it is therefore not clear whether LTNs will typically increase or decrease pollution on boundary roads, nor whether they typically increase or decrease total pollution. Empirical evidence on these points is therefore required.

The existing empirical evidence base is, however, currently limited to a few studies. We are aware of only a single peer-reviewed study that empirically measures the air quality impacts of LTN schemes using a controlled, longitudinal design. This study used direct measurements of air quality and found that, relative to control areas, average pollution concentrations fell inside three London LTNs and in their surrounding areas (Yang et al., 2022). Besides this, several London local authorities have commissioned studies that model the air quality impacts of individual LTNs, based on measured before-and-after changes in traffic volumes. These latter studies typically report beneficial effects inside LTNs and a mixture of beneficial, negligible and adverse effects across different boundary roads (CERC, 2021, CERC, 2022, AECOM, 2022). Outside of London, one local authority monitoring report finds pollution decreases inside three

LTNs in Oxford and a mixture of beneficial, negligible and adverse effects on boundary roads (Oxford City Council, 2023); and one evaluation from Barcelona reports decreases in NO₂ and/or black carbon inside two new superblocks, alongside no overall changes in these pollutants in the immediately surrounding area (Pérez et al., 2025). In addition to these empirical evaluations, some international papers have modelled the potential impacts of superblock schemes based on estimates of how traffic volumes or tree cover might change (Mueller et al., 2020, Rodriguez-Rey et al., 2022, Li and Wilson, 2023).

The existing evidence base thus comprises relatively few studies, many of which cover just a single LTN scheme. In addition, existing modelling studies only model pollution impacts as a function of changes in traffic volumes, without additionally considering changes in congestion. A further limitation of existing studies is that they do not consider the distribution of impacts in relation to characteristics such as ethnicity, socio-economic status and baseline air pollution levels. The present study addresses these research gaps by modelling the air pollution impacts of five LTNs spread across Greater London, using high-resolution pre- and post- traffic and speed/congestion data as inputs. We then model the spatial distribution of these impacts and how these changes in air pollution affect mortality, years of life lost, and childhood asthma incidence.

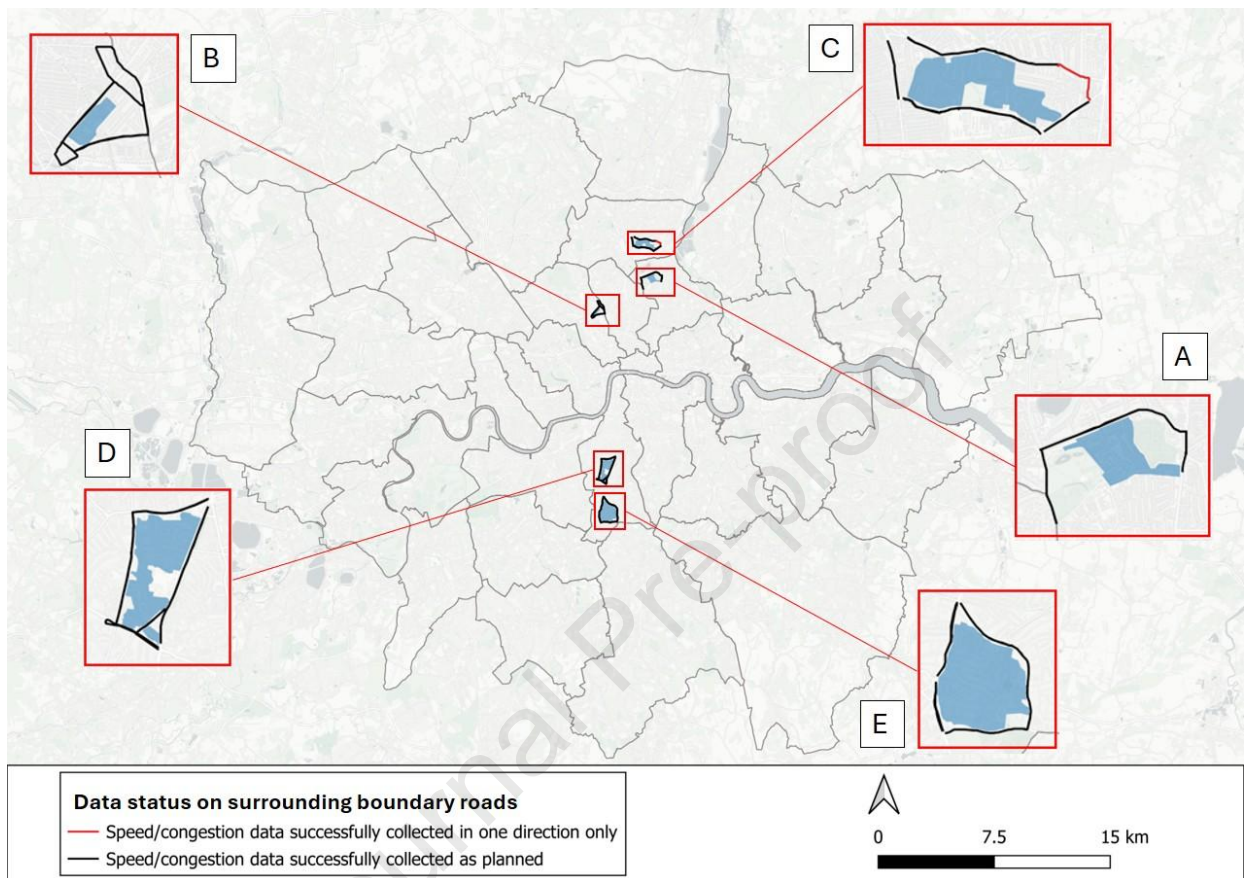
METHODS

LTNs included in the study

Drawing on extensive empirical data, we carried out air quality modelling to estimate the health impact of air pollution changes due to the introduction of five LTNs in London. The five schemes we studied are described in Table 1 and shown in Figure 1.

We modelled air pollution impacts both inside the LTNs and across their surrounding areas. We defined the modelled area covered in terms of Output Areas (OAs), which are administrative census areas covering around 330 people each. Specifically, we modelled impacts across all OAs that were within 200m of any road that experienced a traffic volume change in our scenarios, or that were within a 1-km² grid in which minor road emissions changed. These OAs covered all areas within 250m of the five LTNs and extended up to a maximum of 2km from LTNs.

Figure 1. LTNs included in this study, and their surrounding boundary roads



A = Stoke Newington, B = Camden Square, C = St Ann's, D = Brixton Hill, E = Streatham Wells.

Table 1: Details of the LTNs included in our study

Scheme name and local authority (map reference letter)	Date implemented	LTN area in km ²	Local authority monitoring data on traffic volumes				Google API data on speed and congestion		Extent of modelled area\$
			Number of count points\$	Date of 'before' data†	Date of Year 1 data†	Date of Year 2 data	Number of boundary road segments	Dates of data collection‡	
Stoke Newington Church Street, Hackney (A)	20/09/2021	0.27	8 internal 2 boundary 16 other	Nov 2020, July 2021, Sept 2021	Nov 2021, May 2022, Sept 2022		10 (versus 10 control)	12/06/2021 to 16/09/2023	14 internal OAs 22 boundary road OAs 208 other OAs
Camden Square, Camden (B)	16/12/2021	0.08	5 internal 11 boundary 6 other	June 2018, Mar 2019, June 2021	June 2022		9 (versus 10 control)	12/06/2021 to 12/12/2023	3 internal OAs 30 boundary road OAs 47 other OAs
St Ann's, Haringey (C)	22/08/2022	0.47	35 internal 11 boundary 15 other	Nov 2021	Jan 2023	Nov 2023	13 (versus 7 control)	22/08/2021 to 20/08/2024	25 internal OAs 25 boundary road OAs 172 other OAs
Brixton Hill, Lambeth (D)	04/09/2023	0.61	28 internal 17 boundary 7 other	Nov 2021, June 2023	Feb 2024		16 (versus 14 control)	04/09/2022 to 21/12/2024	35 internal OAs 39 boundary road OAs 147 other OAs
Streatham Wells, Lambeth (E)	23/10/2023 (suspended 07/03/2024)	1.09	16 internal 14 boundary 8 other	Nov/Dec 2021, Oct 2022	Feb 2024		14 (versus 15 control)	23/10/2022 to 05/03/2024	35 internal OAs 27 boundary road OAs 100 other OAs

LTN = low traffic neighbourhood; OA = output area

\$ 'Other' count points/OAs are neither inside the LTNs ('internal') nor on the boundary roads ('boundary') but instead are in the wider surrounding area. Our model uses as an input the impact of traffic volume changes on these 'other' roads, and estimates as an output the air pollution changes in these 'other' OAs.

†Where more than one date is given, this reflects different count points having different dates of data collection.

‡Data collection started on 12/06/2021 or 12 months prior to LTN implementation (whichever was later). Data collection finished 2 years after the LTN was implemented, or when the LTN was suspended, or on 21/12/2024 (whichever was earlier).

