Statistical analysis plan: Journey times and congestion on LTN boundary roads, including the use of this data for air pollution modelling.

Dr Jamie Furlong,[1] Professor Ben Armstrong, Dr David Fevyer, Professor Rachel Aldred, Dr Phil Edwards, Dr Anthony Laverty, Dr Anna Goodman

Research questions

This analysis will address the third research strand of the 'LTNs in London' project, funded by the NIHR[2]. It aims to answer the following questions:

1) What is the impact of new Low Traffic Neighbourhoods (LTNs) in London on a) journey times and b) congestion on the surrounding boundary roads?

2) How do any impacts change over time after implementation?

In addition, in this analysis plan we discuss how we will model changes in journey times and congestion at the road segment level and use this as one data input into our modelling of the air pollution impacts of LTNs (part of the fifth research strand of our study).

Methodology

Selecting LTN and control areas

We collected data on 5 LTNs across 4 local authority boroughs in Greater London. These LTNs were selected for study in 2021 as a purposive (i.e. non-random) sample of planned LTNs, choosing planned schemes that local officers were most confident would be implemented. See Furlong et al. (2023) for more details.[3]

Table 1 outlines the LTN schemes in this study including their implementation date. All LTNs were implemented between September 2021 and October 2023, with one LTN subsequently removed and one temporarily suspended due to roadworks on a boundary road.

---

[1] Active Travel Academy, School of Architecture and Cities, University of Westminster, 35 Marylebone Road, London, NW1 5LS

[2] https://www.westminster.ac.uk/research/groups-and-centres/transport-and-mobilities-research-group/projects/low-traffic-neighbourhoods-in-london-research-study

[3] Available at https://westminsterresearch.westminster.ac.uk/item/w1q51/statistical-analysis-plan-low-traffic-neighbourhoods-in-london-interrupted-time-series-analysis-of-sensor-count-data

Table 1. LTNs included in this analysis

Short name	Scheme name and local authority	London?	Date implemented	Number, in Figures 1-2	Data start date for analysis†	Data end date for analysis‡	Target number of weeks
Stoke New, Hackney	Stoke Newington Church Street, Hackney	Yes	20/09/2021	1	12/06/2021	20/09/2024	171
Cam Sq, Camden	Camden Square, Camden	Yes	16/12/2021 (temporarily suspended 01/09/2024)	2	12/06/2021	31/08/2024	168.5
St Ann's, Haringey	St Ann's , Haringey	Yes	22/08/2022	4	22/08/2021	21/12/2024	174
Brix Hill, Lambeth	Brixton Hill, Lambeth	Yes	04/09/2023	6	04/09/2022	21/12/2024	120
Streat Wells, Lambeth	Streatham Wells, Lambeth	Yes	23/10/2023 (removed 07/03/2024)	7	23/10/2022	21/12/2024	113

† Data start date is the earlier of a) the first day of data collection for that site, or b) 12 months before scheme implementation. ‡ Data end date is the earlier of a) the last day of data collection for that site, b) 36 months after scheme implementation, or c) temporarily effectively suspended due to major roadworks (Camden only).

In 2021, for each planned LTN scheme, we identified a suitable control area in the same local authority borough based on a range of criteria. These were: size and demographic similarity; suitability for an LTN intervention in principle (but without one planned); not adjacent to the study scheme;[4] and likely to contain sites with roughly similar travel patterns to sites selected from the study area. Where possible, we matched by trip generating destinations including schools, parks, and local high streets, i.e. seeking a control site with similar destination types. There is high demographic similarity between intervention and control sites, with similar profiles for all characteristics (see Appendix 1).

