Low Traffic Neighbourhoods in London: statistical analysis plan for examining impacts on the duration of local car trips

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Study aim

The aim of this work is to quantify the impacts of new Low Traffic Neighbourhoods (LTNs) on how long it takes to make car trips in the local area

Proposed methods

LTN areas

This work form one strand of an NIHR study that prospectively identified 8 proposed LTNs in London and matched them to Control areas.[1] We will include in this analysis all LTNs that have been implemented as of September 2024. As of October 2023, five of the LTNs have already been implemented, as shown in Table 1. We think it possible that one further LTN (Woodgrange and Capel, Newham) may be implemented in time for inclusion. The text below is written in the assumption that it is implemented on time and in line with the latest scheme design. It is also written on the assumption that 2 of our proposed LTNs (The Cally in Islington and Cumberland & Holborn in Newham) will not be implemented in time for inclusion in this analysis, although we will add them in if this proves incorrect.

In Camden, the scheme that has ultimately been implemented is considerably smaller than we had originally anticipated. This captures a reality that a proportion of implemented LTNs are indeed modest in their ambition. We will therefore include Camden in our main analysis when pooling estimates across schemes to look at the 'typical' effect of an implemented LTN. As a supplementary analysis, however, we will also present pooled estimates that exclude Camden.

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[1] Further details in 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: Overview of study LTNs and the data collected from them

Local Authority / short name	**Scheme name**	**Date implemented**	**No. 'inside' points, LTN / Control**	**No. 'near' points, LTN / Control**	**Dates of 'before' data collection for driving [and walking/cycling]**	**Dates of '<1 year after' data collection for driving [and walking/cycling]**	**Dates of '1 year after' data collection for driving [and walking/cycling**	**Dates of '2 year after' data collection for driving [and walking/cycling**
Hackney	Stoke Newington	20/09/2021	10 / 10	9 / 10	15/06/2021 to 10/07/2021 [03/07/2021]	07/06/2022 to 02/07/2022 [02/07/2022]	13/06/2023 to 08/07/2023 [01/07/2023]	11/06/2024 to 06/07/2024 [06/07/2024]
Camden	Camden Square	16/12/2021	3 / 10	10 / 10	15/06/2021 to 10/07/2021 [03/07/2021]	07/06/2022 to 02/07/2022 [02/07/2022]	13/06/2023 to 08/07/2023 [01/07/2023]	11/06/2024 to 06/07/2024 [06/07/2024]
Haringey	St Anns	22/08/2022	7 / 10	9 / 8	07/06/2022 to 02/07/2022 [02/07/2022]	13/06/2023 to 08/07/2023 [01/07/2023]	11/06/2024 to 06/07/2024 [06/07/2024]	
Lambeth1	Brixton Hill	04/09/2023	10 / 10	10 / 10	13/06/2023 to 08/07/2023 [01/07/2023]	11/06/2024 to 06/07/2024 [02/07/2024]		
Lambeth2	Streatham Wells	23/10/2023	10 / 10	10 / 10	02/09/2023 to 26/09/2023 [02/09/2023]	31/08/2024 to 24/09/2024 [07/09/2024]		
Newham	Woodgrange & Capel	? May 2024	10 / 10	10 / 10	13/06/2023 to 08/07/2023 [01/07/2023]	31/08/2024 to 24/09/2024 [07/09/2024]		

This table is limited to LTNs which we believe will be implemented by September 2024, in time for inclusion in this planned analysis.

Defining origins and destinations for driving trips of interest

For each LTN area and for each Control area we identified 20 origin points. The starting point for defining these points was the population-weighted centroids of the 2011 census Output Areas.[2] Output areas are an administrative census geography designed to contain around 300 people. We selected at random 10 'inside LTN' origin points inside the area covered by the planned LTN, or inside the matched Control area.[3] We also selected at random 10 'near LTN' origin points that were within 500 metres crow-flies from the nearest edge of the anticipated LTN/control area. This represented a total of 20 points (10 inside + 10 near) * 2 (LTN + Control) * 6 LTNs = 240 points. Of these, 10 'inside' points were ultimately excluded because the boundaries of the LTNs as implemented did not match those we had anticipated (e.g. covering a smaller area. This particularly applied in Camden). A further 4 'near' points were excluded because they lay inside other new LTNs that were implemented in an adjacent area. The final numbers of origin points for each LTN and its Control are shown in Table 1.