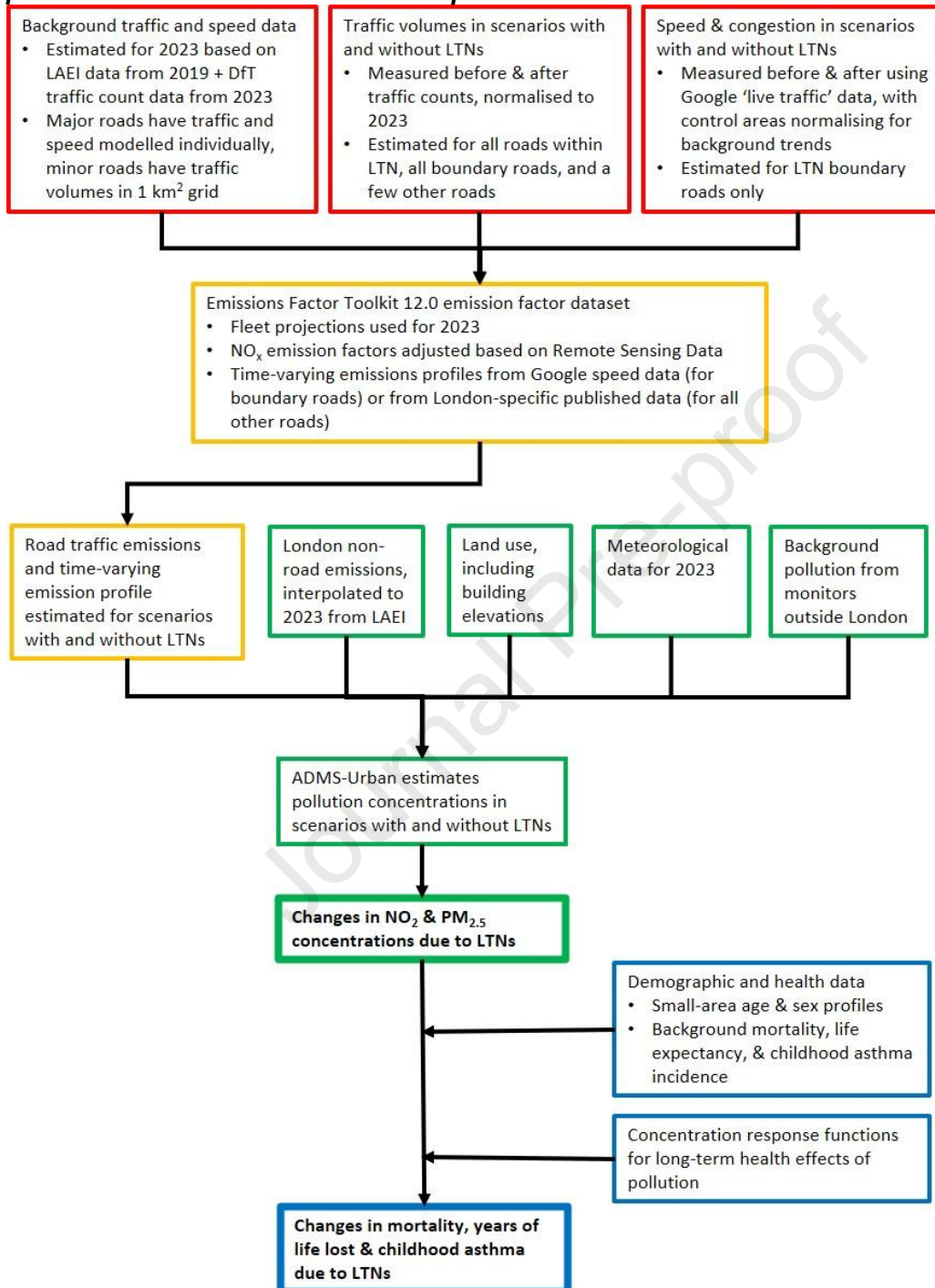
Overview of modelling approach

We implemented a full-chain model (Khreis et al., 2018) outlined in Figure 2 and described briefly below, with full details in Supplementary Material 1. This model 1) used extensive empirical data to estimate traffic volumes, speeds and vehicle types as of 2023, in and around the five LTNs (red boxes in Figure 2); 2) converted these into estimated traffic-related air pollutant emissions (orange boxes); 3) combined these emissions with other data sources to model air pollutant dispersion and concentrations (green boxes); and 4) converted air pollution concentrations into select attributable health impacts (blue boxes). We implemented scenarios with and without LTNs, in which we varied the first element of this model (traffic volumes, speeds and vehicle types) while leaving all other elements unchanged and compared the impacts of the LTNs on pollutant concentrations and the select health outcomes.

This represents an instance of the full-chain modelling approach that has been recommended when studying the impacts of urban transport policies (Khreis et al., 2023). Our implementation of step 1) involved bespoke data manipulation and the novel use of traffic speed data. Our implementation of steps 2), 3) and 4) largely drew on standard approaches derived from peer-reviewed literature, albeit with customisation to the London setting.

Before implementing the model shown in Figure 2, we conducted a validation exercise in which we set up a similar model that utilised traffic and air pollution emission data to model air pollution concentrations in 2019 (i.e. equivalent to the first three stages of the full-chain model: details in Supplementary Material 1). We compared the resulting modelled air pollution concentrations to pollution measurements taken in 2019 from two available continuous monitors (measuring PM₁₀ and NO₂) and 83 diffusion tubes (measuring NO₂) within 1km of the LTNs. Across the five LTNs, 50% of modelled concentrations were within 10% of measured values for PM₁₀ (N=1/2) and 51% for NO₂ (N=43/85). 100% of modelled concentrations were within 25% for PM₁₀ (N=2/2) and 93% for NO₂ (N=79/85, with five of the remaining six sites located ≥500m away from the LTNs and their boundary roads). In addition, metrics for bias, correlation and error indicated good statistical performance, and the average modelled pollution concentrations were within 6% of the average measured concentrations for both pollutants. In line with DEFRA guidance (DEFRA, 2025), we considered these results to indicate acceptable accuracy in our model and an adequate baseline set-up.

Figure 2. Schematic overview of our full-chain model estimating traffic, emissions, air pollution and attributable health impacts in scenarios with and without LTNs



Abbreviations: ADMS = Atmospheric Dispersion Modelling System; DfT = Department for Transport; LAEI = London Atmospheric Emissions Inventory; LTNs = low traffic neighbourhoods. This full-chain model 1) used empirical data to estimate traffic volumes, speeds and vehicle types as of 2023 (red boxes); 2) converted these into estimated traffic-related air pollutant emissions (orange boxes); 3) combined these emissions with other data sources to model air pollutant dispersion and concentrations (green boxes); and 4) converted air pollution concentrations into select attributable health impacts (blue boxes).

Part 1: Estimating traffic, with and without LTNs

Background traffic volumes

The London Atmospheric Emissions Inventory (LAEI) estimates traffic flows and speeds by vehicle type for all major roads in London, and models minor road traffic on a 1km² background grid (GLA and TfL Air Quality, 2021). We took the 2019 LAEI data as our starting point, as this is the latest year that pre-dated both the Covid-19 pandemic and the implementation of our five LTNs. The LAEI provided traffic volumes for seven vehicle types: motorbikes, cars, taxis, light goods vehicles, buses/coaches, rigid heavy goods vehicles (HGVs) and articulated HGVs. We then used Department for Transport traffic count data (Department for Transport, 2024) from 2019 and 2023 to a) cross-check the 2019 total traffic volumes on major roads near our LTNs, and b) to project the 2019 traffic volumes forward to 2023. We used these LAEI data to capture traffic volumes and speeds on all roads for which scenario traffic data were not collected.

Scenario traffic data

To model how traffic volumes changed in scenarios with and without LTNs, we used before-and-after monitoring data published by the four local authorities that implemented our five LTNs (see Table 1 for numbers of count points and dates of data collection). These traffic count data were collected through a mixture of video manual counts, Vivacity AI sensor data, and Automatic Traffic Counters. In Appendix B of Supplementary Material 1, we assess the extent to which traffic impacts on boundary roads may have been underestimated due to the potential for Automatic Traffic Counters to undercount congested traffic. We conclude that it is implausible that this issue introduced any substantial bias.

All traffic counts were 'normalised' to 2023, to adjust the observed values to what one would have expected in 2023 given general background trends in traffic in London. The normalisation factors combined an annual measure of year-on-year change (Department for Transport, 2024), with a monthly adjustment factor (ONS, 2025).

Traffic in the 'without an LTN' scenario was modelled using the normalised 'before' traffic counts where available. Otherwise, we used the 2023 modelled traffic flows from LAEI. There was good agreement between these data sources for the N=83 roads that had both data types (correlation coefficient 0.91, and mean values within 2% in absolute terms).

Traffic in the 'with an LTN' scenarios was modelled using the normalised 'after' traffic counts where available. On average, normalised traffic volumes fell by 66% across count points inside our five new LTNs; increased by +0.7% across count points on the LTN boundary roads; and fell by 13% across these two sets of count points combined. For internal and boundary roads where traffic count data was not available but where that road was modelled explicitly in LAEI, we took the modelled traffic flows from LAEI and applied the average change observed for that road type (internal versus boundary) for the LTN in question (see Supplementary Material 1 for details). For internal roads that lacked traffic count data and that were captured by LAEI in the 1km² minor roads grid (rather than being modelled explicitly), we adjusted the entire 1km² grid by that LTN's internal-road traffic volume change factor, as scaled by the proportion of the area of that 1km² grid covered by the LTN. Note that this approach accurately captures area-wide changes in traffic but misallocates some of that change to areas outside the LTN rather than inside the LTN. Finally, we assumed there was no change in traffic volumes on roads that had no monitoring data and that were neither internal to the LTN nor boundary roads. This is expected to be a conservative assumption if there is traffic evaporation.

Changes in traffic flows were assumed to apply pro rata to all seven vehicle types except buses and coaches. Bus and coach traffic flows were assumed to remain unchanged between the 'without an LTN' and 'with an LTN' scenarios because none of our five LTNs involved a change in bus routes or bus frequency.

Scenario speed data

Previous efforts to model the air pollution impacts of LTNs have only varied traffic volumes (AECOM, 2022, CERC, 2021, CERC, 2022), and assumed no change in traffic speeds and congestion. However, previous research has found evidence that average traffic speeds fall, and congestion increases, on boundary roads in the first year post-LTN implementation (Furlong et al., in preparation).¹ This matters because motor vehicles emit more air pollution at slower average speeds with regular start-stop driving, with the Emissions Factors Toolkit v12.0 indicating that this particularly applies at speeds below around 8km/h (DEFRA, 2023).

We therefore modelled speed, and congestion impacts on boundary roads as follows. First, the LTN boundary roads were divided into segments around 200m to 500m in length. The same was done for boundary road segments around matched control areas (see Table 1 for numbers of segments). Google API was then used to route car journeys along these boundary road segments 'in live traffic conditions'. This was done 30 times per week (24 times on a Tuesday and 6 times on a Saturday) at intervals designed to capture a range of peak and off-peak times, for every week from June 2021 to December 2024 (see Furlong et al., 2025a and Appendix C for details).

From these data we estimated a) mean speed and b) the proportion of congested journeys, defining congestion as a mean speed of <8km/h. Separate averages were taken for each boundary road segment, in each direction of travel; for each year or partial year of follow-up (Baseline, Year 1 or Year 2); and for different times of the day.

