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Changes in motor traffic in London's Low Traffic Neighbourhoods and boundary roads

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ABSTRACT

This paper meta-analyses traffic data extracted from monitoring reports for 46 Low Traffic Neighbourhood schemes in 11 London boroughs introduced between May 2020 and May 2021. Schemes are controversial with still limited academic evidence on impacts. The analysis covers internal and boundary roads, looking at actual changes in motor traffic, and at what changes might have been expected based on background trends in London's three 'functional zones' (Central, Inner, and Outer). All metrics show substantial relative declines in motor traffic on internal roads. For instance, a mean 'pre-LTN' traffic volume of 1,780 dropped to 930 'post-LTN', against a small projected decline to 1,745 if background trends were followed. By contrast, the schemes are only marginally associated with change in traffic volume on boundary roads. While there are inevitable data limitations associated with the use of routine monitoring data, this research provides some support for the position that LTNs can form an effective part of wider strategies to reduce motor traffic and its associated disbenefits. Monitoring data should be publicly shared regionally and nationally to aid analysis.

1. Introduction

Since the start of the Covid-19 pandemic, Low Traffic Neighbourhoods have been introduced in London, and to a lesser extent, other parts of England. LTNs are schemes that seek to reduce motor traffic in primarily residential areas, using traffic management measures such as 'modal filters' to block general motor traffic while permitting walking and cycling.[1] They seek, like many other traffic management measures, to combine 'carrot' and 'stick' by encouraging use of sustainable transport while discouraging car use. The design principle of LTNs is not new: in the Netherlands, this approach to urban planning is called 'unbundling', referring to the goal of separating much motor traffic from people walking and cycling (Schepers et al., 2013). However, research is still emerging on the retrospective introduction of these measures, with stronger evidence for increased walking and cycling than for decreases in car use (Aldred et al., 2021a,b).

London offers an opportunity to study the impacts of such schemes at scale. Within six months of the pandemic starting, newly introduced LTNs in London covered 4% of the population (Aldred et al., 2021a,b). By March 2022, a hundred schemes had been introduced, although a minority had been removed. This scale is noteworthy given the city's complex governance. In London, most transport planning is done by 33 individual districts, which control more than 90% of the roads. Transport for London (TfL) manages 'strategic roads' (many but not all 'A' roads) and oversees much funding to districts, including that provided during Covid-19 for emergency schemes such as LTNs. Generally, districts decide where such schemes should be placed, in negotiation with TfL, which produces strategic analyses that boroughs may refer to in guiding scheme placement.

Planning approaches differ across London districts. One-third chose not to implement any LTN schemes and others vary both in the number of schemes and in the extent to which those schemes are located in more or less deprived or diverse areas (Aldred et al., 2021a,b). Processes by which districts decide whether and where to implement LTNs can be opaque and differ depending on, for instance, technical capacity as well as political leadership (Furlong et al., 2023). This has led to differences in the equity of their distribution (Aldred et al., 2021a,b) and may also potentially mean their impacts vary by district. Approaches to monitoring and evaluation also vary substantially, with a few London districts producing lengthy reports covering a range of potential LTN outcomes

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[1] Modal filters can be camera-enforced (meaning that a range of permitted motor traffic such as disabled residents' cars may be exempted) or physical, potentially with un/lockable bollards to permit emergency service access only. Sometimes measures such as short sections of opposed one-way streets are used to similar ends.

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including metrics such as injury or crime numbers, most using only traffic counts to measure changes in vehicle numbers at specific locations, and other districts not reporting on any monitoring or evaluation metrics. Given this and the devolved nature of London transport planning, there is no city-level monitoring and evaluation of these schemes.

Within the UK (and beyond it, e.g. Nello-Deakin, 2022 on Barcelona's Superblocks), much debate around the impacts of these types of schemes has focused on possible disbenefits for residents and road users on roads to which motor traffic may be displaced from inside an LTN (usually called in the UK 'LTN boundary roads'; Hickman, 2021). Previous studies examining motor traffic capacity reduction suggest such schemes typically induce a mixture of motor traffic redistribution and traffic evaporation, for instance, through mode shift (Cairns et al., 2002). However, Cairns et al. (2002) found that the balance varied substantially from almost all redistribution to almost all evaporation. The nature of this balance will make a large difference to the overall impacts of a particular group of schemes. In response, this study systematically reviews and meta-analyses routine monitoring and evaluation data from 46 London LTN schemes to draw conclusions about changes in motor traffic within the schemes and on their boundary roads.

1.1. Background

LTNs sit within a broader set of interventions that aim to reduce motor traffic and encourage mode shift away from the car. Specifically, LTN schemes seek to cut such traffic both on streets directly affected by traffic reduction measures and across a wider area, and also aim to increase walking and cycling by creating more pleasant neighbourhood streets. There is increasingly evidence demonstrating various benefits of such schemes, much of it from London (Yang et al., 2022). In London, evidence covers schemes introduced in Waltham Forest borough (Outer London) and from London's 2020 'emergency' LTNs. This suggests that Waltham Forest and/or emergency LTNs in London have (i) increased levels of walking and cycling among LTN residents (Aldred et al., 2021a, b; Aldred and Goodman, 2020; Aldred and Goodman, 2021), (ii) reduced car ownership among LTN residents (Goodman et al., 2020a,b), (iii) reduced injuries and risk on roads in LTNs, particularly for pedestrians (Laverty et al., 2021, Goodman et al., 2021a,b,c), (iv) reduced street crime within LTNs (Goodman and Aldred, 2021, Goodman et al., 2021a,b,c), and (v) reduced kilometres driven per vehicle by LTN residents (Goodman et al., 2023). However, no study has yet analysed pan-London impacts on motor traffic inside LTNs and/or on their boundary roads.

Unlike low emission zones or road pricing schemes, LTNs do not involve direct financial disincentives to driving. Instead, they seek to make driving less convenient while making active travel more pleasant. Many of the more worrying concerns about the fairness of LTNs have centred on motor traffic being displaced to LTN boundary roads, leading to disbenefits for those living on, visiting, or using these roads, as well as knock-on impacts on essential car, taxi, or bus journey times. One option in studying these issues is to measure possible disbenefits of increased motor traffic directly. Encouragingly, the papers referenced above on road injuries did not find displacement of injuries to boundary roads. Similarly, analyses of Waltham Forest and 'emergency' LTNs focused on fire response times found no detrimental impact (Goodman et al., 2020a, b, 2021a,b,c).

More recently, Yang et al. (2022) analysed three Islington LTNs, concluding that the LTN implementation led to reduced pollution both inside LTNs and on their boundaries. However, the three Islington schemes might be atypical of LTNs introduced across London; and/or impacted by factors peculiar to that borough. Yang et al's (2022) study used detailed air pollution data provided directly by the local authority, which is more feasible if dealing with a small number of cases. In contrast, Bosetti et al. (2022) discussed 9 scheme reports with information about traffic changes on scheme boundary roads; however, due to their use of already summarised data (rather than data from individual count sites) and the lack of normalisation to background traffic trends, few conclusions could be drawn.

Other research covers related types of scheme in Barcelona, Spain. A recent article by Nello-Deakin (2022) examined road space reallocation in Barcelona's Eixample district. The Eixample schemes were implemented at similar times to London's emergency LTNs and similarly involve substantial reallocation of road space from through motor traffic, with related concerns about traffic displacement. The study used open traffic data provided by the local municipality, generally monthly average traffic counts. Nello-Deakin (2022) reports finding significant 'traffic evaporation' across the intervention area after accounting for background changes, with little change on parallel neighbouring streets (in a grid system, these are analogous to LTN 'boundary roads' with similar concerns about traffic displacement). Specifically, there was a very small relative mean traffic increase on neighbouring roads of 0.7% (median + 3.9%). Nello-Deakin's study is most similar to this research, although the methods differ somewhat due to the spatially and temporally dispersed nature of London interventions and their follow-up, and the lack of collated publicly available data, hence the need in London to conduct a systematic review of such material.