Defining LTN and control area boundary roads

For the 5 LTNs in this study, we identified a set of roads that we classified as 'boundary roads'. Following the approach of Thomas and Aldred (2024)[5] and Furlong et al. (2024),[6]

---

[4] In St Ann's, Haringey, a different LTN 'Bruce Grove West Green, area B' was implemented in November 2022, in an area partly adjacent to both our control area and our LTN area (https://haringey.gov.uk/sites/default/files/2023-11/bruce_grove_west_green_ltn_area_b.pdf). Given that some road segments of our LTN and control areas border the Bruce Grove LTN, this may slightly reduce the counterfactual contrast between them. We will retain all segments in our main analysis and will conduct a sensitivity analysis to check whether excluding segments adjoining the Bruce Grove LTN affects the results.

[5] https://www.sciencedirect.com/science/article/pii/S2213624X23001785

[6] https://westminsterresearch.westminster.ac.uk/item/wqx4q/road-traffic-injuries-and-ltns-statistical-analysis-plan

a boundary road was defined by us as ‘the nearest external road to each LTN scheme that could potentially experience traffic displacement.’ We repeated the same procedure for the 5 control areas, selecting the nearest external roads that might experience traffic displacement if an LTN were implemented in the control area. We focused on the nearest external roads, as we believe these are most likely to experience diverted through-traffic following the implementation of an LTN. While most boundary roads in the study are major roads (A or B classifications), minor roads were also included if they fit the above criteria. Additionally, in cases where the nearest road was one-way but traffic might also reasonably be diverted onto a nearby road in the opposite direction, both roads were designated as boundary roads.

Boundary roads were defined in 2021 based on local authority LTN plans available at the time. In one case (Camden Square, Camden), the implemented LTN was smaller than indicated by the original plans. As this difference was relatively minor, and because the impacted boundary roads would still plausibly be subject to traffic displacement (even if they were now not the nearest external roads), they have been retained in the analysis. We were not able to add in new boundary roads retrospectively, as these would have lacked ‘pre’ data.

Figures 1 and 2 map the LTNs, control areas and their boundary roads across the 5 LTNs we studied. Appendix 1 presents a summary of the demographic characteristics of the population living on the LTN-control boundary road pairs in this study.

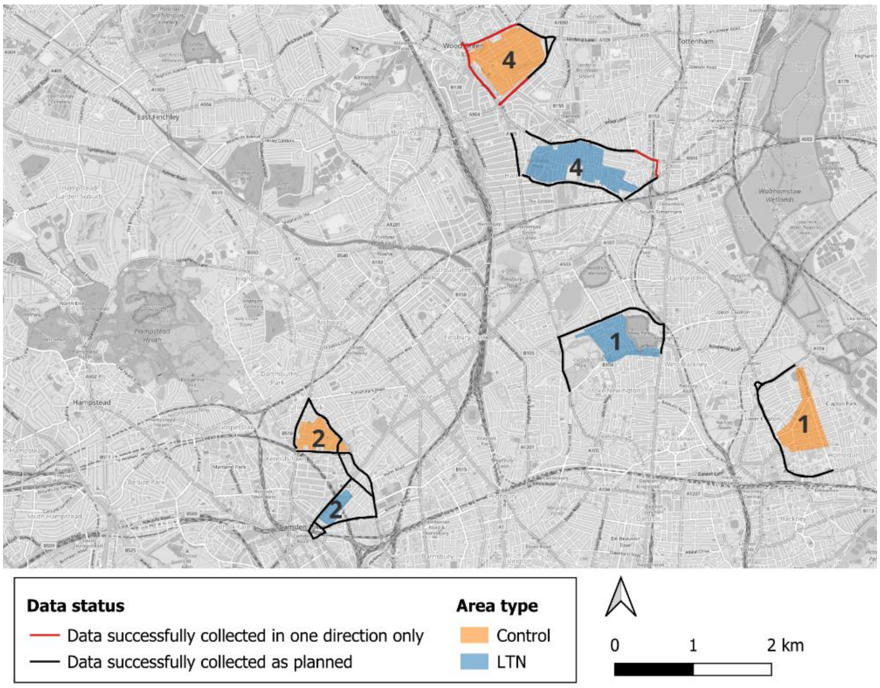

Figure 1. LTNs, control areas and their boundary roads in North London

Figure 2. LTNs, control areas and their boundary roads in South London

Defining segments of boundary roads, and measuring driving times on these segments using Google's 'Directions API'

Once we had defined boundary roads around both LTN and control areas, we divided them into road segments. We created splits between segments at all major junctions and at some minor junctions too, aiming for segments measuring around 500m (but this could be longer or shorter, depending on the density of junctions along a road stretch).