For our scenarios, we normalised all speed and proportion of congested journey results to the observed 'Year 1' values. Specifically:

- For the 'Without LTNs' scenarios, we took the Baseline observed values and scaled these by the average difference in the control group between Baseline and Year 1.
- For the 'With LTNs, Year 1' scenarios, we used the observed Year 1 mean speed and proportion of journeys congested.
- For the 'With LTNs, Year 2' scenarios, we took the Year 2 observed values and scaled these down by the average difference in the control group between Year 2 and Year 1.

The speed and congestion estimates were then applied to the corresponding roads and were assumed to apply to all seven vehicle types modelled. For roads where Google speed data was not collected, traffic speed and congestion were assumed to remain unchanged in the 'with LTNs' scenarios. For these roads, average speed data was taken from the LAEI, where available. For internal roads with no LAEI data, an average speed of 15km/h was used, in line with the average traffic speed in Inner London.

¹ Note that this paper also found that these unfavourable changes reduced substantially or disappeared by Year 2, in the four LTNs that were retained long enough to collect Year 2 data.

Modelled scenarios

Table 2 captures the five scenarios we modelled, using different traffic and speed data measured at different time points. The Baseline scenario captures our estimate of pollution concentrations in the absence of the LTN schemes, and we compared all other scenarios to this. The remaining four scenarios capture estimates of pollution concentrations in the presence of LTNs, with the Latest Data scenario being our primary scenario of interest. This Latest Data scenario uses the most recent data available for each LTN, which corresponds to the Year 1 scenario for Streatham Wells, the Year 2a scenario for Stoke Newington, Camden Square and Brixton Hill, and the Year 2b scenario for St Ann's.

In running our scenarios, each LTN was considered independently. This meant that, for example, the estimated impacts of the Streatham Wells LTN were not affected by the implementation of Brixton Hill LTN nearby.

Table 2: Overview of the scenarios we modelled

Scenario name	What it captures	When was traffic data collected?	When was speed data collected?	No. LTNs covered
Baseline scenario	Pollution without LTNs	Before the LTN was implemented	Before the LTN was implemented	5
Year 1 scenario	Pollution in the first year of LTN implementation	Year 1 of LTN implementation	Year 1 of LTN implementation	5
Year 2a scenario	Pollution in the second year of LTN implementation, using Year 1 traffic data as a proxy for Year 2	Year 1 of LTN implementation	Year 2 of LTN implementation	4 [not Streatham Wells]
Year 2b scenario	Pollution in the second year of LTN implementation	Year 2 of LTN implementation	Year 2 of LTN implementation	1 [St Ann's only]
Latest Data scenario	Pollution with LTNs, using the latest data available	Latest available: Year 1 for N=4 LTNs, Year 2 for N=1 LTN (St Ann's).	Latest available: Year 1 for N=1 LTN (Streatham Wells), Year 2 for N=4 LTNs.	5

Part 2: Modelling traffic emissions

The Emissions Factors Toolkit (Version 12.0, December 2023) was used to estimate the NO_x, primary NO₂, PM₁₀ and PM_{2.5} emissions resulting from a given set of inputs on traffic volumes and traffic speeds. This process involved applying average speed-dependent emission factors, as taken from the COPERT emission calculator Version 5.6 (September 2022; <https://copert.emisia.com/>). Different emission factors were used for each of the seven vehicle types modelled, with further subdivisions according to Emissions Factors Toolkit fleet projections for fuel type (petrol versus diesel), Euro emission standard category and engine size. To account for discrepancies between the COPERT emission factors and real-world emissions, we adjusted the COPERT emission factors based on published remote sensing data (Mehlig et al., 2023).

We initially estimated traffic emissions at the hourly level by applying a time-varying emissions profile to the estimated daily average traffic flows. For LTN boundary roads, the time-varying emissions profile was estimated using road-specific hourly speed and congestion Google API data (see previous section). For all other roads, we applied a default time-varying profile of traffic emissions, as derived using data from London by Beevers et al. (2009). The estimated hourly emissions were then used to create diurnal profiles and average daily emission rates for each modelled road.

Part 3: Modelling air pollution concentrations

We used the Atmospheric Dispersion Modelling System (ADMS)-Urban model (Version 5.0.1.3; <http://www.cerc.co.uk/environmental-software/ADMS-Urban-model.html>). This model is widely used for air quality management and policy assessment by local, metropolitan and national governments in the UK and worldwide. Model inter-comparison evaluations have shown that the model performs well in predicting pollution concentrations (Heist et al., 2013, Carslaw et al., 2013). As illustrated in Figure 2, ADMS-Urban takes as inputs traffic emissions data alongside non-road emissions, land use characteristics, meteorological data, and background concentrations. It uses these as the basis for modelling of how air pollution is generated and dispersed in ambient air and spatially. It produces output in the form of hourly air pollution concentrations with high spatial resolution determined by the user. The following were our key inputs.

Non-road emissions: All large industrial sources within 10km of the LTNs were modelled explicitly as point sources. Emissions for all other non-road sources, including industrial sources more than 10km from the LTNs, were estimated for 2023 by interpolating between the 2019 and the 2025 values in LAEI. The LAEI includes spatially distributed emissions for 26 non-road groups, including commercial and domestic emissions, industrial emissions, rail, shipping, and construction. These other non-road emissions were modelled as aggregated 1km² resolution grid sources covering the whole of London. We derived hourly and monthly profiles for these grid source emissions from European Monitoring and Evaluation Programme (EMEP) emissions data (Denier van der Gon et al., 2011).

Parameters used in ADMS-Urban to represent the effect of land use on dispersion

- Surface roughness length: This affects wind speed and turbulence, which in turn affects air pollution dispersion. We used a value of 1m; a typical value for a built-up area.
- Monin-Obukhov length: This captures the stability of the atmosphere. In cities, urban heat island effects mean that the Monin-Obukhov length will never fall below some minimum value in stable conditions. In line with previous work in London (CERC, 2024), our model used a minimum value of 75m.
- Urban canopy flow: The flow field that drives dispersion of pollutants within an urban area is not homogeneous: buildings displace the upwind wind speed profile above the building canopy and reduce in-canopy wind speeds. The ADMS-Urban spatially varying urban canopy flow option captures this on a neighbourhood-by-neighbourhood basis. In our model we used derived inputs for London (Jackson et al., 2016).
- Street canyons: The presence of buildings can create street canyon effects that result in pollutants being trapped. We captured this using the ADMS Advanced Canyon option, taking building footprint data from OpenStreetMap and elevation data from the Environment Agency National LIDAR programme.

Meteorological data: We used hourly sequential meteorological data measured at Heathrow Airport across 2023.

Background data: The modelling used the ADMS-Urban NO_x photolytic chemistry module, which uses the Generic Reaction Set of equations to account for fast, near-road oxidation of NO by O₃ to form NO₂, and which uses simple sulphate chemistry to account for the conversion of SO₂ to PM_{2.5} and PM₁₀. The chemistry schemes are calculated on an hourly basis and require background pollution concentrations, in addition to source emissions.

We explicitly modelled direct emissions of NO_x, NO₂, PM₁₀ and PM_{2.5} from all sources in Greater London. We also estimated the background concentrations of NO_x, NO₂, ozone, PM₁₀ and PM_{2.5} in air carried into London from outside the area. These estimates of background concentrations came from air pollution monitors in four rural locations outside of London, with hourly data taken from whichever site best matched the wind direction for that hour. In order to discount hours affected by local sources of particulate matter at these rural sites, these data were supplemented with measurements of PM₁₀ and PM_{2.5} from London suburban and background sites (see Supplementary Material 1).

Output points, contour maps and OA-level averages: Within each LTN's output domain, concentrations were calculated on a regular grid of output points with a resolution of 20m, with additional sets of points added along the major roads where the concentration gradient is steepest (see Supplementary Material 1 for details). We used this model output to generate 2m resolution contour maps using the natural neighbour interpolation method. Average pollution concentrations were calculated at the OA level for each scenario as a simple average of all 2m by 2m concentration cells in each OA.

Part 4: Modelling health impacts

Impacts on mortality and years of life lost (YLLs) were modelled via a joint function of both NO₂ and PM_{2.5}, using concentration response functions of 1.024 for a 10 µg/m³ increase in NO₂ adjusted for PM_{2.5}; and 1.035 for a 5 µg/m³ increase in PM_{2.5} adjusted for NO₂ (Chen et al., 2024). These estimates come from a meta-analysis of population-level studies looking at the effect of average pollution concentrations at participants' homes, as modelled largely at the residential address level or at the small-area level and without accounting for individual mobility and variations beyond the residential location. They are therefore considered appropriate to apply to the OA-level average pollution concentrations that we estimated (OAs being the smallest Census geography level), and this is standard practice when conducting health impact assessments of air pollution.

The number of deaths attributable to air pollution was calculated by sex and 5-year age band for each OA. In line with recommendations from Public Health England guidance for estimating local mortality burdens (Gowers et al., 2014), mortality attributable to long-term exposure to air pollution was based on the number of deaths in adults aged 30 years or more. This calculation involved combining a) the attributable fraction of deaths in each OA, as derived based on the relevant concentration response functions plus the average pollutant concentration for that OA in a given scenario; b) the number of people aged 30 years or over living in that OA in 2023, by sex and age band, and c) borough level age-standardised all-cause mortality rates in 2023 (available from <https://www.nomisweb.co.uk/>)

To calculate the number of YLLs per OA due to air pollution, we multiplied the 5-year age band and sex-specific attributable deaths by the corresponding borough-level 2021-2023 period life expectancy for each group (ONS, 2024).

Impacts on childhood asthma incidence were modelled twice, first as a function of NO₂ (1.05 per 4 µg/m³ increase in NO₂), and second as a function of PM_{2.5} (1.03 per 1 µg/m³ increase in PM_{2.5}), using single-pollutant concentration response functions from the meta-analysis by Khreis et al. (2017). Results modelled via both NO₂ and PM_{2.5} are presented in text, to give a range of plausible results and are not meant to be summed. The number of new cases of childhood asthma per year was calculated by combining a) the attributable fraction of asthma in each OA, based on the average pollutant concentration for that OA in a given scenario; b) the number of children aged 0 to 18 living in that OA in 2023, and c) the Global Burden of Disease estimated asthma incidence in Greater London in 2023 (available from <https://vizhub.healthdata.org/gbd-results/>).

Statistical analysis

We first examined average effects across the different scenarios modelled (Table 2), to assess whether air pollution impacts changed according to which year of ‘after’ data was used. We then proceeded to focus on comparing the Latest Data scenario to the Baseline scenario for more detailed analysis.