This study explores changes in motor traffic on primarily residential streets within London LTN schemes and on generally busier 'boundary roads', on which concerns about traffic redistribution have focused. The aim is not to come up with a yes-or-no answer regarding traffic displacement versus traffic evaporation, given wider evidence suggests there tend to be a combination of these effects (Cairns et al., 2002), although the balance may vary substantially. The paper represents an early assessment of LTNs in London, considering underlying differences in the changes in overall traffic within Greater London experienced during the pandemic. This comparator is based on available data from Transport for London's designation of London into three large heterogeneous areas (Central Activities Zone, Inner London, and Outer London).

2. Materials and methods

This paper examines levels of traffic reduction within London LTNs, and whether there is a systematic and/or substantial impact on motor traffic on boundary roads. The research question guiding the systematic review conducted was:

What does data from existing monitoring and evaluation reports indicate about the impact that Low Traffic Neighbourhoods in London have had on motor vehicle traffic, on both internal and boundary roads?

The analysis separately examines impacts on internal and boundary roads in response to the framing of the debate and questions about unintended consequences. Both critics and promoters of LTNs typically agree that LTNs if successful can produce substantial reductions in motor traffic inside their borders, while disagreeing about impacts on what both call 'boundary roads' (Hickman, 2021). Specifically, the argument centres on whether most or all motor traffic removed from LTNs simply relocates to their boundaries, or whether there is sufficient 'traffic evaporation' (for instance, through mode shift, or other mechanisms) that traffic impacts on boundary roads are small or minimal (Aldred et al., 2021a,b). The analysis conducted here does not exclude the existence of other, perhaps more complex or longer-term impacts that were not measured (e.g., whether LTNs in East London may over time encourage more car-dependent residents to move to West London) However, it does begin to study an under-researched issue that cannot be easily resolved at scheme or district level, due to many factors affecting traffic in any one site and the typical lack of controls or comparators within local authority analysis.

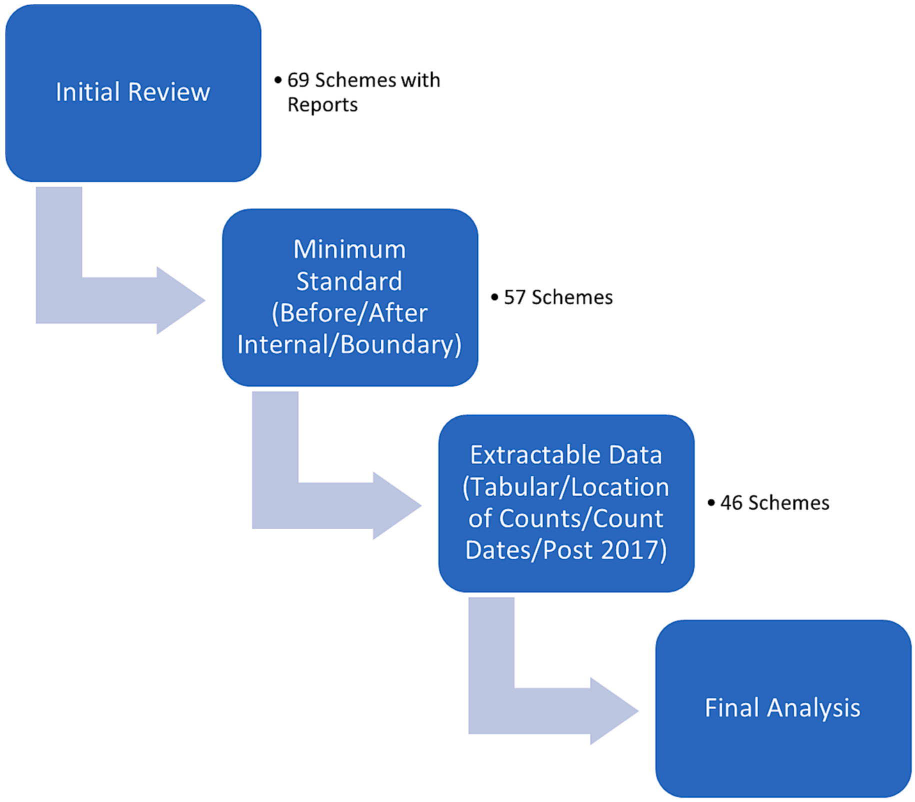

Fig. 1. Search strategy and filtering.

2.1. Document search

By mid-2022, an increasing number of individual reports on London LTN schemes had been published. Local authorities implementing LTNs have been much more likely to monitor motor traffic than to monitor other transport-related outcomes such as bus journey times, cycling flows or (even more so) walking flows. This provided an opportunity to analyse this data and hence draw conclusions across scheme about LTN-induced changes in motor traffic. However, little work has been done so far to analyse this monitoring and evaluation data. Perhaps this is because the format, use and presentation of data, and calculation of impacts (where provided) varies so substantially, making synthesis challenging across multiple schemes and boroughs. These reports also sit on different websites and website sections belonging to London's 33 district councils (known as boroughs).

In May and June 2022, we systematically searched London local authority websites for monitoring and evaluation reports of all low traffic neighbourhood schemes from the 21 (of 33) London districts known to have installed LTNs since March 2020.[2] The search primarily used Google Advanced search tools, i.e., searching within local authority websites using LTN-related keywords, including the names and 'brands' used to refer to specific schemes or by specific boroughs (e.g. 'People Friendly Streets'). We had a pre-existing dataset of 100 London LTNs introduced up to March 2022 and so were able to search for each of these individually.

In total we found 106 documents covering 69 LTN schemes from 16 local authorities (Fig. 1). Of these, 57 schemes had reports with both before and after data on motor vehicle traffic on boundary and/or internal roads. For 46 of these schemes, traffic data was extractable for meta-analysis (our minimum requirement was tabular data, with at least one internal or boundary road data point providing 'pre' and 'post' count data for that specific site from a defined month from 2017 onwards, and the locations of count sites). The earliest of the schemes we could include was introduced in May 2020, and the latest in May 2021.

2.2. Data extraction

The 46 schemes that we were able to include in this report were drawn from 11 different local authorities. From these reports, we extracted measures of pre/post changes in motor vehicle volumes at each included site. We extracted this data at the traffic counter level, recording the spatial location and whether the count point was indicated by the local authority as lying on a boundary road or within the LTN area.[3] We recorded this information on spreadsheets and a GIS file linked by internally generated count point IDs and held regular meetings between the two authors to discuss uncertainties or disagreement from borough classification.

2.3. Count sites

Across all 46 scheme reports that met our inclusion criteria, we found 641 count sites with spatial location data. We then had to remove 40 points (6%) due to data issues that meant that they could not be analysed, primarily the lack of a valid 'pre' and/or 'post' count date including a month. Some minor data issues were identified (such as using 5 day counts rather than the more typical 7-day average). These were included in the main analysis but marked for exclusion during a sensitivity analysis.

[2] This excludes the two boroughs of Redbridge and Wandsworth which installed LTNs but following opposition removed them quickly, before monitoring and evaluation could take place.

[3] In a minority of cases the type of road was not specified, with the counts displayed without this context. In these cases our own database was used as the basis for determining which category each count site fell into.