We then used Google's 'Directions API' to measure driving journey times in live traffic conditions along each segment. Each segment was treated as a separate short journey for this purpose, with separate journeys routed in both directions on two-way roads. We routed these segments specifying one 'waypoint' midway along the desired segment, to attempt to force the Google API to route along the desired segment, even if an alternative route might be quicker.

Using Google API, we routed car trips along each of these segments 30 times per week, on Tuesdays (N=24 measurements across the day, at 06:15, 06:45, 07:15, 07:45, 08:15, 08:45, 09:15, 09:45, 10:30, 11:30, 12:30, 13:30, 14:30, 15:30, 16:15, 16:45, 17:15, 17:45, 18:15, 18:45, 19:15, 19:45, 20:15, and 20:45) and Saturdays (N=6 measurements, at 10:30, 11:30, 12:30, 13:30, 14:30, and 15:30. This time window was selected by us as the weekend period with the most car driving trips in London, based on analysis of the National Travel Survey 2017-19[7]).

Segments included in our analysis

In total, data collection was planned for 64 segments across all LTN boundary roads and 60 segments across control area boundary roads (range from N=9 in Camden Square, Camden to N=17 in Lambeth Brixton Hill). As shown in Table 2, a total of N=5 of these planned routes were fully excluded from our analyses. These routes were excluded because at some point the Google API started permanently mis-routing them - for instance, no longer routing 'up the road and stopping at the traffic lights' but instead 'up the road, through the traffic lights, all the way around the junction and returning to the traffic lights on the other side of the street'. In one case, the mis-routing was connected to the implementation of an LTN, as the LTN measures included a new turning restriction onto what we had expected to be a boundary road.[8] In the remaining 4 cases, these instances of mis-routing seemed entirely unconnected to the implementation of LTNs, and instead appeared to reflect minor changes to the map or the algorithm underling the Google Directions API, such that the same lat/long input suddenly started returning a different route.

The 119 segments used in our scheme-level longitudinal analysis had a mean length of 546m (median 531m; inter-quartile range 391-736m; range 130-1183m). Their combined length for each LTN is shown in Table 2.

[7] https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=5340

[8] Specifically, as part of implementing St Ann's LTN in Haringey, a turning restriction was introduced such that vehicles could no longer turn from the A503 eastbound onto Suffield Road northbound. Google API therefore largely stopped returning the desired route (which included part of Seven Sisters road, Suffield Road, and part of West Green Road) after LTN implementation. However, for unclear reasons, the desired route was once again returned by Google API during February-April 2024. The mean journey time on this segment between February-April 2022 (before LTN implementation) was 4.82 min/km, as compared to a mean journey time between February-April 2024 (1.5 years after LTN implementation) of 4.69 min/km. This indicates that, if anything, these stretches of road saw somewhat improved journey times after LTN implementation, and so its exclusion is expected to have had a conservative effect in our analysis.

Table 2. A summary of LTN and control segments that were a) planned and b) actually used in our analysis of LTN level congestion impacts

	LTN segments			Control segments		
Scheme	**Planned**	**Used for scheme-level longitudinal analysis**	**Percent**	**Planned**	**Used for scheme-level longitudinal analysis**	**Percent**
Stoke New, Hackney	4928m (N=10)	4928m (N=10)	100%	4646m (N=10)	4646m (N=10)	100%
Cam Sq, Camden	5287m (N=9)	5287m (N=9)	100%	4000m (N=10)	4000m (N=10)	100%
St Ann's, Haringey	8827m (N=14)	8215m (N=13)	93%†	6340m (N=10)	4231m (N=7)	67%
Brix Hill, Lambeth	10286m (N=17)	10286m (N=17)	100%	7963m (N=15)	7538m (N=14)	95%
Streat Wells, Lambeth	9193m (N=14)	9193m (N=14)	100%	7416m (N=15)	7416m (N=15)	100%