Our primary outcomes were the absolute changes in $PM_{2.5}$ and NO_2 concentrations, plus their resulting impacts on mortality and asthma. To provide context for these absolute changes, we also present the results in terms of relative changes and, in the case of air pollution concentrations, relative to background improvements in air pollution. Specifically, UK government estimates of background air pollution concentrations (DEFRA, 2024) indicate that all-source background NO_2 fell by an average of $0.85\mu g/m^3$ between 2023 and 2024 in the relevant areas of London, while $PM_{2.5}$ fell by $0.07\mu g/m^3$. This allowed us to quantify the modelled LTN-related changes in terms of ‘number of days of progress / delay’ relative to this favourable background trend – i.e. how far had the LTN accelerated, or delayed, air quality improvements in London relative to the observed background trend. For instance, one would describe the LTN as ‘accelerating progress by 365 days’ if the LTN were estimated to reduce NO_2 pollution by $0.85\mu g/m^3$, as that is equal to the background annual improvement in NO_2 .

We conducted our analyses of pollution impacts at the OA level. To capture average effects, we took simple means across OAs. To calculate confidence intervals we used the ‘acreg’ package in Stata (Colella et al., 2023), fitting the ‘spatial’ command to take account of spatial clustering between OAs; specifying 2km as the maximum distance between which the error terms of OAs were assumed to be correlated; and using the ‘bartlett’ option to impose a distance linear decay between the error terms of nearby OAs. The 2km threshold was chosen as it comfortably spans LTNs and boundary roads, and also as trialling various thresholds indicated that 2km resulted in conservative (least significant) estimates. These confidence intervals capture uncertainty only due to variation between OAs and allowed us to assess how far any differences between different groups of OAs (e.g. different LTNs) might be due to chance.

In our primary analyses, we looked at average effects across the 929 OAs in the five LTNs modelled, treating these as a single sample. This approach captures average air pollution impacts in these five schemes. In sensitivity analyses, we instead ran a two-stage process that first calculated average effects for each of the LTNs separately and then used random-effects meta-analysis to pool the results across the five LTNs. This approach captures the estimated air pollution impacts for a ‘typical’ LTN in London and produced similar findings. A further set of sensitivity analyses excluded Camden Square, because Camden Square is the smallest LTN in our study, and is the only LTN that a) used ‘before’ data collected before Covid-19, and b) saw boundary roads traffic decrease in the ‘with LTNs’ scenario.

As previously mentioned, the potential for increased pollution on boundary roads is typically a leading point of controversy in relation to LTNs, and this is sometimes combined with claims that this will disadvantage ethnic minorities, poorer residents, or residents living on roads that are already more polluted. We therefore sought to examine the spatial distribution of the impacts of our five LTNs, as well as examining variation between the five schemes. We did so by defining the following five small-area characteristics at the OA level.

- 1) LTN scheme: i.e. Stoke Newington Church Street, Camden Square, St Ann’s, Brixton Hill, or Streatham Wells
- 2) OA area type, defined as:

- Inside the LTN: defined as >50% of the OA's buildings lie inside the LTN, plus <20m of the boundary roads intersect the OA.
 - On the LTN boundary roads: defined as ≥ 20 m of the boundary roads intersect the OA, and/or the boundary road runs directly alongside the OA.
 - Other external areas: OAs that did not meet the two above definitions.
- 3) Proportion of non-White residents in the 2021 Census.
 - 4) Mean number of deprivation dimensions per household in the 2021 Census (covering domains of employment; education; health and disability; and household overcrowding).
 - 5) Average NO₂ concentrations in our baseline model.

The final three of these small-area characteristics were divided into quarters on an LTN-by-LTN basis (i.e. 'most deprived quarter from Stoke Newington' through to 'least deprived quarter from Stoke Newington', and likewise for the other LTNs). This was done in order to adjust for scheme effects (i.e. Stoke Newington versus Camden Square etc.) when examining the distribution of impacts. To test for heterogeneity across these groups, we ran successive single-variable linear regression models (using the 'acreg' package, as described above) that entered the relevant OA-characteristic as a categorical variable. We then performed a Wald test for heterogeneity. This was done for each variable in turn in separate models, without adjusting for co-variables, because our primary concern was the raw spatial distribution of the attributable health impacts (e.g. 'do average effects differ between poorer and richer areas?'), rather than the identification of independently causal predictors (e.g. 'do average effects differ between poorer and richer areas, after adjusting for baseline pollution levels?'). When examining health impacts, we summed OA-level estimates to generate aggregated estimates of total impact.

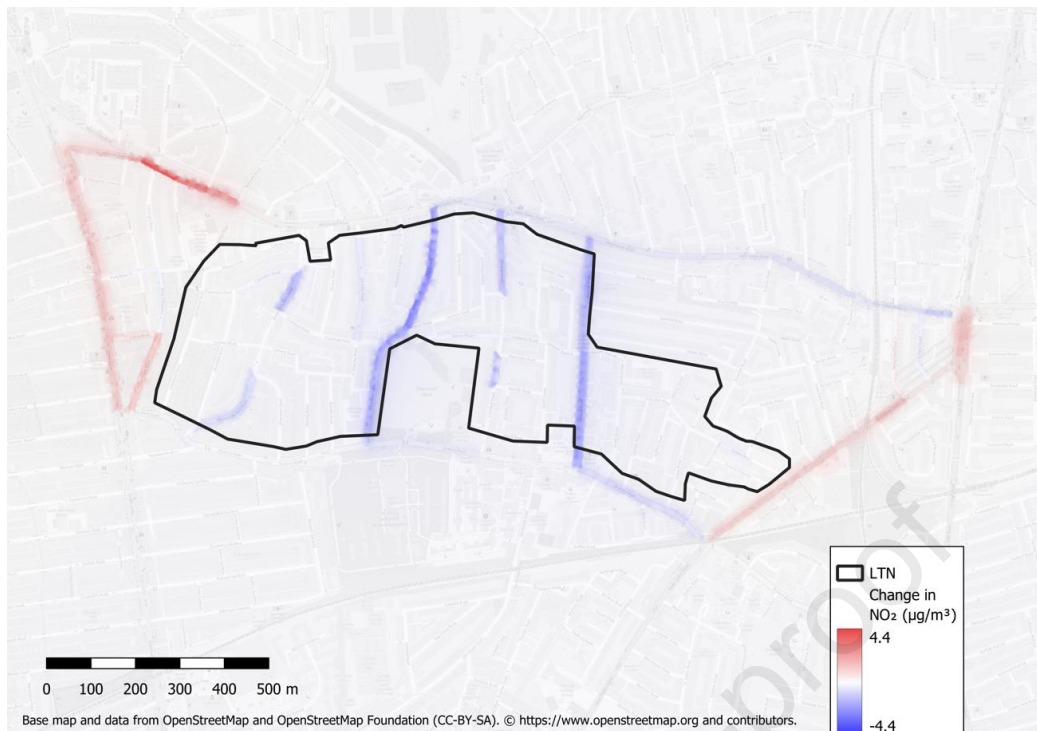
RESULTS

Baseline pollution levels and mapping results

In the 'without LTNs' Baseline scenarios, average pollution concentrations across the areas we modelled were 18.9 $\mu\text{g}/\text{m}^3$ for NO₂ and 8.4 $\mu\text{g}/\text{m}^3$ for PM_{2.5}. These values are below the current legal limits in the UK (40 $\mu\text{g}/\text{m}^3$ for NO₂ and 25 $\mu\text{g}/\text{m}^3$ for PM_{2.5}), but above the air quality guideline values proposed by the World Health Organisation (10 $\mu\text{g}/\text{m}^3$ for NO₂ and 5 $\mu\text{g}/\text{m}^3$ for PM_{2.5}).

Our results indicated a reduction in pollution on most streets inside LTNs, whereas on boundary roads there was a mix of pollution increases and decreases. This is illustrated in the map shown in Figure 3, with Supplementary Material 2 showing maps for all schemes and pollutants.

Figure 3: Change in annual average NO₂ in St Ann's LTN, Haringey, between Baseline and the Latest Data Scenario



Note that this map shows estimated changes with a 4m^2 (2m by 2m) resolution, a far finer spatial resolution than output areas (average area $\approx 30,000\text{m}^2$). As this map shows, some 4m^2 cells along major roadways saw changes in NO_2 in the range of -4 to $+4 \mu\text{g}/\text{m}^3$, an order of magnitude larger than the range at the OA level (range -0.40 to $+0.35$ in St Ann's).

Comparison of scenarios: how air pollution impacts change as schemes become longer established

Table 3 presents average changes in air pollution in the three scenarios, across the areas inside and surrounding the five LTNs. As Table 3 shows, average concentrations fell for both NO_2 and $\text{PM}_{2.5}$ in the first year of scheme implementation (Year 1 scenario). In the four LTNs with available data, a reduction in congestion between Year 1 and Year 2 led to a further modest fall in average NO_2 concentrations but had little effect on $\text{PM}_{2.5}$ (Year 2a scenario). In the one LTN with available data, the reduction in congestion and traffic between Year 1 and Year 2 led to a more substantial further decrease in both NO_2 and $\text{PM}_{2.5}$ (Year 2b scenario). These results were similar in analyses restricted to peak-time air pollution concentrations (see Supplementary Material 3), and in analyses that sought to estimate impacts in a 'typical' LTN (see Supplementary Material 3).

In the remainder of the results section, we use the Latest Data scenario for each of the five LTNs as a proxy for long-term air pollution impacts.

Table 3: Average absolute change in OA-level annual average pollution concentrations, relative to the Baseline scenario: comparing results across scenarios

Outcome	Schemes	'Without LTNs' Baseline scenario	Change in Year 1 scenario	Change in Year 2a scenario	Change in Year 2b scenario
NO_2 ($\mu\text{g}/\text{m}^3$)	5 LTNs	18.90	-0.028		
	4 LTNs with Year 2a results	19.21	-0.029	-0.034	
	1 LTN with Year 2b results	17.93	-0.004	-0.007	-0.016

PM _{2.5} (µg/m ³)	5 LTNs	8.39	-0.0048		
	4 LTNs with Year 2a results	8.45	-0.0044	-0.0044	
	1 LTN with Year 2b results	8.23	-0.0035	-0.0034	-0.0046

OA= Output Area; LTN = low traffic neighbourhood. The results in this table combine OAs inside and around the LTNs (distance up to 2km). See Supplementary Material 3 for a version including 95% confidence intervals.