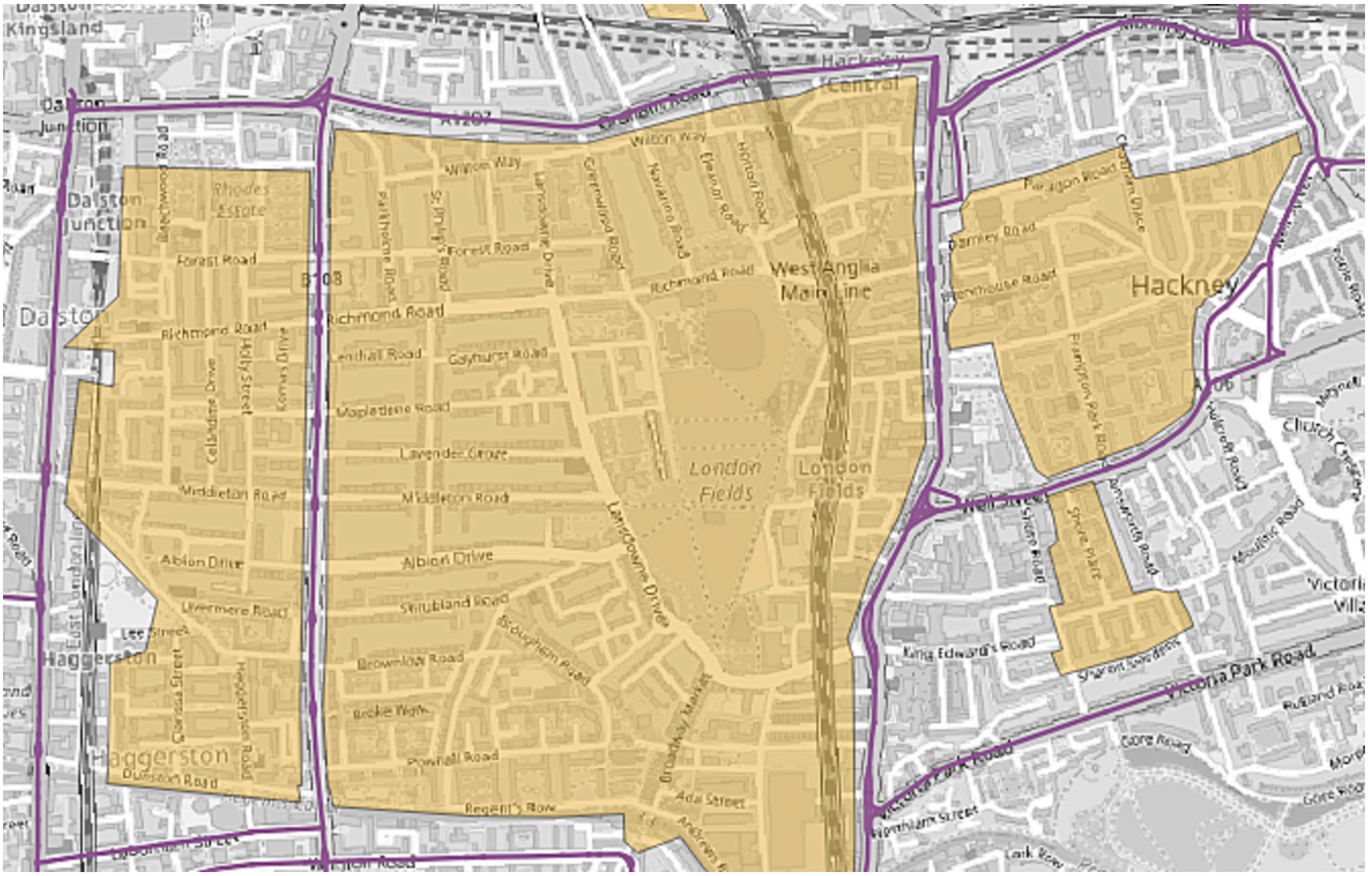

Fig. 2. Map of LTN areas in part of Hackney (yellow), with boundary roads in purple.

Districts almost always classified sites as being 'internal' or 'boundary'. As discussed above, much concern about LTN impacts centres around possible negative impacts on boundary roads, and so this distinction was crucial to our analysis. Districts usually mapped the extent of LTNs, showing where they considered a scheme's boundaries to lie. Often, this extended to an entire 'traffic cell', in the case where a new LTN was immediately adjacent to an area that already had some traffic restrictions. As the Active Travel Academy (ATA) we had for other analysis already collated our own dataset of LTNs introduced since March 2020, although our dataset focused on identifying newly quietened areas. Fig. 2 shows an example in Hackney where new LTNs are coloured in yellow and boundary roads in purple. Typically, these were immediately adjacent roads to which a journey previously going through an LTN would most likely divert.

The ATA dataset was used to cross-check districts' classifications for internal and boundary roads, and in almost all cases the districts' classifications were retained. The cross-checking did lead to the removal of 16 points (2%) from our main analysis, as both reviewers were confident that these lay outside a scheme area of influence. Ten were originally classified by a borough as a boundary road and five as internal roads (one was not stated). All 16 we felt were neither subject to potential traffic displacement, nor within the traffic cell of a scheme, and in some of the 16 cases we felt the local authority might be intending to monitor the road more for background information on traffic in the area rather than to study LTN impacts. This left us with 587 points from the 46 reports that could be included in the analysis. These used a variety of 'pre' and 'post-intervention' months, and we took the latter as being the latest available monitoring point where more than one was provided. Baseline counts were taken between January 2017 and May 2021; while post-intervention counts were taken between July 2020 and February 2022.

Fig. 3 below demonstrates the lack of included count points in Central London (dark green) and Outer London (pale green). While both City of London and Westminster introduced some (albeit atypical) LTN-type schemes, we could not find reports for these with traffic count data.[4] Outer London is more sparsely covered than Inner London, due to a lack of monitoring reports available for some boroughs (e.g. Croydon, Merton), others not providing tabular count data in reports (e.g. Ealing), and Outer boroughs having been less likely than Inner boroughs to implement schemes.[5] Within Inner London, count sites cluster North and North-East (Camden, Islington, Hackney), and South-Central (Lambeth, Southwark).

From the 587 count points, 175 (30%) were boundary road count sites, and 412 (70%) were internal road count sites. Of these, we have reclassified 14 (2%) between boundary and internal, only done where (i) there was disagreement between our mapping and the borough mapping and (ii) upon double-checking and discussion, we believed that the borough had made an error. One was reclassified from boundary to internal, and 13 reclassified from internal to boundary. We conducted sensitivity analysis to explore the impacts of these reclassifications.

As might be expected, almost all (404/412) of the internal streets are classed as local or minor streets (Table 1). However, there is more variability for boundary roads. While around two-thirds are more major A and B roads (110/175), one third are classed as local or minor streets.

[4] Westminster's schemes were primarily aimed at supporting outdoor dining, so motor traffic reduction would not have been a main aim.

[5] As we are using TfL's Functional Zone classification which is based on the GLA definitions of Inner and Outer, Newham and Haringey count as Inner, and Greenwich as Outer London. ONS uses a different classification when analysing and presenting Census data.