Percentages calculated by distance. † The 13 included segments include N=1 segment that started mis-routing to a modest degree after 17/08/2024, with the route returned becoming 31m longer as it started additionally looping a mini-roundabout at the end of the segment. We decided to retain this route, however, as the mis-routing had only a modest effect on journey time (≈+0.2km per min). We confirmed that our findings for this LTN were similar if this route was excluded, including in year 3 post-implementation.

Missing data

After excluding the N=5 segments that permanently started mis-routing, there were 512,784 individual routes from Google API that were eligible for our scheme-level longitudinal analysis of congestion impacts (273,234 LTN routes, 239,550 control routes). This total reflects 7 to 17 segments per LTN/Control (Table 2) routed 30 times per week each for 113 to 174 weeks (see Table 1). Of these 512,784 routes:

a) N=3384 routes (1838 LTN routes, 1546 control routes) were not saved to the database, on 7/09/2024, 10/09/2024, 19/10/2024, 22/10/2024 and 26/20/2024. This reflected instability in the database, accidentally introduced by our team.
b) N=1116 routes (446 LTN routes, 670 control routes) were not saved to the database from across the remainder of the target data collection period. These failures to save appeared to represent a random technical glitch and occurred seemingly at random across segments and across time.
c) N=2729 routes (1711 LTN routes, 1018 control routes) were excluded by us as the returned route had a distance that differed by more than 15m from the modal distance. This could happen if Google API used an alternative route, for example to avoid a temporary road closure due to roadworks. By contrast, visual inspection indicated that discrepancies smaller than 15m typically reflected very minor changes – often of only 1 or 2m - along essentially the same route.

d) N=1225 routes (545 LTN routes, 680 control routes) were excluded because they fell on a day where 80% or more journeys on that segment had a speed of under 8km per hour (our definition of 'congestion'). 80% is far higher than the average congestion rate for any of our routes (mean 4%, median 0.9%, range 0 to 37% across the 119 segments). These high-congestion days typically clustered together (e.g. 'every day for 1 week, then never again') and we believe they most likely reflected the presence of roadworks.[9]

In total, 1.65% of planned routes were missing or excluded for these reasons (1.66% of LTN routes, 1.63% of control routes. Range 0-11% across the 119 segments). This left a sample of 504,330 routes in our analysis (268,694 LTN routes, 235,636 control routes), drawn from 5,493 unique 'time points' (or 'runs'), each at distinct times on specific dates. Note that missing and excluded data means that, in the subsequent analysis, not every LTN or control journey is included for each of the 5,493 time points. However, as the journeys are not matched (i.e. an LTN journey does not have an equivalent control journey), it is not possible to remove a control journey when an LTN journey is excluded from the data or vice versa. Missing or excluded data are rare and relatively evenly balanced between the LTN and control group, such that we consider them unlikely to introduce bias or substantial measurement error. For this reason, we also chose not to impute this very small amount of data.

Statistical analysis

Modelling segment-level air pollution impacts

For each journey at each time point, the Google Directions API returns the route distance and the estimated journey time in seconds, given live traffic conditions. From this, we can calculate two pre-specified outcome variables at the segment level for each of the 504,330 routes in our analysis:

- Segment-level speed (km per hour).
- Segment-level congestion (binary), which we defined as speed < 8km per hour.[10]

[9] A record of roadworks that took place on our LTN/control boundary roads across our study would enable us to examine the effect of including or removing periods of roadworks. However, retrospective roadworks data is not publicly available and after investigation, we found obtaining consistent data from authorities would be infeasible. Furthermore, interpreting roadworks consistently is difficult, as they can range from full closures to minor footway blockages with minimal impact on traffic. Instead, we chose to empirically identify and remove clear anomalies (as outlined above) in the data, which we determined to be the most practical and reliable approach.