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[2] https://geoportal.statistics.gov.uk/datasets/ons::output-areas-december-2011-population-weighted-centroids-1/about

[3] When selecting these points, the edges of the LTN and Control polygons were drawn up to the boundary roads. An alternative method of drawing these polygons involves trimming them by a small amount to exclude properties facing onto the boundary roads or cul-de-sacs coming off the boundary roads. Using this alternative method, 9 of our 'near' points lay 500-580m from the edge of the LTN/Control area, and 10 of our 'inside' points lay just outside the LTN/Control area. We will conduct a sensitivity analysis excluding these points.

Each of the remaining 226 origin points were matched to the crow-flies nearest instance of 10 destination types, as identified using the Points Of Interest (POI) database[4] for all locations except schools.[5] These 10 destinations were: Local food shop; Primary school; GP surgery; Post Office; Larger supermarket; Vet & animal hospital; Shopping Centre; A&E Hospital; Hospice; Recycling centre.[6] We chose the first four destination types as these are the four local services featured in the Index of Multiple Deprivation 'Geographical Barriers' sub-domain.[7] We chose the latter six destination types as potentially more distant locations that people may want to travel to by motor vehicle in order to transport heavy objects (e.g. a weekly shop) or unwell people or animals. We adopted this approach in order to be able to a) provide some insight into impacts on these specific trip types (e.g. 'LTN impacts on trips to GPs'), while also b) looking at typical impacts across a 'basket' of trips covering a range of distances and destinations.

Using Google API to route trips

We are routing our origin-destination pairs using the Google direction API.[8] This service uses the same data source as Google Maps to route a given trip by a given mode. Options for mode include driving, walking, and cycling. The recommended trip route is returned, along with summary data on the trip distance and estimated trip duration. In the case of a driving trip, this trip duration is estimated given live traffic conditions.

For each origin-destination pair, we are routing trips in both directions. During each week of data collection we are routing these trips at four times: Tuesday 08:30; Tuesday 13:00; Tuesday 17:30; Saturday 13:00. As summarised in Table 1, for driving we collected 4 weeks of 'before' data in each LTN, and have collected/will collect 4 weeks of 'after' data in each follow-up wave in each LTN. The dates of data collection varied across the LTNs (see Table 1) but were always the same for each LTN and its matched Control. Post LTN implementation, we will confirm that Google Maps has correctly been updated and is not routing driving trips through modal filters.

For walking and cycling durations we use a single measurement, at 13:00 on a Saturday, at each data collection wave. We used a single measurement because Google does not use live data in estimating trip durations for these modes, and so its estimated trip duration does not vary across the day, across the week, or from week to week.[9]

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[4] https://www.ordnancesurvey.co.uk/documents/product-support/support/points-of-interest-classification-scheme.pdf

[5] https://get-information-schools.service.gov.uk/

[6] The Points Of Interest (POI) codes for these destination codes were: Local food shop (POI code 09470699); Primary school (identified using the easting and northing for mainstream state primary schools registered with the Department for Education); GP surgery (POI code 05280369); Post Office (POI code 09480763); Larger supermarket (POI code 09470819); Vet & animal hospital (POI code 05260322); Shopping Centre (POI code 09480708); A&E Hospital (POI code 05280780); Hospice (POI code 05280370); Recycling centre (POI code 06340462).

[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835115/IoD2019_Statistical_Release.pdf

[8] https://developers.google.com/maps/documentation/directions/overview

[9] We confirmed this invariance by collecting 1 week of data (Tuesday 08:30; Tuesday 13:00; Tuesday 17:30; Saturday 13:00) for walking and cycling in 2021. In 99% of measurements, the variation across these four time points was under 5 seconds. The remaining 1% did not show systematic differences between peak and off-peak, but instead seemed likely to reflect transient factors such as temporary roadworks.

Our target number of trips to route per year is therefore as follows:

- Driving data: 226 (226 origin points, from the 8 schemes shown in Table 1) * 10 (10 destinations per origin) * 2 (routing both to and from) * 4 (4 times per week) * 4 (4 weeks) = 72,320 trips per year.
- Walking and cycling data: 226 (226 origin points) * 10 (10 destinations per origin) * 2 (routing both to and from) = 4,520 trips for each mode per year.

Among all these trips, Google API failed to route a trip as intended in 14/244,080 instances (0.006%) in 2021-2023 combined. This seemed to represent random glitches. Given the very small number of missing trips, we check whether a similarly low rate applies in 2024, and if so we will not seek to impute this data but will proceed to analysis without these missing trips.