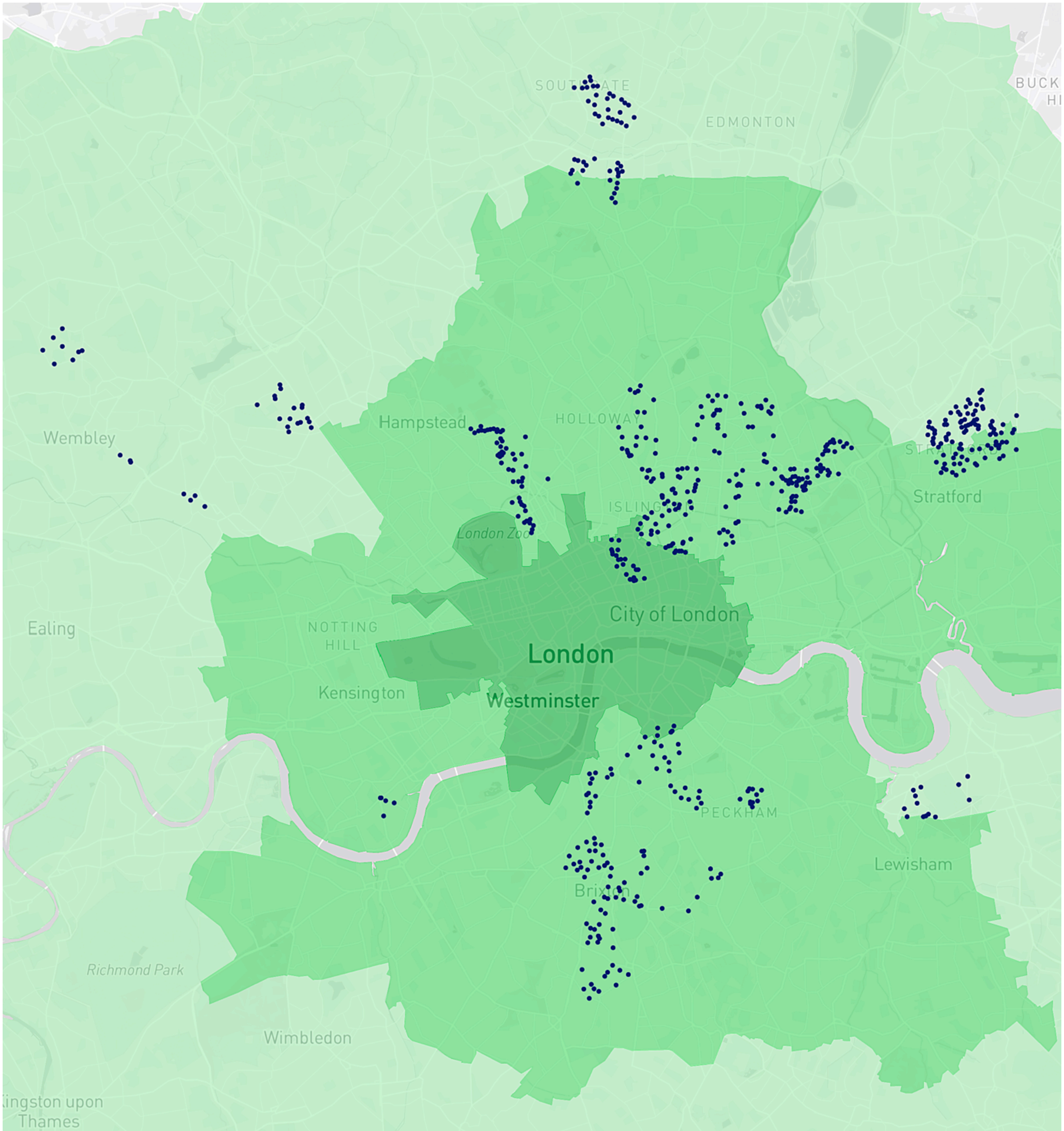

Fig. 3. Count sites, showing as background London's three functional zones.

Table 1
Road classification by whether internal or boundary road.

	A Road	B Road	Local or minor streets	Grand Total
Boundary	77	33	65	175
Internal	0	8	404	412
Grand Total	77	41	384	587

2.4. *Calculating background trends*

We obtained data from Transport for London (TfL) (Appendix A and Fig. 4) to allow us to calculate background trends month-by-month, and hence, estimate the change that might have been expected to occur anyway in that area's functional zone (Central, Inner, Outer) if no scheme had been implemented, between 'pre' and 'post' intervention months. London's functional zones have different traffic characteristics and showed different trends in terms of traffic volumes during Covid times and longer term. Most notably, Central areas saw very large Covid-era changes, which were less sharp and less sustained for Inner or Outer London (see Fig. 4). While these zones are large in the context of a global mega-city, we take some comfort from being able to separate out very different trends in the Central Zone, where relatively few LTNs were implemented, from the much more similar trends in the Inner and Outer Zones. The use of an albeit imperfect comparator/control already is an additional contribution that an academic study in this area can make, compared to typical local authority reporting. Having more comparator zones would be better, in allowing a more accurate normalisation based on borough-specific trends for example; but the analysis was constrained by the available data.

The TfL dataset covered January 2017–June 2022, showing the typical percentage difference between average daily motor traffic in that

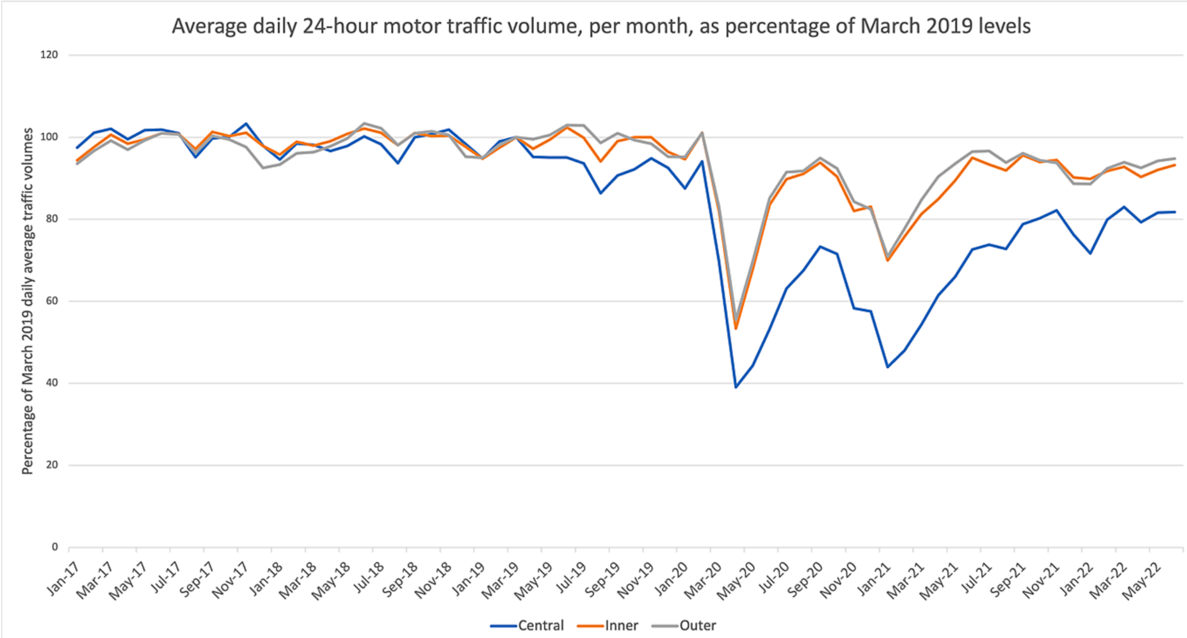

Fig. 4. Chart indicating the background traffic trend in each London functional zone from TfL data.

functional zone compared to March 2019. Thus, for instance, in March 2021 the figure for Inner London was −19%, meaning that average daily motor traffic was 19% less in March 2021 than in March 2019. We initially turned these figures into percentages (and associated ratios) of March 2019. Where average daily motor traffic is 19% less than in March 2019, this is 81% of the March 2019 figure, or a ratio of 0.81 to 1. These percentages were used as 'adjustment factors' as explained below.

We used this dataset to calculate expected average daily motor traffic flows for each count site at the post-intervention point, based on the background trends experienced in its functional zone between baseline and post-intervention month. We did this by dividing the adjustment factor for the post-intervention date by the adjustment factor for the baseline date and then multiplying the resultant background trend factor by the observed baseline flow:

Expected Flow = (Post-Intervention Adjustment Factor/Baseline Adjustment Factor) × Baseline Flow.

The Expected Flow can then be subtracted from the actual post-intervention flow to calculate the difference between observed and expected traffic levels. This allows us to estimate deviation from the background change expected in each count point's particular functional zone (Central, Inner, Outer), between 'pre' and 'post' intervention count months.

2.5. Analysis

Our main analysis presents before and after changes for internal and boundary roads, providing both actual changes and changes relative to background change in the relevant functional area of London. In other words, it separates traffic changes inside and on the boundary of LTNs introduced between May 2020 and May 2021 in London (for which data were available) from changes that might have anyway been expected over the relevant monitoring period in that functional area. The analysis provides both means and medians and distributional plots giving further information on variation and skews. Both absolute and percentage changes are generally provided to give a rounded picture of the impacts of schemes. We provide analysis showing how many count points have 1,000+ motor vehicles per day 'pre' and how many 'post', i.e. the extent to which monitored streets are pedestrian-priority, in line with the level estimated in the UK Department for Transport's Manual for Streets (DfT, 2007, 83).