[10] 8kph (or ≈5mph) was selected by us as a threshold for congestion in discussion with our collaborators Cambridge Environmental Research Consultants. One rationale is that 8kph approximates the point when NOx air pollution emissions (g/km) start rising more steeply with slower speeds. As a sensitivity analysis, we will check whether our findings are similar when instead using 10kph as a threshold.

One use of these data in our 'LTNs in London' study is to provide speed and congestion profiles for boundary road segments for use in our air pollution modelling. This air pollution modelling takes the approach of first modelling road traffic pollution given observed road traffic counts measured post-LTN; and then comparing this with the modelled pollution arising from estimated counterfactual road traffic counts if the LTN had not been implemented. We therefore use a similar approach here, estimating both the observed and the counterfactual speed and congestion profiles of each boundary road segment.

For the *observed* speed and congestion post-LTN we will, for each segment in each LTN, calculate a) the mean speed after the LTN has been implemented and b) the proportion of journeys congested on that segment after the LTN has been implemented. We will take separate averages for each year or partial year of follow-up (year 1, year 2, year 3), and will also take separate averages for different times of the day. We will map the Google API times of measurement onto the hours of the week (e.g. Google API data collected on 'Tuesday 07:15' and 'Tuesday 07:45' are averaged to model the hours 'Monday-Friday, 7-8am' – see Appendix 2 for details).

We will then estimate a) mean speed and b) proportion congested for the LTN segments under the *counterfactual* scenario in which the LTN had not been implemented. For this we will use a difference-in-differences approach. Because our data are not matched at the segment level, each segment in an LTN area will be compared to the average scheme-level change across all segments in the control area. This will be done as follows, giving the example of estimating the year 1 impact at 7-8am on a Tuesday morning for a given segment.

Observed LTN speed	= SegmentSpeed_LTN_Year1_Tues07
Counterfactual LTN speed	= SegmentSpeed_LTN_Baseline_Tues07 + (SchemeSpeed_Control_Year1_Tues07 - SchemeSpeed_Control_Baseline_Tues07)

Where 'SegmentSpeed_LTN_Year1_Tues07' is the average speed for the relevant segment at 7am on a Tuesday during year 1 post-LTN implementation; where 'SegmentSpeed_LTN_Baseline_Tues07' is the average speed for the same segment at 7am on a Tuesday during the pre-LTN baseline period; where 'SchemeSpeed_Control_Year1_Tues07' is the average speed across all segments in the control area at 7am on a Tuesday during year 1 post-LTN implementation; and where 'SchemeSpeed_Control_Baseline_Tues07' is the average speed across all segments in the control area at 7am on a Tuesday during the baseline period.

Equivalent calculations will be performed where the outcome is 'percent congested' not 'mean speed', with zero set as a floor for the counterfactual percent congested.

Our primary air pollution analyses will model all segment-level differences regardless of whether they are statistically significant or not. In sensitivity analyses, we will set the counterfactual speed and congestion level as equal to the observed congestion level unless the difference in speed, for that segment at that time point, is statistically significant.[11] Statistical significance will be assessed in a segment-level linear regression model (restricted to the day and time of week in question) that includes the segment under consideration plus the relevant 10 to 15 control segments. The outcome will be speed, with fixed effect predictor variables of LTN status (yes/no), before/after status, and the segment ID. An interaction term between LTN status and before/after status will be fitted, and the difference treated as statistically significant if the p-value is <0.05

Modelling LTN-level longitudinal impacts on journey times and congestion

Our air pollution analysis measures impacts at the road segment level. This has the advantage of allowing us to map impacts with fine geographical detail, and we will also include some such descriptive mapping in our analysis of scheme-level impacts.