Average air pollution effects using latest available scenario data

Using the latest available scenario data for each LTN, the average change across the five LTNs and their surrounding areas was -0.034 µg/m³ in NO₂ (95%CI -0.056 to -0.011) and -0.0051 µg/m³ in PM_{2.5} (95%CI -0.0077 to -0.0025; see also Table 4). Similarly, in analyses that used random-effects meta-analysis to estimate impacts in a 'typical' LTN, the change was -0.044 µg/m³ in NO₂ (95%CI -0.082 to -0.006) and -0.0062 µg/m³ in PM_{2.5} (95%CI -0.0103 to -0.0021).

As context, these observed average changes across the five LTNs correspond to a mean -0.18% relative decrease in NO₂ as compared to the estimated level of 18.9µg/m³ in the 'without LTNs' scenario; and -0.06% mean relative decrease in PM_{2.5} as compared to the estimated level of 8.4µg/m³ in the 'without LTNs' scenario. Relative to background improvements in air pollution in London between 2023 and 2024, this is equivalent to gaining an average of 14 days of progress in relation to NO₂ and gaining 27 days of progress in relation to PM_{2.5}. In other words, across the five LTNs and their surrounding areas, the beneficial average effects were statistically significant but were small.

Distribution of air pollution effects according to selected area characteristics

When looking at LTNs individually, all five schemes were modelled as having a decrease in average NO₂ and PM_{2.5} concentrations in the latest data (see Supplementary Material 3 for LTN-level results for all three scenarios, and Supplementary Material 2 for contour maps). The magnitude of these changes ranged from -0.55% to -0.03% for NO₂, and from -0.15% to -0.01% for PM_{2.5}, with the largest effects seen in Camden Square. Camden Square is the smallest LTN in our study and is also unusual as a) its 'before' data was collected before Covid-19 and b) pollution was estimated to fall on almost all boundary roads (see Supplementary Material 2). The estimated average air quality improvements were up to a quarter smaller in sensitivity analyses excluding Camden Square (see Table 4).

We next examined the distribution of changes in air pollution according to whether the OA was inside the LTN, was on its boundary roads, or was an external OA beyond the boundary roads. Unsurprisingly, we found the largest pollution decreases inside the LTN areas, with a -0.87% fall in NO₂ (from 18.05µg/m³ in the 'without LTNs' scenario to 17.90µg/m³ in the 'with LTNs' scenario) and a -0.33% fall in PM_{2.5} (from 8.25µg/m³ to 8.23µg/m³). This reflected the fact that modelled air pollution fell on almost all internal roads inside the five LTNs (see Supplementary Material 3). As context, this average effect is equivalent to gaining 68 days of progress relative to the background trend in relation to NO₂ and gaining 144 days in relation to PM_{2.5}.

Smaller average decreases in air pollution were seen for boundary road OAs of -0.18% for NO₂ (from 19.98µg/m³ to 19.94µg/m³), and -0.06% for PM_{2.5} (from 8.551µg/m³ to 8.546µg/m³). This resulted from a mixture of positive and negative changes in boundary road air pollution which largely cancelled each other out when averaged. There was, however, substantial spatial heterogeneity across boundary roads, with some segments seeing modest to moderate localised increases in concentrations, while others saw decreases (see

Supplementary Material 3). Finally, 'other' external OAs saw the smallest decrease in pollution (-0.06% for NO₂, -0.02% for PM_{2.5}).

In sensitivity analyses excluding Camden Square, these effects remained similar for 'internal' and 'other' OAs. However, the effect on boundary road OAs changed to a small and non-significant increase (+0.03% (95%CI -0.31% to +0.38%) for NO₂; +0.001% (95%CI -0.08% to +0.08%) for PM_{2.5}), equivalent to one to four days of delay relative to the favourable background trend for air quality in London.

We did not find statistically significant evidence that the change in pollution concentrations varied according to small-area level ethnic diversity or deprivation (all $p \geq 0.15$ for heterogeneity between quarters, see Table 4), although the non-significant trend was for slightly smaller improvements in the quarter of OAs with the highest proportion of non-White residents and in the half of OAs with the highest proportion of deprived residents. There was also strong evidence of an inverted U-shaped relationship with baseline air pollution, with larger pollution decreases estimated in areas with intermediate baseline pollution, and with minimal improvements in areas with the highest baseline pollution.

Finally, at the level of individual OAs, there was a mix of positive and negative effects. The size of these effects was generally small to negligible, and at most modest. For instance, across all 929 OAs, the size of the latest-data changes in NO₂ ranged from a 4.5% decrease (equivalent to 337 days, or 11 months, of progress relative to background trends) to a 2.6% increase in NO₂ (equivalent to 243 days, or 8 months, of delay relative to background trends).

Health impacts of air pollution changes

Table 5 shows the estimated changes in deaths, YLLs and incident cases of childhood asthma attributable to the implementation of the five LTNs and the associated modelled reductions in air pollution. Across the 307,734 people living in and around the five LTNs, we estimated that on average there were 1,481 deaths and 22,023 YLLs per year in the 'without LTNs' Baseline scenario. In the scenario with LTNs, we estimated that 0.15 of these deaths and 2.28 of these YLLs were averted per year, equivalent to a -0.01% reduction. We further estimated that in the 'with LTNs' scenario 0.13 to 0.34 cases of childhood asthma were averted each year (depending on whether we estimated the change via PM_{2.5} or via NO₂), equivalent to a 0.02% to 0.04% reduction.

In sensitivity analyses restricted to the four larger LTNs (i.e., excluding Camden Square), this fell to an estimated 0.11 deaths and 1.70 YLLs averted per year (0.008% reduction); and to an estimated 0.11 to 0.25 incident cases of childhood asthma averted per year (0.01% to 0.03% reduction).

Table 4: Annual average pollution concentrations, relative to Baseline scenario, using the latest available scenario data for each LTN: Distribution of changes according to selected area characteristics

		No. OAs	NO ₂		PM _{2.5}	
			Absolute change (µg/m ³)	Relative change	Absolute change (µg/m ³)	Relative change
All schemes	5 LTNs	929	-0.034	-0.18%	-0.0051	-0.06%
	Typical LTN	929	-0.044	-0.22%	-0.0062	-0.07%
Larger schemes	4 larger LTNs (excluding Camden Square)	849	-0.025	-0.14%	-0.0043	-0.05%
	Typical larger LTN (excluding Camden Square)	849	-0.024	-0.14%	-0.0041	-0.05%
LTN	Stoke Newington, Hackney	244	-0.006	-0.03%	-0.0010	-0.01%
	Camden Square, Camden	80	-0.130	-0.55%	-0.0138	-0.15%
	St Ann's, Haringey	222	-0.016	-0.10%	-0.0046	-0.06%
	Brixton Hill, Lambeth	221	-0.057	-0.30%	-0.0056	-0.07%
	Streatham Wells, Lambeth	162	-0.020	-0.15%	-0.0070	-0.09%
	p-value for heterogeneity		p<0.001	p<0.001	p<0.001	p<0.001
Area type	Inside the LTN	112	-0.157	-0.87%	-0.0276	-0.33%
	On the LTN boundary roads	143	-0.043	-0.18%	-0.0053	-0.06%
	Other external areas	674	-0.011	-0.06%	-0.0013	-0.02%
	p-value for heterogeneity		p<0.001	p<0.001	p<0.001	p<0.001
Proportion non-White residents ‡	Quarter 1 (lowest)	233	-0.034	-0.18%	-0.0060	-0.07%
	Quarter 2	259	-0.037	-0.19%	-0.0060	-0.07%
	Quarter 3	240	-0.033	-0.18%	-0.0045	-0.05%
	Quarter 4 (highest)	197	-0.029	-0.15%	-0.0036	-0.04%
	p-value for heterogeneity		p=0.88	p=0.87	p=0.40	p=0.40
Residents' mean number of deprivation dimensions ‡	Quarter 1 (lowest)	228	-0.033	-0.17%	-0.0059	-0.07%
	Quarter 2	242	-0.045	-0.23%	-0.0064	-0.08%
	Quarter 3	223	-0.027	-0.14%	-0.0036	-0.04%
	Quarter 4 (highest)	236	-0.029	-0.16%	-0.0043	-0.05%
	p-value for heterogeneity		p=0.26	p=0.24	p=0.15	p=0.15
Baseline NO ₂ air pollution‡ \$	Quarter 1 (lowest)	145	-0.013	-0.07%	-0.0017	-0.02%
	Quarter 2	271	-0.044	-0.24%	-0.0067	-0.08%
	Quarter 3	270	-0.061	-0.31%	-0.0089	-0.11%
	Quarter 4 (highest)	243	-0.004	-0.01%	-0.0010	-0.01%
	p-value for heterogeneity		p<0.001	p<0.001	p<0.001	p<0.001

OAs= Output Areas; LTN = low traffic neighbourhood. See Supplementary Material 3 for a version of this table with 95% confidence intervals that capture uncertainty due to variation between OAs. Significance levels in tests for heterogeneity were calculated via Wald tests, in single-variable linear regression models fitted with the 'acreg' command, and that entered the relevant OA-characteristic as a categorical variable. ‡ Quarters defined on an LTN-specific basis. \$ Results similar in analyses that instead used quarters of PM_{2.5}, which correlates 0.94 with NO₂.