Further analysis splits results by functional area, although noting that Outer and particularly Central London have relatively few count sites compared to Inner London. It also compares traffic changes on boundary roads depending on whether these are A, B, or local/minor roads. Finally, we briefly summarise key points from a set of results for sensitivity analysis re-running the main analysis firstly eleven times to sequentially exclude one of the boroughs, followed then by the main analysis re-run but (i) changing the 14 points reclassified by us back to the borough definitions (ii) using the ATA's definition of LTNs and boundary roads (which results in some points being classed as 'external'), (iii) removing data where the counts referred to 5-day rather than 7-day averages or where baseline counts had been normalised or estimated using telemetry services, (iv) including points deemed 'external' in the main analysis using their original borough definitions as either boundary or internal. The sensitivity analysis is presented in full in Appendix C.

3. Strengths and limitations

The focus of the paper is an aggregated analysis across multiple sites, as we believe that is where the power of the dataset lies (its ability to examine the typical or total impact of many schemes across London). It avoids looking at impacts at an individual-LTN level, where we there are handfuls of count points at most and where results may be atypical but which are likely to have very little or no impact on overall means or medians. The sensitivity analysis includes looking at the effects of removing individual districts, finding little impact.

Meta-analysing 46 schemes from 11 districts provides a broad coverage and includes some schemes that have since been removed (e.g. Hills and Vales, Greenwich) as well as many still in place. However, there are inevitable limitations. Firstly, data gaps are not random. While we found data issues across districts, some either did not provide any reports at all or provided them without spatially located tabular count data. Hence, we cannot include schemes from Tower Hamlets or Ealing, for instance. Across London during this period, many different schemes such as School Street closures and temporary cycle lanes were happening (Thomas et al., 2022), alongside factors related to Covid-19

Table 2
Count sites.

Count site numbers per borough by road type, as used in main analysis			
Borough	Total	Boundary	Internal
Brent	32	12	20
Camden	53	10	43
Enfield	50	8	42
Greenwich	13	5	8
Hackney	125	44	81
Hammersmith and Fulham	4	4	0
Islington	91	31	60
Lambeth	78	19	59
Newham	16	7	9
Newham/Waltham Forest combined schemes	34	6	28
Southwark	45	20	25
Waltham Forest	46	9	37
Total	587	175	412

and other non-transport issues, and ongoing major schemes such as gyratory removal. Hence, it is challenging to attribute change to a specific intervention. By aggregating results from many schemes across functional zones, controlling for background trends, we improve our ability to identify possibly causal relationships. However, it is still possible, for instance, that LTNs tend to be co-located near to other interventions, such as temporary cycle lanes, and that some effects found may be due to these. LTNs were not introduced randomly across London but were concentrated in more deprived areas (Aldred et al., 2021a,b), and differences in area composition may affect trends in motor traffic levels.

There are known issues with data quality. Usually, reports used Automatic Traffic Counters (ATCs) to monitor traffic, in most cases 'tubes' across the road. These are imperfect. Parked or very slow-moving motor traffic may affect results; although in most cases, count sites were placed away from junctions where queueing is likely, which should reduce this problem. Data problems due to parking may be more an issue on internal residential roads than on boundary roads. Adjusting for expected changes should help control for such bias as that data too is largely based on ATCs. We have not accessed raw data directly from counters, as this would not be feasible for so many count points, schemes, and boroughs (and data may be held by contractors). It is possible that authorities or contractors have made errors[6] (in one report a clearly wrong count was given for one site, for instance). We believe that a small number of undetected errors should not bias the overall results; and sensitivity analyses assess if any borough's exclusion substantially changes the results.

Our background trend analysis has limitations. Disaggregating by functional zone is clearly superior to using background trends for Greater London, which would be strongly skewed by extreme changes in the Central Zone. However, it is still broad brush and individual district trends may vary; and it is derived from the TfL network of counters which tend to be on larger roads, so may be more reliable in relation to boundary than internal roads. The normalisation does however make only a small difference to the results overall, probably because districts tried to avoid use of count data collected when Covid measures were at their peak and background variability highest. Finally, there are limitations to what one can conclude from average daily motor traffic counts. For instance, changes in motor traffic volumes do not correlate linearly with congestion, which is time-specific, nor do they directly map onto air pollution where speed and other variables play an important role.

[6] At the time of finalising this article, specific questions were being raised about a scheme report from one borough – Enfield – due to a contractor error in collecting follow-up data. While we have left this data in the paper, we note that removing Enfield from the dataset makes little difference to results.

Table 3
Mean and median internal and boundary road traffic changes.

Internal Roads	**Medians (middle values)**	**Means (average of all values)**
Baseline	1220	1780
After Observed	662	930
Difference from Baseline	−363	−850
% difference from Baseline	−33.3%	−47.8%
After Predicted	1199	1745
Difference from Predicted	−321	−815
% difference from Predicted	−31.9%	−45.8
Boundary Roads	**Medians (middle values)**	**Means (average of all values)**
Baseline	11,034	11,706
After Observed	11,074	11,505
Difference from Baseline	106	−201
% difference from Baseline	1.2%	−1.7%
After Predicted	10,526	11,429
Difference from Predicted	242	77
% difference from Predicted	4.2%	0.7

3.1. *Schemes included in the study*

Table 2 shows the count sites included for each borough. More detail on each borough's schemes is provided in Appendix 2.

4. Results

4.1. *Main analysis*

Of the 412 internal road count sites, 303 (73.5%) saw any decline in motor traffic, compared to 109 (26.5%) which saw any increase. For the 175 boundary road count sites, 83 (47.4%) saw any decline in motor traffic, against 92 (52.6%) which saw an increase. Below we present the results of the main analysis, using summary statistics as well as distributions. Table 3 presents the median and mean results together for internal and boundary roads, also outlined in accompanying text.

4.1.1. *Internal roads*

Whether measured through median or mean averages, internal roads see a substantial relative reduction in motor traffic - of almost half for mean averages, and almost a third for medians. Adjusting for expected changes made relatively little difference to the percentage reduction. The robustness of results to different measures highlights the systematic impact of LTN schemes within their area, shown also in Fig. 5.

Specifically, a median baseline of 1,220 vehicles per day fell to 662. Had the expected trend been followed, the median 'after' count would have been 1,199. The actual median change was a reduction of 363 motor vehicles per day, and the median difference from the predicted change was a reduction of 321 vehicles per day. The actual median percentage change was a 33.3% reduction, and the median difference from the predicted percentage change was a reduction of 31.9%.

A baseline mean average of 1,780 vehicles per day reduced to 930. Had the expected trend been followed, the mean 'after' count would have been 1,745. The actual mean change was a reduction of 850 motor vehicles per day, and the mean difference from the predicted change was a reduction of 815 vehicles per day. The actual mean percentage change, calculated by dividing the mean change by the mean 'pre' figure, was a 47.8% reduction, and the mean difference from the predicted percentage change a reduction of 45.8%.