Working at the road segment level has, however, an important disadvantage when it comes to modelling the overall LTN-level impacts on journey times and congestion. This disadvantage is that analysing the data at the segment level gives more weight 'per metre' to shorter segments than to longer segments. This is undesirable given that the length of segments varies substantially (inter-quartile range 391-736m; range 130-1183m) and, to a certain extent, arbitrarily (e.g. whether a 700m stretch of road is left as a single segment or split into two segments of 350m each). We believe that weighting each segment by its distance is likely better to capture the real-world impact of LTNs, as speed and congestion on a long segment have a greater influence on total journey times and air pollution emissions than speed and congestion on a short segment.

When modelling LTN-level results, we will therefore calculate our primary outcome variables at the level of the LTN/control area as follows:

- LTN-level journey time (minutes per km): equal to the total duration of travel, across all constituent segments in both directions, divided by the total distance covered.[12]

[11] We fit this model only for speed because speed is a continuous variable, making it straightforward to model the difference-in-difference effect at the segment level using linear regression. In contrast, a logistic regression model for the binary outcome of congestion would not measure the same effect, as it focuses on relative rather than absolute differences. Additionally, logistic regression is prone to convergence issues in this context where many segments consistently have a zero value for congestion at certain times of day.

[12] Journey time is the reciprocal of speed. We use speed in our air pollution analysis as that is the parameter the air pollution models are set up to use. We use journey time in our scheme-level longitudinal analysis to make our results easier to interpret, as it means that both our journey time and our congestion results follow the rule of 'higher regression coefficients indicate more congestion'.

- LTN-level congestion (percent): equal to the proportion, by distance, of all constituent segments that are congested.

Our two primary outcomes will be absolute changes in these two LTN-level variables. As a secondary outcome, we will also measure relative change in scheme-level journey time. [13]

These scheme-level variables will be calculated for each of our 5,493 time points (i.e. runs at specific times on a certain date), calculated separately for up to 5 LTN areas and 5 control areas (see Table 1 for which LTNs/controls are in scope at each date).

We will then use a difference-in-differences approach to compare the changes in our outcome variables across the LTN boundary roads and control boundary roads over time. To do this we will fit linear regression models, with each time point as a unit of analysis. The model specification is as follows:

$$Y_{it} = \beta_0 + \beta_1(prepostperiod) + \beta_2(LTN) + \beta_3(prepostperiod * LTN) + \delta_t$$

Where:

- Y_{it} is the dependent variable (journey times, congestion) for LTN/control area *i* across time period *t* (i.e. one of the 5,493 time points).
- β_0 is the intercept (i.e. the baseline value of Y_{it} when all covariates are zero).
- $\beta_1(prepostperiod)$ is a categorical variable defining the time period (within 12 months pre-LTN, year 1 post implementation, year 2 post implementation, year 3 post implementation).
- $\beta_2(LTN)$ is a binary variable defining LTN versus control status.
- $\beta_3(prepostperiod * LTN)$ is the Difference-in-Differences estimator, representing the causal effect of LTN implementation on the outcome variable Y_{it}.
- δ_t are the other fixed-effect covariates (year, month, school holiday status (termtime/school holiday/public holiday[14] and a cross-classified categorical variable representing all combinations of time of day and day of week). Mean daily temperature and mean precipitation are included

[13] We have chosen to make absolute changes our primary outcome as we think these have the most meaningful real-world impact. We recognise, however, that how a change is experienced will also depend on the relative change. For instance, a 2-minute increase in journey time around an LTN may be more noticeable, or experienced as more problematic, if the baseline journey time were 4 minutes (+50% increase) compared to a baseline of 10 minutes (+20% increase). We therefore also examine relative change as a secondary outcome in relation to journey time.

[14] Defined using data from the local authority of Camden, as this had historical data available since 2021. Comparing school term dates between Camden and our other local authorities for 2024/25 suggested they were very similar. Weekend days were defined as school holidays if there were school holiday days both before and after.

both as continuous variables and as quadratic terms to capture linear and non-linear relationships with the outcome variables).[15]

We will use clustered robust standard errors on a cross-classified year-month variable (i.e. every month*year combination is a unique level) to account for potential temporal autocorrelation in the data. This approach ensures that the standard errors are not underestimated because of within-cluster correlations i.e. observations within the same month or year being correlated and therefore more similar to each other than observations from other time periods.