Note that post-LTN implementation, our routing using Google does not take into account the exemptions for some disabled people ('Blue Badge' holders[10]) which exist in some form for all our study LTNs except Sheffield. It also aims to route door-to-door rather than, for example, potentially minimizing journey duration by directing someone to park near a modal filter and then walk a short distance on the other side. It therefore captures a conservative scenario for driving duration, and may overstate the actual trip duration for someone who holds a Blue Badge, or for someone who is able to park and walk short distances.

Statistical analysis - stratification

We will stratify all our analyses by three variables:

- Trips with the origin 'inside' an LTN versus 'near' it. We expect the increase in trip duration to be greater for trips with the origin 'inside'.
- Trips at peak time (08:30 or 17:30 on a Tuesday) versus off-peak (13:00 on a Tuesday or Saturday). We expect a greater absolute increase in trip durations at peak time, as travel is slower in general.
- Destination is <1km walking distance from the origin vs 1km+, as defined based on Google API routing for walking in 2021. We expect some short trips will see particularly large absolute increases, as a trip that both starts *and also ends* within the same LTN may suddenly become very circuitous if a filter is in the way. This stratification is also useful as the trip distance affects interpretation - a large increase in trip duration on a <1km trip is less of a concern, since this is a distance that most people could generally walk or cycle. Indeed, one of the aims of LTNs is to achieve mode shift for these shorter journeys.

In addition, we will initially run all analyses separately by LTN, to examine how far one sees heterogeneity between different schemes. We will then pool results across LTNs using random effects meta-analysis techniques, to approximate a 'typical scheme'.

For most purposes, we will pool trips across different destination types, but we will present supplementary analyses stratifying by destination type.

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[10] https://www.londoncouncils.gov.uk/services/parking-services/blue-badge-scheme . As of March 2021, 4.2% of the population of England held a Blue Badge https://www.gov.uk/government/statistics/blue-badge-scheme-statistics-2021/blue-badge-scheme-statistics-england-2021

Overview of outcomes and statistical methods

Our outcomes, and associated analysis methods, are as follows. See the Appendix Table 2 to Table 6 for 'worked example' illustrations of these calculations, plus further details on the calculation of confidence intervals.

Our primary outcomes are:

1. Change in average driving trip duration. We will present descriptive statistics showing the average trip duration 'before' versus 'after'. We will calculate the difference-in-differences effect using linear regression, by fitting an interaction term between before/after * LTN/Control status in a model with trip duration as the outcome. This regression analysis will account for the matched design, whereby each journey type (i.e. a unique origin-destination * day of week * time of day) was collected both before and after. Specifically, the xtset and xtreg commands in Stata will be used to run fixed-effects linear regression models, with the journey type as the fixed effect. Note that we have chosen to make our primary outcome absolute rather than relative increases in trip duration, because a large increase in absolute trip duration is what would seem most problematic to us in terms of, for example, reducing access to services for disabled people who are dependent on their cars.
2. The proportion of 'after' driving trips that increased by ≥10 minutes as compared to the 'before' average. For this, we will calculate the 4-week average for the four 'before' driving trips in each origin-destination pair in each time slot (e.g. a given origin-destination pair, in a specific direction, at 08:30 on Tuesdays). We will compare each 'after' trip to this 4-week average, to see if the absolute travel duration increases by an amount equal to or more than 10 minutes. Our choice of 10 minutes as a threshold is informed by survey work indicating that most people think a delay of up to 5 minutes is acceptable to achieve healthy streets objectives, but only around 10% think a delay of over 10 minutes acceptable.[11] We will present the difference between the LTN vs Control areas in this proportion, using the Stata 'csi' command to generate confidence intervals for this difference in proportions.[12]

Our secondary outcomes are:

1. Relative change in driving trip duration. We will calculate this by first logging the duration values. We will then use logged duration a the outcome in a difference-in-differences linear regression, fitting an interaction term between before/after * LTN/Control status. Performing this linear regression on logged values is equivalent to modelling the ratio between the geometric mean after/before ratio for driving duration across journeys in the LTN groups versus the mean after/before ratio for driving duration across journeys in the Control group. As when looking at absolute changes in duration, we will use the xtset and xtreg commands in Stata to run fixed-effects linear regression models that account for the matched design. For presentation we will use the formula [exp(β)-1]*100 to convert the interaction term

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[11] https://findingspress.org/article/81100

[12] We will use the Stata 'csi' command to generate exact confidence intervals for these differences in proportions because we expect that some of the numerators will be small or zero. In cases where the numerator is zero in both the LTN and the Control area, we will approximate the confidence interval by setting the LTN numerator to 1 for estimation of the standard error. For example, 0/800 in the LTN vs 0/500 in the Control will be treated as 1/800 in the LTN and 0/500 in the Control for the purpose of approximating a confidence interval of -0.12% to +0.37% using the 'csi' command. This will then be centred around 0 to give -0.24% to +0.24%. This approximation will allow the inclusion of these zero-numerator data points in the random-effects pooled estimates.

coefficients from these regression models into estimates of percentage increase in the LTN versus control areas.