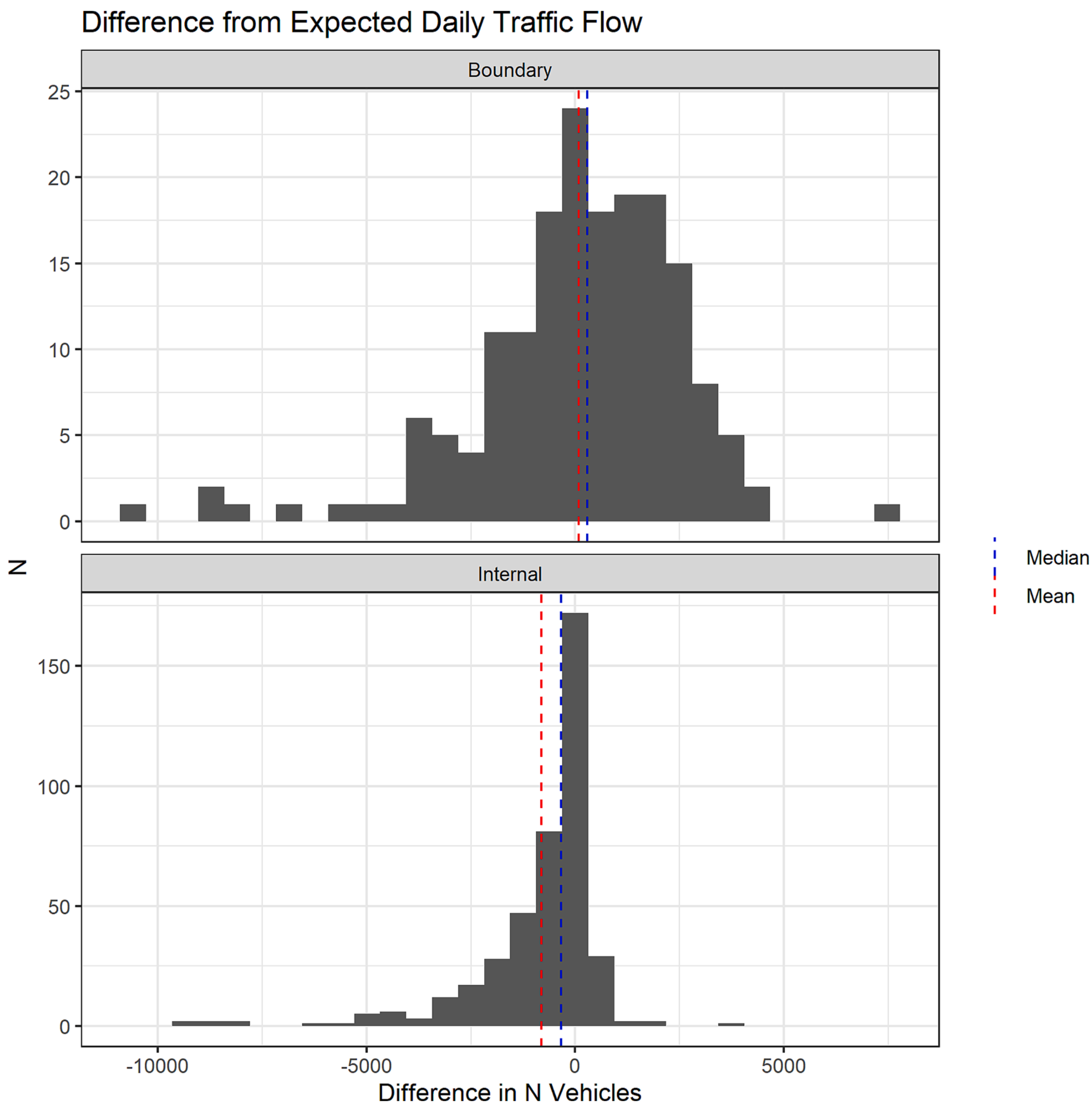

Fig. 5. Histogram showing changes compared to background traffic trends.

4.1.2. *Boundary roads*

By contrast, the average boundary road saw very little change in motor traffic. Whether this has been maintained following 'post' monitoring will depend on whether the background small reduction in traffic during those periods represents a longer-term trend. This in turn will partly depend on the introduction and maintenance of measures to discourage driving and to support walking, cycling, and public transport.

Specifically, a median baseline of 11,034 vehicles per day grew very slightly to 11,074. Had the expected trend been followed, the median 'after' count would have been 10,526. The actual median change was a rise of 106 motor vehicles per day, and the median difference from the predicted change was an increase of 242 vehicles per day. The actual median percentage change was a 1.2% increase, and the median difference from the predicted percentage change was an increase of 4.2%.

A mean baseline of 11,706 vehicles per day reduced to 11,505. Had the expected trend been followed, the mean 'after' count would have been 11,429. The actual mean change was a reduction of 201 motor vehicles per day, and the mean difference from the predicted change was an increase of 77 vehicles per day. The actual mean percentage change, calculated by dividing the mean change by the mean 'pre' figure, was a 1.7% reduction, and the mean difference from the predicted percentage change was a rise of 0.7%. This is the same as in Nello-Deakin's study, which had a median adjusted change similar to this study at +3.7%.

As in Nello-Deakin's research, average differences are typically modest as means or medians. Fig. 5 highlights the lack of a clear systematic pattern, by contrast to impacts within LTNs. The actual changes on boundary roads are in different directions for medians and means, although both are small (+1.2% vs. −1.7%). Taking perhaps the most 'negative' result, roads with around 11,000 motor vehicles per day typically saw a rise of 242 motor vehicles daily during the monitoring period in question, compared to background trends in the relevant functional areas. In practice, due to those background trends being towards slight decline, the typical actual rise was half this (140; plausibly within a margin of error).

4.1.3. *Distributions: internal and boundary roads*

Fig. 5 highlights the different patterns on internal and boundary roads, shown as the difference from the expected change based on functional areas. Three-quarters of monitored internal roads saw

Table 4
Comparison of changes on major and minor boundary roads.

Analysis	Calculation	A Road	B Road	Local/ minor
Baseline	Median	15,306	10,832	6738
After Observed	Median	14,879	11,074	6627
Difference from Baseline	Median	42	414	−10
% Difference from Baseline	Median	0.2	6.1	−0.9
After Predicted	Median	14,912	10,122	6381
Difference from Predicted	Median	292	739	204
% Difference from Predicted	Median	2.5	6.4	5.0
Baseline	Mean	16,076	10,609	6947
After Observed	Mean	15,861	10,723	6600
Difference from Baseline	Mean	−215	115	−347
Difference as a % Change from Baseline	Mean	−1.33	1.08	−5.00
After Predicted	Mean	15,931	10,219	6565
Difference from Predicted	Mean	−69	504	35
Difference from Predicted as a % Change from Baseline	Mean	−0.4	4.7	0.5
Number of Counts	N	78	33	64

able to use the entire carriageway (DfT et al., 2007). Thus, we explored how this changed for internal roads (no boundary road count site recorded less than 1,000 motor vehicles daily at baseline). At baseline, 241 of 412 internal roads (58.5%) carried over 1,000 motor vehicles per day. After the interventions, only 139 (33.7%) did. Of the 273/412 internal roads that had under 1,000 motor vehicles per day post-intervention, 123 of these were newly quietened. A further 21 roads moved from having under 1,000 to over 1,000 motor vehicles per day.

Table 4 compares changes on boundary roads depending on their classification. It shows that changes on A roads are relatively small both in numerical and in percentage terms, and sometimes in different directions. The largest impact metric is for median difference from predicted volumes, at 292 motor vehicles per day. By contrast, the means show 69 fewer motor vehicles per day than predicted. Local minor roads have a higher median percentage difference from predicted, at 5.0% (+204 motor vehicles daily), although the mean increase is negligible in absolute or percentage terms (+35 motor vehicles per day, or +0.5%). It is B roads that show a larger percentage increase, 6.4% greater than predicted for the median and 4.7% for the mean. Note though that there are only 33 data points and that schemes in Central London (in some cases, near major ongoing roadworks) appear to be driving some of this relatively high mean increase.

Table 5
Changes on internal and boundary roads by functional zone of London.