For our primary outcomes, we will use untransformed scheme-level journey time and scheme-level congestion as the outcomes. For our secondary outcome, we will use logged scheme-level journey times as the outcome, and then exponentiate the regression coefficients to generate a measure of relative percentage change (calculated as [exp(β)-1]*100).

Models will be estimated in Rstudio and replicated in Stata. An example of the Stata syntax is shown below:

*xi: regress ltntime_minpkm i.prepostperiod*LTN i.year i.month i.schoolholiday i.timedow dailytemperature dailytemperaturesq dailyprecipitation dailyprecipitationsq if scheme==”Stoke Newington”, cluster(yearmonth)*

We will initially run all analyses separately by LTN, to examine how far there was heterogeneity between different schemes. We will then pool results across LTNs using random effects meta-analysis techniques, to estimate the impacts of a ‘typical scheme’.

After first running these analyses for all trips pooled together, we will re-run our analyses split between peak-time (Tuesday 07:00-10:00 and 16:00-19:00) and off-peak times (Tuesday before 07:00, 10:00-16:00, and after 19:00, and all day Saturday).

Although our primary focus in the present study is on the average scheme-level impacts of LTNs, we also recognise the potential for substantial variation between different segments surrounding the same LTN. We will therefore additionally present descriptive statistics for our two primary outcomes at the segment level, comparing the distribution of change between the LTN and control groups. We also hope, either in the present study or in future work, to examine which segment-level road characteristics may predict between-segment heterogeneity.

[15] Historical meteorological data for each city on each day comes from the Open-Meteo Weather API, available at: https://open-meteo.com/en/docs/historical-weather-api

Appendix 1: Demographic characteristics of residents of LTN and control areas

Appendix Table A1.1: Demographic and geographical characteristics of the LTN and control areas

		Stoke New, Hackney		Cam Sq, Camden		St Ann's, Haringey		Brix Hill, Lambeth		Streat Wells, Lambeth	
Characteristic	**Variable (% unless stated)**	**LTN**	**Control**	**LTN**	**Control**	**LTN**	**Control**	**LTN**	**Control**	**LTN**	**Control**
Population	Population (N)	4,172	6,734	947	3,422	9,079	8,099	11,105	10,475	12,569	13,251
Area	Area (km2)	0.27	0.32	0.08	0.17	0.47	0.48	0.64	0.51	1.09	0.82
Population density	Population density (people per km2)	15,693	21,286	12,158	20,168	19,203	16,721	17,451	20,377	11,575	16,159
Age	5 to 19	17	14	14	12	16	15	11	11	14	12
	20 to 64	67	72	70	71	68	70	77	78	70	74
	65 plus	10	7	13	12	9	9	8	7	10	8
Sex	Female	53	53	53	52	51	52	52	49	51	53
	Male	47	47	47	48	49	48	48	51	49	47
Ethnicity	White	66	55	66	74	51	50	60	57	58	73
	Black	14	20	9	8	19	19	22	25	19	10
	Asian	6	12	14	8	11	13	5	5	9	8
	Mixed	7	7	7	7	6	7	8	8	9	6
	Other ethnicity	7	5	4	4	12	12	5	6	6	3
Disability	Not disabled	86	86	81	84	86	84	87	87	86	90
	Limited a little	8	9	11	9	8	8	8	8	8	6
	Limited a lot	6	6	8	7	7	8	5	5	6	4
Household car ownership	None	56	58	62	59	58	59	59	67	51	46
	One	38	36	32	36	36	33	35	28	39	46
	Two+	6	5	6	5	7	8	6	5	10	8
Employment	Employed	68	68	57	67	60	58	71	71	68	77
Household deprivation	No dimensions	52	45	47	54	38	37	52	50	49	63