2. Absolute and relative change in average driving trip distance. We will present difference-in-difference analyses examining impacts on trip distance, as an alternative way to capture trips becoming 'longer'. These analyses will use the same approach as described above in relation to trip duration.
3. The proportion of 'after' driving trips increased ≥2 minutes / ≥5 minutes / ≥15 minutes as compared to the 'before' average. This will use the same approach as described above in relation to a 10-minute threshold for our second primary outcome.
4. Change in travel time reliability, with a focus on how often a trip may take much longer than normal. For this we will calculate the difference between the longest observed trip length and the median trip length across all four weeks for a given trip type (e.g. a given origin-destination pair, in a specific direction, at 08:30 on Tuesdays in the 'before' sample). We will then compare this difference to that observed for the same trip type in the 'after' data, and calculate the proportion of trip types where the maximum-median 'after' discrepancy increases by ≥2 minutes / ≥5 minutes / ≥8 minutes as compared to the 'before' discrepancy. As a sensitivity analysis, we will check if our findings are similar if we compare the longest trip to the mean of the 3 shorter trips, as opposed to comparing it to the median of all 4 trips.
5. Change in the proportion of trips that are faster by a) walking or b) cycling than the typical (median) driving duration. This will allow us to quantify how far LTNs affect the relative time efficiency of driving versus walking or cycling in terms of trip duration, which may be one mechanism for achieving modal shift between these modes. Note that these estimates may be conservative, in that the Google API driving durations do not take account of the time needed to park.

We will use as baseline data the most recent wave of data collection before the implementation of the LTNs (see Table 1). In a sensitivity analysis, we will confirm our findings are similar if 2021 is used as the baseline year for all LTNS.

We will examine short-term effects (<1 year) for all LTNs, using the most recent wave of 'after' data available following LTN implementation. We will also look at 1-year and 2-year effects for schemes with sufficient follow-up available (see Table 1).

Appendix – worked example of selected outcomes and statistical methods

Table 2: ***Example of raw results, underlying the 'difference-in-difference' estimates of the absolute change in LTN areas compared to Control areas. This example is for Hackney, origins inside LTNs, on peak trips of <1km, <1 year after scheme implementation.***

	No. trips before / after	**Mean trip durations**		
		Before (minutes)	**After (minutes)**	**Absolute change (minutes)**
LTN	704 / 704	2.4	7.5	+5.1
Control	1088 / 1088	4.0	3.9	-0.1
Difference-in-differences				+5.2

Difference-in-difference point estimates for mean absolute trip durations are calculated as the absolute change in the LTN group minus the absolute change in the Control areas. Confidence intervals around this point estimate are then calculated in a fixed-effect linear regression analyses, with mean trip duration as the outcome, with an interaction between the two binary predictor variables of LTN/Control and Before/after, and with the unique journey type (origin-destination * day of week * time of day) as the fixed effect.

Note that as Table 2 shows, a lower proportion of trips were <1km in the Hackney LTN area than in the Control area (44% vs 68%). This imbalance was not systematic across all our study LTNs – pooling all schemes together, the proportions were 49% vs 44% - but was observed in Hackney and, to a lesser extent Haringey. A further advantage of our consistent stratification by trip distance is that it adjusts for this imbalance. For example, after stratification, mean distances with strata were similar (e.g. mean distance 0.5 in both the LTN and Control areas, for trips of distance <1km in Hackney. Mean distance 3.0 in the LTN area vs 3.1 in the Control area, for trips of distance 1km+ in Hackney).

Table 3: ***Example of raw results, underlying the 'ratio-of-ratios' estimates of the relative change in journey durations in LTN areas compared to Control areas. This example is for Hackney, origins inside LTNs, on peak trips of <1km, <1 year after scheme implementation.***

	No. trips before / after	**No. journey types before / after**	**Geometric mean of the ratio of after/before change across constituent journey types**
LTN	704 / 704	176 / 176	2.27
Control	1088 / 1088	272 / 2723	0.97
Ratio-of-ratios, and corresponding percentage increase			2.34 , equivalent to percent increase of 134%

Ratio-of-ratios point estimates for relative trip durations are calculated as the geometric mean ratio of after/before change in the LTN group divided by the geometric mean ratio of after/before change in the Control areas. The resulting ratio-of-ratios can be converted into a percentage increase by subtracting 1 and multiplying by 100.