Internal roads	Medians				Means			
	Central	Inner	Outer	Total	Central	Inner	Outer	Total
Number of cases	20	281	111	412	20	281	111	412
Baseline	816	1447	843	1226	1429	2031	1208	1780
After Observed	453	768	493	666	729	1019	741	930
Difference from Baseline	−212	−484	−99	−364	−701	−1012	−467	−850
% Difference from Baseline	−16.9%	−41.1%	−20.5%	−32.7%	−49.0	−49.8	−38.7	−47.8%
After Predicted	876	1383	861	1202	1289	2000	1182	1745
Difference from Predicted	−147	−415	−101	−332	−560	−981	−441	−815
% Difference from Predicted	−25.7%	−40.2%	−17.6%	−31.8%	−39.2	−48.3	−36.5	−45.8

Boundary roads	Medians				Means			
	Central	Inner	Outer	Total	Central	Inner	Outer	Total
Number of cases	13	125	37	175	13	125	37	175
Baseline	7755	11,190	10,223	11,034	9476	11,608	12,823	11,706
After Observed	7120	11,472	10,150	11,074	9523	11,360	12,692	11,505
Difference from Baseline	106	−22	355	106	46	−247	−131	−201
% Difference from Baseline	0.4%	−0.1%	2.1	1.2%	0.5	−2.1	−1.0	−1.7%
After Predicted	7179	10,956	9840	10,526	10,032	11,263	12,478	11,429
Difference from Predicted	−59	333	410	242	−509	97	214	77
% Difference from Predicted	−0.8	4.1	6.5	4.2%	−5.4	0.8	1.7	0.7

declines. There is a long tail of outliers seeing very substantial declines, and only two outliers showing substantial growth. Overall, there is a clear tendency for traffic to fall on internal roads, which we consider highly likely to be caused by the schemes.

By contrast, boundary roads show a much more ‘normal’ distribution; with variation either side of the mean and median (+77, +242), not just identified outliers but also within the curve itself. Combined with the relatively small ‘typical’ or average changes at the centre of the distribution,[7] this may largely highlight the contribution of exogenous factors to variation at an individual count site, compared to the wider functional area trends from month to month.

4.2. Further analysis

As noted above, in the UK a level of 1,000 motor vehicles daily, or 100 at peak hour, is often taken as a tipping point for pedestrians being

Next, we present results split by functional zone (Table 5), and briefly report on sensitivity analysis (see also Appendix C). In aggregate, Inner London schemes perform somewhat better than Outer London schemes: in terms of actual counts, 78.3% (220) of 281 Inner London internal sites saw a reduction in motor traffic, compared to 63.1% (70) of 111 Outer London internal sites. For boundary roads, the 124 Inner London count sites were almost equally split with 63 seeing traffic reduction and 62 seeing traffic growth, whereas 62.2% (23 of 37) Outer London boundary road count sites recorded traffic growth. However, note that due to data availability, many Outer London boroughs and schemes are not in the analysis, with relatively few Outer London boundary road count sites in particular.

4.2.1. Internal roads

For medians, Table 5 shows that the typical count point in Inner London achieves higher relative and absolute reductions than those in Outer London, on roads that are typically initially busier (baseline median 1447 motor vehicles per day compared to 843 in Outer London). When considering means, similar patterns appear. Across all London

[7] The mean change of 0.7% compared to expected background change is comparable in magnitude to similarly calculated changes in Inner London’s non-holiday seasonal fluctuation: for instance, such fluctuation meant average daily motor traffic in March 2019 was 1.4% higher than in May 2019.

schemes, motor traffic fell on average 45.8% more than predicted; this is −48.3% in Inner London, but somewhat less in Central and Outer London (−39.2% and −36.5%).

4.2.2. Boundary roads

Table 5 shows boundary road changes broken down between the Central, Inner, and Outer zones. There are even fewer Central boundary road count sites than for internal roads – 13 – so we caution against taking too much from these results. For Inner London, the actual figures show no change or a small decrease depending on the averaging methods. Taking into account expected changes, the Inner London median boundary road count is 333 vehicles daily or 4.1% higher than the background predictions, while the mean boundary road count is 97 vehicles daily or 0.8% higher than might have been expected.

Outer London figures show that actual counts on boundary road sites rose by a median average of 355 and fell by a mean average of 131. However, because the background trend at these sites across the relevant monitoring periods was slightly more towards decline at Outer than Inner London sites, these become a slightly higher rise than expected compared to Inner London (6.5% median rise and 1.7% mean increase). These figures are only based on 37 sites, so caution should be taken in interpreting them.

4.2.3. Sensitivity analysis

Most differences found during the sensitivity analysis were very small. For boundary roads the three most prominent deviations from the headline findings occurred when (i) when non-standard counts were removed (5-day counts, counts estimated from telemetry data, baseline counts normalised to a specific month), (ii) when the schemes from the borough of Brent were removed, and (iii) roads were classified only using the borough definitions. This represented (respectively) +2.45, +1.55, and +0.92 changes from the overall figures for median % difference from predicted.

For internal roads, the three most prominent deviations from the headline findings occurred when (i) roads were classified only using the stricter ATA definitions, (ii) the points from the borough of Waltham Forest were removed, and (iii) again when the points from the borough of Brent were removed. This represented −6.37%, −4.46%, and −4.24% respectively in terms of changes from the overall median % difference from predicted.

4.3. Discussion

This is the first systematic review of motor traffic volume changes associated with Low Traffic Neighbourhoods in London. We have summarised changes on internal and boundary roads across 46 schemes in 11 boroughs, with nearly 600 data points. This allows us to generalise across the schemes studied, providing median and mean averages and distributional data. Data on seasonal and longer-term changes in three functional zones allows us to separate estimated likely background changes from changes due to LTNs. While as with any study there are limitations related to data sources, methods, and analysis (see above), we believe that these results represent the best evidence so far on the impacts of LTNs in London on motor traffic both within schemes and on their boundary roads.

The results suggest that LTNs in London introduced between May 2020 and May 2021 have typically resulted in a substantial relative reduction in motor traffic inside the scheme area, with particularly strong reductions in Inner London. The typical monitored internal road is now well under 1,000 motor vehicles per day, rather than above this threshold, which may generate a qualitative change in walking and cycling experiences as also suggested by growth in active travel following LTN introduction (Aldred and Goodman, 2020).

On boundary roads, by contrast, we found little change. In terms of raw numbers, ‘pre’ and ‘post’ monitoring sites on boundary roads were similar, around 11,000 motor vehicles per day (with a very small rise if comparing medians, or a very small fall if comparing means). This became a small increase when background trends were accounted for. The picture of little change on average in motor vehicle numbers on boundary roads is good news for the potential for exemptions to limit potential journey length and hence time increases for key users, if this is judged necessary. There was some evidence that as LTN boundary roads, B roads may be more likely to see motor traffic increases, compared to A roads or local/minor streets. While B roads are often excluded from LTN schemes, authorities might consider whether local B roads could be suitable for inclusion given this has happened in some cases (e.g., in Hackney, Lambeth, and Waltham Forest schemes) and that the 8 internal count points on B roads included in this study all saw decreases in motor traffic.

Substantial variation in change on boundary roads as well as some extreme outliers highlight the danger in drawing conclusions about causation (in either direction) from a small or selected group of schemes. Even excluding outliers, a quarter of boundary road count sites saw decreases of 1,000–5,000 motor vehicles per day, while a quarter saw growth of 1,750–4,500 motor vehicles per day (adjusted for expected changes). These and even larger variations in either direction may in part or entirely result from exogenous variation or atypicality that cannot easily be controlled for. For instance, Newham’s monitoring and evaluation reports highlight the likely large impact of Olympic development on boundary roads; and this will be inadequately controlled for by our functional zone normalisation. However, further research could usefully seek to identify those ‘real’ scheme factors that may promote motor traffic reductions rather than growth on boundary roads.

The review highlighted the importance of monitoring and evaluation, including the need in the UK for more accessible, transparent, and standardised data. This is a potential role for organisations like Transport for London, Combined Authorities, the Department for Transport or Active Travel England, and devolved national governments. Nello-Deakin’s (2022) analysis of traffic reduction measures in Barcelona was facilitated by the municipal authority publishing open access monthly average traffic count figures from locations across the city. At the time of writing, London has no such publicly available data. Its provision across the UK could make it easier for academics and others to explore the impacts of a range of interventions and would permit the use of (for instance) more sophisticated normalisation approaches than we were able to use here.