Table 5: Estimated health impacts of changes in air pollution due to the LTNs, across the LTNs and their wider surrounding areas

	All 5 LTNs	The 4 larger LTNs (excluding Camden Square)
No. OAs	929	849
Population	307,734	283,651
Population aged 0 to 18	62,184	57,830
Number of deaths per year in Baseline scenario without LTNs	1,481	1,388
Absolute change in deaths per year in scenario with LTNs	-0.15	-0.11
Relative change in deaths per year in scenario with LTNs	-0.011%	-0.008%
Absolute change in deaths per million population per year in scenario with LTNs	-0.49	-0.39
Number of YLLs per year in Baseline scenario without LTNs	22,023	20,469
Absolute change in YLLs per year in scenario with LTNs	-2.28	-1.70
Relative change in YLLs per year in scenario with LTNs	-0.011%	-0.008%
Absolute change in YLLs per million population per year in scenario with LTNs	-7.41	-5.99
Number of incident cases of childhood asthma per year in Baseline scenario without LTNs	964	896
Absolute change in incident cases of childhood asthma per year in scenario with LTNs	-0.34 (NO ₂) / -0.13 (PM _{2.5})	-0.25 (NO ₂) / -0.11 (PM _{2.5})
Relative change in incident cases of childhood asthma per year in scenario with LTNs	-0.04% (NO ₂) / -0.02% (PM _{2.5})	-0.03% (NO ₂) / -0.01% (PM _{2.5})
Absolute change in incident cases of childhood asthma per million children (aged 0 to 18) per year in scenario with LTNs	-5.47 (NO ₂) / -2.09 (PM _{2.5})	-4.32 (NO ₂) / -1.90 (PM _{2.5})

OAs= Output Areas; LTN = low traffic neighbourhood; YLLs = years of life lost. See Supplementary Material 3 for results stratified by LTN scheme, and for results stratified by internal/boundary/other OA status.

DISCUSSION

Summary

This study uses extensive empirical data alongside a full-chain modelling approach to model the impacts of five low traffic neighbourhoods (LTNs) in London on NO₂ and PM_{2.5} concentrations, plus select associated health outcomes. The model inputs included observed before-and-after traffic count, traffic speed and congestion data. We found that LTNs led to statistically significant but small decreases in NO₂ and PM_{2.5} concentrations. This decrease reflected a combination of 1) a mixture of pollution increases and decreases in surrounding boundary areas, which largely cancelled each other out; plus 2) consistent (but modest) pollution decreases inside the LTNs. There was no statistically significant evidence that the average improvement in air quality varied by ethnic diversity or deprivation, but there was evidence that areas with the highest baseline pollution saw the smallest benefits. The overall improvements in average air quality translated into benefits in terms of mortality and childhood asthma, but the effects were very small (0.01% to 0.04% area-wide, 0.05% to 0.19% inside the LTNs). We conclude that LTNs typically improve air quality and public health in London but, at the current modest scale of implementation, their effect is small.

Study strengths and limitations

In this study, we implemented a comprehensive full-chain air pollution modelling framework, which was rigorously validated against observed air pollution measurements. The validated baseline configuration demonstrated good performance and was consistent with established regulatory and scientific guidance. Our analysis advances previous work in several important ways: by examining multiple LTNs across London; by integrating speed and congestion metrics alongside traffic volume data; and by assessing the distribution of impacts at a fine spatial (small-area) scale. In addition to mortality, which is commonly included in similar assessments, we estimated health impacts related to childhood morbidity, an outcome that remains comparatively understudied. Collectively, these contributions add to the limited empirical evidence on the effectiveness of LTNs and provide new insights into their implications for environmental justice and health equity.

Our study also has some important limitations, most of which are expected to be conservative – i.e. to have led us to underestimate the beneficial effects of LTNs. First, we were limited in the traffic data available to us, creating structural uncertainty in our estimates that is not captured in our confidence intervals. In particular, most of the measurement points were inside the LTNs or on immediately surrounding boundary roads, meaning we had to assume no change in traffic on more distant roads. Another structural uncertainty was our use of rather coarse 1km² grids to assign minor road emissions, which may tend to underestimate benefits inside the LTNs. These uncertainties could usefully be assessed in future sensitivity analyses, and compared to other sources of uncertainty in the full modelling chain such as the input data parameters themselves and the assumptions and processes underpinning the emission, dispersion and health simulation models.

Second, we were limited to using ‘after’ data collected one or at most two years after the schemes were implemented. Our findings suggest that the air pollution impacts of LTNs become more favourable over time, which is consistent with the general expectation that it may take some time to realise the full mode shift benefits of road reallocation schemes (Cairns et al., 2002, Furlong et al., in preparation). It is therefore an important limitation that we did not have access to longer follow-up data, and our findings may underestimate the longer-term air quality benefits of LTNs. Future studies should measure or model this when

longer-term data becomes available, and include other more specific traffic-related pollutants, as discussed next.

Third, we only modelled air pollution effects via NO_2 and $\text{PM}_{2.5}$. Although these are traditionally the two key pollutants used to model air quality impacts on health, we note that recent studies highlight the growing significance of black carbon due to its strong associations with adverse health outcomes (Redaelli et al., 2019). Black carbon, a component of particulate matter, is also a particularly sensitive indicator of traffic-related emissions and may show more pronounced reductions following traffic restriction interventions compared to broader particulate matter measures. Black carbon is therefore a worthwhile pollutant for future studies on LTNs and other urban transport policies to model explicitly or measure directly. In addition, our study also does not model ozone (O_3) directly. O_3 is often negatively associated with NO_2 in urban areas and reductions in NO_x emissions can, in some contexts, trigger increases in O_3 . O_3 may therefore have increased slightly with the implementation of the LTNs. This is not expected to have materially affected our estimates of health impacts, however, as we used NO_2 concentration response functions that were estimated without adjustment for O_3 . As such, these estimates may be interpreted as reflecting the effects of NO_2 within the broader pollutant mixture which includes O_3 . Future work could benefit from explicitly modelling O_3 alongside other pollutants and including concentration response functions which appropriately account for O_3 and potential interactive effects.

Fourth, we only modelled health impacts in terms of mortality/years of life lost and childhood asthma. Total health impacts would have been larger had we included the many health outcomes that have been associated with traffic-related air pollution (Health Effects Institute, 2022).

Fifth, in the present study we only model air pollution effects at the local level. Yet air pollution disperses, and most traffic-related background air pollution in London is not generated locally. Specifically, DEFRA produce 1km^2 resolution background concentration maps which provide source apportionment of NO_x concentrations by source group (traffic, industry, domestic etc.) and source location (inside versus outside each 1km^2 grid square). In Greater London in 2023, these DEFRA maps estimate that on average around four times more background NO_x pollution came from traffic outside a given grid square than from traffic inside that grid square (23% from traffic outside, 5% from traffic inside, and 72% from other sources) (DEFRA, 2024). This means that if one achieved London-wide the same relative reduction in traffic that we observed in and around our LTNs, the London-wide relative decrease in NO_2 would likely be several times larger than was estimated in this study. Future simulation studies would be useful to investigate this point.

Finally, we recognise that air pollution is only one of the pathways whereby LTNs may affect population health, and that a holistic assessment of health impacts will be more informative for policymakers (Glazener et al., 2021). Our wider study has previously reported that London's LTNs reduce traffic injuries inside LTNs by a third (and decrease injuries on boundary roads for some groups or locations) (Furlong et al., 2025b, Furlong et al., 2025c). We are currently working on estimating the physical activity impacts of the schemes, and on comparing the magnitude of impacts across those different pathways.

Interpretation of findings in relation to wider evidence

Our results generally align with the limited existing evidence base in pointing towards net air quality benefits from LTNs (AECOM, 2022, CERC, 2021, CERC, 2022, Yang et al., 2022). Most of the existing evidence base consists of studies that, like the present study, model air quality impacts based on changes in traffic counts. These previous modelling studies align

with the present study in finding larger air quality benefits for NO₂ than PM_{2.5}, which is expected since NO₂ is the more specific marker of traffic-related air pollution. These previous modelling studies also generally align with the present study in finding that 1) the air quality benefits inside LTNs are relatively small; and 2) that surrounding boundary roads experience a mixture of positive and negative effects, which to some extent cancel each other out. For instance, in the present study we found average NO₂ changes of -0.87% inside the LTN areas, and -0.18% in boundary road areas (or +0.03% in a sensitivity analysis which removed Camden Square LTN).

By contrast, the only previous controlled study that measured air pollution directly (using NO₂ monitors around three LTNs in a single borough) found much larger effects, with NO₂ changes of -5.7% inside the LTN areas and -8.9% in boundary and surrounding areas (Yang et al., 2022). This discrepancy is puzzling, particularly the large air quality benefit for boundary and surrounding areas. We therefore think it would be valuable to conduct further controlled before-and-after studies that directly measure air pollution in and around new LTNs.

In interpreting our findings, we think it important to consider two further points from the wider literature on this topic. The first point is that interventions may achieve proportionally greater impacts when scaled up to the city level as compared to when implemented in just a few local areas. For instance, when Mueller *et al.* (2020) considered the potential effects of scaling Barcelona's superblocks across the whole city, they estimated that the pollution benefits could be substantial (e.g. -24.3% in NO₂ pollution, city-wide), driven by large modelled modal shifts. At present, London is very far from having LTNs implemented city wide: as of June 2024, an estimated 5% of Londoners live in an LTN (Furlong et al., 2025b), and implementation is generally slow and piecemeal. If LTNs were implemented city-wide, we would expect larger proportional air quality benefits for two reasons. First, as discussed above, our model is limited to a focus on local air quality benefits. Because air pollution disperses, our model is expected to underestimate several-fold the relative air quality benefits of city-wide LTNs. In other words, a 10% reduction in local traffic delivers substantially smaller local air quality benefits than a 10% reduction in city-wide traffic. Second, more speculatively, it seems possible to us that the traffic reduction impacts of LTNs might scale in a non-linear way, with greater effects per LTN above a certain threshold of implementation. For instance, the approximately 10% reduction in local traffic that we observed after implementing a single LTN might become, say, a 20% reduction in city-wide traffic if implementing LTNs city-wide.

The second point is that cities are expected to achieve the biggest air quality benefits when they combine road-reallocation policies like LTNs with other measures such as clean air zones. For instance, in a scenario modelling study from Barcelona, Rodriguez-Rey *et al.* (2022) found that the largest NO₂ reductions were estimated when superblocks (which are similar to LTNs) were implemented alongside a clean air zone. This is in line with best practice when it comes to generating policy options, where packaging sustainable urban mobility policies is recommended as the gold standard as it can increase acceptability, effectiveness, and impact (Khreis et al., 2023, May et al., 2018). In London, a clean air zone (the "Ultra Low Emission Zone") was progressively rolled out across the city between 2019 and 2023, contributing to substantial improvements to air quality, particularly on busy main roads (GLA and TfL, 2025). We consider such policies highly complementary to LTNs, as they mitigate the modest negative air pollution impacts that LTNs have on some boundary roads. In other words, if LTNs are implemented alongside a strong clean air zone or similar interventions, even boundary roads that experience an increase in *traffic* may experience a decrease in *pollution*.