Confidence intervals around this point estimate are calculated in a fixed-effect linear regression analyses, with logged mean trip duration as the outcome, with an interaction between the two binary predictor variables of LTN/Control and Before/after, and with the unique journey type (origin-destination * day of week * time of day) as the fixed effect. The coefficients are then converted into percentage increases using the formula [exp(β)-1]*100.

Table 4: ***Example of raw results, underlying the percentage difference estimates of the change in large trip duration increases in LTN areas compared to Control areas. This example is for Hackney, origins inside LTNs, on peak trips of <1km, <1 year after scheme implementation.***

	No. trips before / after	**% of 'after' trips that exceed the 4-week 'before' mean by more than….**			
		≥2min	**≥5min**	**≥10min**	**≥15min**
LTN	704 / 704	52.3%	51.8%	23.3%	4.8%
Control	1088 / 1088	1.7%	0%	0%	0%
Percent difference		50.6%	51.8%	23.3%	4.8%

Percent difference point estimates are then calculated as the percentage in the LTN minus the percentage in the Control. Confidence intervals around this are calculated using the csi command in Stata.

Table 5: ***Example of raw results, underlying the percentage difference estimates of the change in journey reliability in LTN areas compared to Control areas. This example is for Hackney, origins inside LTNs, on peak trips of <1km, <1 year after scheme implementation.***

	No. trip types after	**% of 'after' trips where the longest trip exceeds the median by…**		
		≥2min	**≥5min**	**≥8min**
LTN	176	30.1%	8.0%	0%
Control	272	1.8%	0%	0%
Percent difference		28.3%	8.0%	0%

Percent difference point estimates are then calculated as the percentage in the LTN minus the percentage in the Control. Confidence intervals around this are calculated using the csi command in Stata.

Table 6: ***Example of raw results, underlying the percentage difference estimates of the proportion of trips faster by a) walking and b) cycling than by driving in LTN areas compared to Control areas. This example is for Hackney, origins inside LTNs, on peak trips of <1km, <1 year after scheme implementation.***

	No. driving trips before / after	**No. walking trips before / after**	**Comparison of LTN versus Control area in proportion of trips where walking is faster than the median driving duration**			**No. driving trips before / after**	**No. cycling trips before / after**	**Comparison of LTN versus Control area in proportion of trips where cycling is faster than the median driving duration**		
			Before	**After**	**Change**			**Before**	**After**	**Change**
LTN	704 / 704	88 / 88	6.8%	54.6%	47.7%	704 / 704	88 / 88	82.4%	92.1%	9.7%
Control	1088 / 1088	136 / 136	17.7%	17.7%	0%	1088 / 1088	136 / 136	82.7%	80.2%	-2.5%
Difference-in-differences					47.7%					12.2%

Difference-in-difference point estimates for the change in proportions are then calculated as the before/after change in the LTN group minus the before/after change in the Control areas.

To generate confidence intervals for the difference-in-differences estimates illustrated in Table 6, we started by calculating the matched before-and-after difference in proportions for the LTN and control group separately, using stata's mcc command, a discordant pairs approach.[13] The standard errors (SE_change) were deduced from the CIs given by stata as

SE_change = (upper_CI-lower_CI-2/n)/(2*1.96)

We then estimated the difference-in-difference standard error between the LTN and control areas as follows

Point estimate ($_{DiD}$) = (p_change$_1$) - (p_change$_2$)

Standard error ($_{DiD}$) = $\sqrt{}$ [(SE_change$_1$)^2 + (SE_change$_2$)^2]

Upper CI ($_{DiD}$) = point estimate + 1.96 * standard error

Lower CI ($_{DiD}$) = point estimate - 1.96 * standard error

Where p_change$_i$ denotes the change in proportion (i: 1= LTN areas, 2= Control areas), and SE_change$_i$ is the corresponding standard error. DiD is the difference-in-differences change between 'before' and 'after' in the LTN areas versus the Control areas.

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[13] See Fleiss, J. L., B. Levin, and M. C. Paik. 2003. Statistical Methods for Rates and Proportions. 3rd ed. New York: Wiley; p376. Note that Stata, following Fleiss, adds as a continuity correction 1/n to each side of the CI. The back-calculation of the SE(diff) from the CI is therefore 'SE=(ucl-lcl-2/n)/(2*1.96)'. Fleiss implies that the continuity correction is appropriate for the CI but not intrinsic to the SE.