		Stoke New, Hackney		Cam Sq, Camden		St Ann's, Haringey		Brix Hill, Lambeth		Streat Wells, Lambeth	
	One dimension	31	33	32	29	35	35	32	31	33	26
	Two dimensions	12	15	16	12	19	21	12	13	14	9
	Three dimensions	5	6	4	5	7	7	3	4	4	2
	Four dimensions	0	1	1	0	0	1	0	1	0	0
Usual, main commute	Bicycle	7	11	7	5	5	3	6	6	4	4
	Walk	7	8	10	8	6	7	5	6	5	4
	Car or motorbike	9	9	7	6	15	17	9	7	15	7
	Public transport	16	21	18	16	37	41	23	28	29	17
	Work from home	59	49	58	63	36	29	56	51	46	67
	Other mode	2	2	1	2	2	2	2	1	2	1
Usual, main commute (2011)	Bicycle	19	19	12	11	6	3	10	9	5	8
	Walk	7	8	16	10	6	8	6	8	4	5
	Car or motorbike	14	15	10	9	18	19	11	10	21	12
	Public transport	51	52	53	60	66	66	68	69	64	70
	Work from home	7	5	8	8	3	3	4	4	4	4
	Other mode	1	1	1	1	1	1	1	1	1	1

Appendix 2: Mapping days and hours of the week onto Google API routing times, for air pollution analyses

Appendix Table A2.1: How we mapped the Google API routing data that we collected onto different hours of the week

Day and hour of the week (hour = hour starting)	Google API routing(s) used (average taken, if more than one listed)
Monday-Friday, 00:00, 01:00,0 2:00, 03:00, 04:00, 05:00	Tuesday 06:15
Monday-Friday, 06:00	Tuesday 06:15; Tuesday 06:45
Monday-Friday, 07:00	Tuesday 07:15; Tuesday 07:45
Monday-Friday, 08:00	Tuesday 08:15; Tuesday 08:45
Monday-Friday, 09:00	Tuesday 09:15; Tuesday 09:45
Monday-Friday, 10:00	Tuesday 10:30
Monday-Friday, 11:00	Tuesday 11:30
Monday-Friday, 12:00	Tuesday 12:30
Monday-Friday, 13:00	Tuesday 13:30
Monday-Friday, 14:00	Tuesday 14:30
Monday-Friday, 15:00	Tuesday 15:30
Monday-Friday, 16:00	Tuesday 16:15; Tuesday 16:45
Monday-Friday, 17:00	Tuesday 17:15; Tuesday 17:45
Monday-Friday, 18:00	Tuesday 18:15; Tuesday 18:45
Monday-Friday, 19:00	Tuesday 19:15; Tuesday 19:45
Monday-Friday, 20:00	Tuesday 20:15; Tuesday 20:45
Monday-Friday, 21:00	Tuesday 20:45
Monday-Friday, 22:00, 23:00	Tuesday 06:15
Saturday-Sunday, 00:00, 01:00, 02:00, 03:00, 04:00, 05:00, 06:00, 07:00	Tuesday 06:15
Saturday-Sunday, 08:00, 09:00, 10:00	Saturday 10:30
Saturday-Sunday, 11:00	Saturday 11:30
Saturday-Sunday, 12:00	Saturday 12:30
Saturday-Sunday, 13:00	Saturday 13:30
Saturday-Sunday, 14:00	Saturday 14:30
Saturday-Sunday, 15:00, 16:00, 17:00, 18:00	Saturday 15:30
Saturday-Sunday, 19:00, 20:00, 21:00	Tuesday 20:45
Saturday-Sunday, 22:00, 23:00	Tuesday 06:15

Where possible, we matched each hour to measurements taken within that hour. Where this was not possible we approximated as shown below, with our mapping informed by examining the profile of speeds among N= 36,467 trips driven by car in London in the National Travel Survey (2017, 2018, 2019, 2022).