Environmental justice implications

One of the central debates around urban traffic interventions is their impact on environmental justice, that is, whether they improve or worsen already entrenched exposure disparities. When we stratified areas by proportion of non-White residents and by levels of household deprivation, we found pollution decreases in all areas, with no statistically significant differences across these groups in the magnitude of this improvement. Our ability to detect inequitable effects was, however, constrained by modest sample sizes, small effect sizes and the fact we only analysed five LTNs. This makes it possible that inequitable impacts existed that we were not statistically powered to detect. Further investigation of the spatial impacts of LTNs would therefore be valuable, across a larger number of LTNs.

In addition, we did find evidence that areas with the highest baseline NO₂ levels benefited the least. We note that the areas in our study with the highest baseline pollution typically lay alongside main roads, which do not generally receive any traffic restrictions when an LTN is implemented but instead become boundary roads. This finding of smaller benefits on roads with higher baseline pollution is therefore in line with our finding of smaller benefits in boundary areas than inside the LTNs.

In interpreting these findings, it is important to note that we did not find evidence that on average there was a *harm* either to the most polluted quarter of areas (change -0.01% in NO₂) or to boundary road areas in general (change -0.18% in NO₂). This finding is in line with previous evidence that there is no large, systematic increase in traffic on boundary roads (Thomas and Aldred, 2024). Our study therefore indicates the inaccuracy of a common theme of opposition to LTNs, namely “LTNs [...] have proven time and time again to increase congestion/pollution” (Gössling et al., 2024).

Nevertheless, the fact that the benefits were small to negligible on the most polluted roads does demonstrate the potential for LTNs to exacerbate pre-existing inequalities in air pollution exposure and this is a key area for policy intervention. Moreover, although we found no net harm to boundary roads on average, we did find increases in traffic and pollution on some specific roads. We believe these findings further reinforce the case for implementing LTNs as part of a package of transport policies, with measures like LTNs (which bring the largest benefits to minor roads) coupled with other measures like clean air zones, fuel taxes or price increases, alternative fuel and vehicle technologies, or diesel surcharges (which bring the largest benefits to main roads). We also consider that local authorities should monitor all LTN boundary roads carefully to identify those specific road segments which experience traffic increases and should adaptively target those boundary roads that are negatively affected with additional local mitigation measures. A synthesis of 58 unique urban policy interventions to reduce traffic-related air pollution in cities can be found in Khreis et al. (2023).

Conclusions

We conclude that LTNs do typically improve air quality at the local level, which translates into benefits in terms of mortality and childhood asthma incidence. Their average effect is small, however, and largely confined to the areas inside the schemes. Impacts appear broadly equitable by small-area ethnic diversity and deprivation, however areas with higher baseline pollution (which typically lie alongside main roads) benefit the least and warrant further targeted intervention. LTNs should therefore be seen as complementing, not replacing, broader policies like clean air zones, clean bus fleets, and road user charging.

We find that, despite being a prominent concern in the opposition to LTNs (Verlinghieri et al., 2025), boundary road areas do not experience an increase in modelled air pollution on average. We do, however, find that pollution increases by a small to moderate amount on some specific boundary roads (as offset by decreases on other boundary roads). This

highlights a need for granular monitoring of traffic and air pollution impacts, which can be used for iterative scheme refinement to address or mitigate any harms.

As cities around the world implement and expand traffic reduction measures, policy makers should situate LTNs within broader, justice-oriented urban environmental strategies, and commit to ongoing, evidence-based monitoring and adjustment.

REFERENCES

- AECOM 2022. Hackney Stoke Newington Church Street Low Emission Neighbourhood. Air Quality Modelling Study. Prepared for the London Borough of Hackney. Accessed 31/10/2025 from https://drive.google.com/file/d/12g1sZedoV2JI88SLk1HQ2fA-TM_MLTl4/view.
- ALDRED, R. & GOODMAN, A. 2021. The Impact of Low Traffic Neighbourhoods on Active Travel, Car Use, and Perceptions of Local Environment during the COVID-19 Pandemic. *Findings*, March.
- ALDRED, R., GOODMAN, A. & WOODCOCK, J. 2024. Impacts of active travel interventions on travel behaviour and health: Results from a five-year longitudinal travel survey in Outer London. *Journal of Transport & Health*, 35, 101771.
- BEEVERS, S., CARSLAW, D., WESTMORELAND, E. & MITTAL, H. 2009. Air pollution and emissions trends in London. London: King's College London. Accessed 03/11/2025 from https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1004010934_MeasurementvsEmissionsTrends.pdf.
- BELCHER, K., DAVIES, C., GUSCOTT, E., HOLLAND, E. & VEY, J. 2022. *Low Traffic Neighbourhoods: Research Report*, London, NatCen.
- CAIRNS, S., ATKINS, S. & GOODWIN, P. 2002. Disappearing traffic? The story so far. *Proceedings of the Institution of Civil Engineers – Municipal Engineer*, 151, 13-22.
- CARSLAW, D., APSIMON, H., BEEVERS, S., BROOKES, D., CARRUTHERS, D., COOKE, S., KITWIROON, N., OXLEY, T., STEDMAN, J. & STOCKER, J. 2013. Defra Phase 2 urban model evaluation. UK-AIR, Department for Environment, Food and Rural Affairs.
- CERC 2021. Dulwich Streetspace Air Quality Modelling (June 2021 traffic monitoring): Prepared for London Borough of Southwark. Accessed 31/10/2025 from <https://services.southwark.gov.uk/transport-and-roads/improving-our-streets/live-projects/streetspace/dulwich-review?chapter=2>.
- CERC 2022. Assessing the Air Quality Impact of Lambeth's Low Traffic Neighbourhoods: Pre-Scheme and Post-Scheme Scenarios, Ferndale. Prepared for the London Borough of Lambeth. Accessed 31/10/2025 on https://www.lambeth.gov.uk/sites/default/files/2022-02/CERC_FerndaleLTN_AirQuality.pdf.
- CERC 2024. Assessing the Air Quality Impact of Brixton Hill Low Traffic Neighbourhood. Prepared for the London Borough of Lambeth. Accessed 31/10/2025 from Appendix B in <https://moderngov.lambeth.gov.uk/documents/s161365/Appendix%20B%20-%20Stage%20Two%20Monitoring%20Report.pdf%20>.
- CHEN, X., GEHRING, U., DYER, G. M. C., KHOMENKO, S., DE HOOGH, K., TONNE, C., TATAH, L., VERMEULEN, R., KHREIS, H., NIEUWENHUIJSEN, M. & HOEK,

- G. 2024. Single- and two-pollutant concentration-response functions for PM(2.5) and NO(2) for quantifying mortality burden in health impact assessments. *Environ Res*, 263, 120215.
- COLELLA, F., LALIVE, R., SAKALLI, S. O. & THOENIG, M. 2023. acreg: Arbitrary correlation regression. *The Stata Journal: Promoting Communications on Statistics and Stata*, 23, 119-147.
- COOKE, P., SHERRINGTON, R. & HERRMANN, M. 2021. How Politicians and Lobby Groups Tried — And Failed — To Co-opt Legitimate Concerns Over Low Traffic Neighbourhoods. DeSmog: Accessed 22/05/2026 from <https://www.desmog.com/2021/08/18/low-traffic-neighbourhoods-politicians-lobby-groups/>.
- DEFRA 2023. Emissions Factors Toolkit v12.0. User guide accessed 01/11/2025 via <https://laqm.defra.gov.uk/wp-content/uploads/2023/11/EFTv12.0-user-guide-v1.0.pdf>. Data available from laqmhelpdesk@bureauveritas.com
- DEFRA 2024. Background Mapping data for local authorities - 2021. Accessed 03/11/2025 from <https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2021>.
- DEFRA 2025. Local Air Quality Management Technical Guidance (TG22). Accessed 31/10/2025 from <https://laqm.defra.gov.uk/air-quality/featured/uk-regions-exc-london-technical-guidance/>.
- DENIER VAN DER GON, H., HENDRIKS, C., KUENEN, J., SEGERS, A. & VISSCHEDIJK, A. 2011. Description of current temporal emission patterns and sensitivity of predicted AQ for temporal emission patterns. EU FP7 MACC deliverable report D_D-EMIS_1.3. Utrecht: TNO Report.
- DEPARTMENT FOR TRANSPORT 2024. Road traffic statistics. Accessed 31/10/2025 on <https://roadtraffic.dft.gov.uk>.
- DEPARTMENT FOR TRANSPORT 2025. Domestic air pollution emissions from transport in 2023. Accessed 30/10/2025 from <https://www.gov.uk/government/statistics/transport-and-environment-statistics-2023--2/domestic-air-pollution-emissions-from-transport-in-2023>.
- FURLONG, J., ARMSTRONG, B., FEVYER, D., ALDRED, R., EDWARDS, P., LAVERTY, A. A. & GOODMAN, A. 2025a. Statistical analysis plan: Journey times and congestion on LTN boundary roads, including the use of this data for air pollution modelling. Accessed 03/11/2025 from <https://westminsterresearch.westminster.ac.uk/item/wyq50/statistical-analysis-plan-journey-times-and-congestion-on-ltn-boundary-roads-including-the-use-of-this-data-for-air-pollution-modelling>
- FURLONG, J., FEVYER, D., ARMSTRONG, B., EDWARDS, P., ALDRED, R. & GOODMAN, A. 2025b. Low Traffic Neighbourhoods in London reduce road traffic injuries: a controlled before-and-after analysis (2012-2024). *Inj Prev*.
- FURLONG, J., FEVYER, D., BERKOFF, N., ARMSTRONG, B., LAVERTY, A. A., ALDRED, R., VERLINGHERI, E. & GOODMAN, A. in preparation. Low Traffic Neighbourhoods in London: boundary road journey times and congestion. Available at SSRN: <https://ssrn.com/abstract=6795014> or <http://dx.doi.org/10.2139/ssrn.6795014>.
- FURLONG, J., FEVYER, D., CASEMENT, B., ALDRED, R., LAVERTY, A. A., ARMSTRONG, B., EDWARDS, P. & GOODMAN, A. 2025c. Removing Through-Traffic on Minor Roads Reduces Road Danger at Junctions with Surrounding Major Roads. *Findings*, August.
- GLA AND TFL 2025. London-wide Ultra Low Emission Zone One Year Report. London Greater London Authority. Accessed 03/11/2025 from <https://content.tfl.gov.uk/london-wide-ulez-one-year-report.pdf>.

- GLA AND TFL AIR QUALITY 2021. London Atmospheric Emissions Inventory (LAEI) 2019. Accessed 31/10/2025 from <https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-laei-2019-e758q/>.
- GLAZENER, A. & KHREIS, H. 2019. Transforming our cities: best practices towards clean air and active transportation. *Current environmental health reports*, 6, 22-37.
- GLAZENER, A., SANCHEZ, K., RAMANI, T., ZIETSMAN, J., NIEUWENHUIJSEN, M. J., MINDELL, J. S., FOX, M. & KHREIS, H. 2021. Fourteen pathways between urban transportation and health: A conceptual model and literature review. *Journal of Transport & Health*, 21, 101070.
- GLAZENER, A., WYLIE, J., VAN WAAS, W. & KHREIS, H. 2022. The impacts of car-free days and events on the environment and human health. *Current Environmental Health Reports*, 9, 165-182.
- GÖSSLING, S., SCHWEIGGART, N., NIEUWENHUIJSEN, M., MCEACHAN, R. R. C. & KHREIS, H. 2024. Urban transport system changes in the UK: In danger of populism? *Cities*, 153, 105273.
- GOWERS, A. M., MILLER, B. G. & STEDMAN, J. R. 2014. Estimating Local Mortality Burdens associated with Particulate Air Pollution. London: Public Health England.
- HEALTH EFFECTS INSTITUTE 2022. Systematic Review and Meta-analysis of Selected Health Effects of Long-Term Exposure to Traffic-Related Air Pollution. Special Report 23. Boston, MA: Health Effects Institute.
- HEALTH EFFECTS INSTITUTE 2024. State of Global Air 2024. Special Report. Boston, MA: Health Effects Institute.
- HEIST, D., ISAKOV, V., PERRY, S., SNYDER, M., VENKATRAM, A., HOOD, C., STOCKER, J., CARRUTHERS, D., ARUNACHALAM, S. & OWEN, R. 2013. Estimating near-road pollutant dispersion: A model inter-comparison. *Transportation Research Part D: Transport and Environment*, 25, 93-105.
- JACKSON, M., HOOD, C., JOHNSON, C. & JOHNSON, K. 2016. Calculation of Urban Morphology Parameterisations for London for use with the ADMS-Urban Dispersion Model. *Int. J. Adv. Remote Sens. GIS*, 5, 1678–1687.
- JAFARI, A. J., CHARKHLOO, E. & PASALARI, H. 2021. Urban air pollution control policies and strategies: a systematic review. *J Environ Health Sci Eng*, 19, 1911-1940.
- KHREIS, H., DE HOOGH, K. & NIEUWENHUIJSEN, M. J. 2018. Full-chain health impact assessment of traffic-related air pollution and childhood asthma. *Environ Int*, 114, 365-375.
- KHREIS, H., KELLY, C., TATE, J., PARLOW, R., LUCAS, K. & NIEUWENHUIJSEN, M. 2017. Exposure to traffic-related air pollution and risk of development of childhood asthma: A systematic review and meta-analysis. *Environ Int*, 100, 1-31.
- KHREIS, H., SANCHEZ, K. A., FOSTER, M., BURNS, J., NIEUWENHUIJSEN, M. J., JAIKUMAR, R., RAMANI, T. & ZIETSMAN, J. 2023. Urban policy interventions to reduce traffic-related emissions and air pollution: A systematic evidence map. *Environ Int*, 172, 107805.
- LARRINGTON-SPENCER, H. & SHERRIFF, G. 2025. Agree to Disagree? Insights into Community Views and Sources of Division in Relation to Low Traffic Neighbourhoods in Greater Manchester. *Active Travel Studies*, 5.
- LEACH, F. C. P., YANG, J., SHANKAR, V., COLE, S., PARNELL, K., ENTEZAMI, M. & BARTINGTON, S. E. 2024. The impact of a low traffic neighbourhood intervention on urban noise measured with low-cost sensors in Oxford, UK. *Transportation Research Part D: Transport and Environment*, 134, 104357.
- LI, K. & WILSON, J. P. 2023. Modeling the Health Benefits of Superblocks across the City of Los Angeles. *Applied Sciences* [Online], 13.

- MAY, A. D., KHREIS, H. & MULLEN, C. 2018. Option generation for policy measures and packages: An assessment of the KonSULT knowledgebase. *Case Studies on Transport Policy*, 6, 311-318.
- MEHLIG, D., APSIMON, H., MURRELLS, T., ROSE, R. & CARSLAW, R. 2023. Investigating the use of remote sensing data for emission inventories and modelling NO₂ concentrations in the UK (TFEIP Workshop - Transport, Oxford). Accessed 03/11/2025 from https://www.tfeip-secretariat.org/_files/ugd/e5a9c7_215a730f8428490d8ab4a93a2419cecd.pdf.
- MUELLER, N., ROJAS-RUEDA, D., KHREIS, H., CIRACH, M., ANDRES, D., BALLESTER, J., BARTOLL, X., DAHER, C., DELUCA, A., ECHAVE, C., MILA, C., MARQUEZ, S., PALOU, J., PEREZ, K., TONNE, C., STEVENSON, M., RUEDA, S. & NIEUWENHUIJSEN, M. 2020. Changing the urban design of cities for health: The superblock model. *Environ Int*, 134, 105132.
- NIEUWENHUIJSEN, M., DE NAZELLE, A., PRADAS, M. C., DAHER, C., DZHAMBOV, A. M., ECHAVE, C., GOSSLING, S., IUNGMAN, T., KHREIS, H., KIRBY, N., KHOMENKO, S., LETH, U., LORENZ, F., MATKOVIC, V., MULLER, J., PALENCIA, L., PEREIRA BARBOZA, E., PEREZ, K., TATAH, L., TIRAN, J., TONNE, C. & MUELLER, N. 2024. The Superblock model: A review of an innovative urban model for sustainability, liveability, health and well-being. *Environ Res*, 251, 118550.
- ONS 2024. Life expectancy for local areas of Great Britain. Accessed 03/11/2025 from <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/datasets/lifeexpectancyforlocalareasofgreatbritain>.
- ONS 2025. Traffic Camera Activity. Accessed 31/10/2025 from <https://www.ons.gov.uk/economy/economicoutputandproductivity/output/datasets/trafficcameraactivity>.
- OXFORD CITY COUNCIL 2023. 2022 Air Quality Annual Status Report (ASR). Oxford: Oxford City Council. Accessed 11/05/2026 from <https://mycouncil.oxford.gov.uk/documents/s74777/Annual%20Air%20Quality%20Status%20Report%202022.pdf>.
- PÉREZ, K., PALÈNCIA, L., LÓPEZ, M. J., LEÓN-GÓMEZ, B. B., PUIG-RIBERA, A., GÓMEZ-GUTIÉRREZ, A., NIEUWENHUIJSEN, M., CARRASCO-TURIGAS, G. & BORRELL, C. 2025. Environmental and health effects of the Barcelona superblocks. *BMC Public Health*, 25, 634.
- PRITCHETT, R., BARTINGTON, S. & THOMAS, N. 2024. Exploring expectations and lived experiences of Low Traffic Neighbourhoods in Birmingham, UK. *Travel Behaviour and Society*, 36, 100800.
- REDAELLI, M., SANCHEZ, M., FUERTES, E., BLANCHARD, M., MULLOT, J., BAEZA-SQUIBAN, A., GARÇON, G., LÉGER, C. & JACQUEMIN, B. 2019. Health effects of ambient black carbon and ultrafine particles: review and integration of the epidemiological evidence. *Environmental Epidemiology*, 3.
- RODRIGUEZ-REY, D., GUEVARA, M., LINARES, M. P., CASANOVAS, J., ARMENGOL, J. M., BENAVIDES, J., SORET, A., JORBA, O., TENA, C. & GARCÍA-PANDO, C. P. 2022. To what extent the traffic restriction policies applied in Barcelona city can improve its air quality? *Science of The Total Environment*, 807, 150743.
- ROYAL COLLEGE OF PHYSICIANS 2025. A breath of fresh air: responding to the health challenges of modern air pollution. London: Royal College of Physicians.
- THOMAS, A. & ALDRED, R. 2024. Changes in motor traffic in London's Low Traffic Neighbourhoods and boundary roads. *Case Studies on Transport Policy*, 15, 101124.

- VERLINGHERI, E., LARRINGTON-SPENCER, H., FURLONG, J., ALDRED, R. & GOODMAN, A. 2025. Can mixed-methods help us better understand congestion on Low Traffic Neighbourhood boundary roads? *Journal of Transport Geography*, 128, 104360.
- WHELAN, I., LUIU, C. & POPE, F. D. 2024. Assessing the Polarising Impacts of Low-Traffic Neighbourhoods: A Community Perspective from Birmingham, UK. *Int. J. Environ. Res. Public Health*, 21, 1638.
- XIAO, C. S., SINCLAIR, N., SAUNDERS, L. & PANTER, J. 2023. Evaluating the impact of low traffic neighbourhoods in areas with low car ownership: A natural experimental evaluation. *Journal of Transport & Health*, 33, 101658.
- YANG, X., MCCOY, E., HOUGH, K. & DE NAZELLE, A. 2022. Evaluation of low traffic neighbourhood (LTN) impacts on NO₂ and traffic. *Transportation Research Part D: Transport and Environment*, 113, 103536.

Highlights

- We estimated the impacts of 5 low traffic neighbourhoods (LTNs) in London, UK
- Inside LTNs, pollution fell by 0.87% in relative terms for NO₂ and by 0.33% for PM_{2.5}
- Surrounding 'boundary roads' saw mixed changes, averaging to near zero.
- We estimate that the number of deaths fell 0.01% area-wide, or 0.05% inside LTNs.
- We conclude that LTNs improve local air quality but, at the current modest scale of implementation, the effect is small.

Declaration of interests

☐ 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.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

The CERC co-authors (Matthew Williams, Chetan Lad, David Jinks) report a relationship with Lambeth Council that includes: funding grants. AG lives in a former LTN in South London, that is not one of the schemes studied in this paper. From time to time, AG volunteers in a personal capacity with local healthy streets and safe routes to school groups. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.