5. Conclusions

Mean falls in motor traffic on internal roads are around ten times greater than mean rises in motor traffic on boundary roads, adjusting for background trends. We believe that this result suggests that these LTN schemes may be contributing to ‘traffic evaporation’ or ‘disappearing traffic’ (Cairns et al., 2002). Traffic evaporation refers to the many ways in which people adjust habitual behaviour in response to restrictions, which may lead to a reduction in motor traffic. This may simply mean a car trip to a specific destination is directly replaced by a walking or cycling trip. Probably more common, however, are more complex changes: for instance, a person makes fewer trips to the supermarket (by car) and more shopping trips on foot to the local shops, or combining car trip destinations to increase efficiency.[8] We cannot say which of these types of behavioural response is dominant in the schemes studied here.

Specifically, this study found substantial reductions in motor traffic within scheme areas, while across boundary roads there was very little aggregate change (+0.7% mean average compared to background trends). We have not attempted to calculate overall traffic reduction due to these schemes, because aggregation is affected by the number of

[8] Other research has found evidence of a relative decrease in driving (Goodman et al., 2023) or car ownership (Goodman et al., 2020a,b) associated with London LTN schemes.

Table A6
Table of Adjustment Factors.

Month	Central	Inner	Outer
Jan-17	97.48	94.38	93.54
Feb-17	101.13	97.59	96.72
Mar-17	102.07	100.65	99.16
Apr-17	99.51	98.43	97.01
May-17	101.72	99.46	99.23
Jun-17	101.89	101	100.96
Jul-17	100.99	100.75	100.71
Aug-17	95.14	97.15	96.26
Sep-17	99.75	101.34	100.33
Oct-17	100.07	100.28	99.47
Nov-17	103.28	101.14	97.63
Dec-17	97.96	97.92	92.51
Jan-18	94.59	95.77	93.33
Feb-18	98.49	98.93	96.11
Mar-18	98.16	97.98	96.36
Apr-18	96.68	99.07	97.78
May-18	97.86	100.81	99.73
Jun-18	100.25	102.15	103.39
Jul-18	98.27	101.12	102.17
Aug-18	93.73	98.1	98.12
Sep-18	100.04	101.01	100.95
Oct-18	100.79	100.26	101.48
Nov-18	101.9	100.44	100.54
Dec-18	98.34	97.65	95.27
Jan-19	94.77	94.77	95.03
Feb-19	98.96	97.49	98.17
Mar-19	100	100	100
Apr-19	95.18	97.18	99.56
May-19	95.1	99.47	100.58
Jun-19	95.05	102.42	102.99
Jul-19	93.61	99.9	102.88
Aug-19	86.39	94.1	98.65
Sep-19	90.71	99.07	100.99
Oct-19	92.2	100.03	99.3
Nov-19	94.88	100.03	98.4
Dec-19	92.55	96.46	95.29
Jan-20	87.55	94.68	95.22
Feb-20	94.12	101.1	101.04
Mar-20	69.66	82.07	82.99
Apr-20	39.04	53.38	55.51
May-20	44.28	67.85	69.7
Jun-20	53.23	83.56	85.11
Jul-20	63.08	89.8	91.47
Aug-20	67.49	91.12	91.75
Sep-20	73.32	93.87	94.91
Oct-20	71.51	90.41	92.36
Nov-20	58.32	82.02	84.3
Dec-20	57.53	83.07	82.47
Jan-21	43.99	69.95	70.93
Feb-21	48	75.78	77.68
Mar-21	54.32	81.29	84.73
Apr-21	61.44	84.94	90.41
May-21	65.98	89.41	93.58
Jun-21	72.66	94.99	96.49
Jul-21	73.82	93.38	96.66
Aug-21	72.79	91.92	93.84
Sep-21	78.8	95.63	96.13
Oct-21	80.25	93.98	94.37
Nov-21	82.15	94.46	93.79
Dec-21	76.3	90.17	88.71
Jan-22	71.66	89.83	88.64
Feb-22	79.92	91.79	92.42
Mar-22	82.99	92.82	93.9
Apr-22	79.27	90.36	92.57
May-22	81.6	92.08	94.27
Jun-22	81.74	93.23	94.83

count points, and in most cases, more counters could have hypothetically been placed (particularly on internal roads, more numerous than boundary roads). However, the results indicate that motor traffic has been reduced, and only a small proportion re-routed to boundary roads. This is suggested by the mean increase of 82 vehicles per day on each boundary road being much lower than the mean reduction of 815

Table B1
Summary of London boroughs with and without schemes included in the study.

Borough	Schemes included	Comment
Brent	5	Reports with traffic data found for all schemes introduced.
Camden	5	Reports available for most schemes introduced during this period.
City of London	0	We did not find any scheme reports containing traffic data at time of collation. (City introduced two LTN-type schemes as we defined them, although these were atypical given the largely non-residential nature of City).
Croydon	0	We did not find any scheme reports containing traffic data at time of collation. (Five LTN-type schemes were introduced, although some were later removed).
Ealing	0	We found six reports on Ealing schemes introduced during this period (most later removed); however, these did not contain tabular data that we could use, only graphs and/or summary comments.
Enfield	2	Reports found for both LTN-type schemes introduced during this period.
Greenwich	1	We found a report for one of the two Greenwich LTNs introduced during this period. This has since been removed.
Hackney	11	Reports containing usable traffic data found for almost all the Hackney schemes introduced during this period.
Hammersmith and Fulham	1	The only LTN-type scheme introduced by the borough in this period.
Harrow	0	We found three reports related to four Harrow schemes; however, these lacked pre-post vehicle count data. Internally, the borough used filtering points as count sites and assumed that no motor vehicles passed these following scheme implementation, while boundary road traffic was monitored via queue length surveys and hence was not comparable data.
Hounslow	0	No suitable reports available at time of collation. While borough-wide reports covered seven schemes, these did not contain pre-post figures for individual sites (but rather graphs and/or averages).
Islington	6	Reports found for all but one scheme introduced during this period (this was not installed until February 2022).
Lambeth	5	Reports found with traffic data for all LTN schemes introduced.
Lewisham	0	No suitable reports available at time of collation. A report on Lee Green (introduced, then later scaled down) did not contain a map indicating locations of count sites so this was not included.
Merton	0	We did not find any reports containing traffic data for the two Merton schemes at time of collation.
Newham	2	We found reports with traffic data for two of the five Newham schemes introduced during this period.
Southwark	5	We found reports for all but one LTN scheme introduced by Southwark during this period.
Sutton	0	We did not find any scheme reports containing traffic data at time of collation (Sutton had one scheme, since removed).
Tower Hamlets	0	We did not find any scheme reports containing traffic data at time of collation. Tower Hamlets had two LTN-type schemes (as defined by us) introduced during this period, which remain at the time of writing.
Waltham Forest	3	Three (plus one) scheme reports with traffic data found out of eight introduced during this period. (One of the Newham reports covers a joint scheme with Waltham Forest, and is accounted for above under Newham.)

Table C1
Sensitivity Analysis.

MEDIANS

Excluded Values	Road Type	Baseline	After Observed	Difference from Baseline	% Difference from Baseline	After Predicted	Difference from Predicted	% Difference from Predicted
Brent	Boundary	10,963	11,074	111	2.12	10,521	381	5.75
	Internal	1228	633.5	−594.5	−36.37	1204	−360	−36.15
Camden	Boundary	11,116	11,379	263	1.54	10,526	370	5.21
	Internal	1187	675	−512	−30.75	1190	−298	−30.37
Enfield	Boundary	10,549	10,723	174	0.50	10,216	242	4.20
	Internal	1219.71429	697.5	−522.21429	−33.97	1199	−321	−31.91
Greenwich	Boundary	11120.5	11235.5	115	0.72	10,595	233	3.98
	Internal	1219.71429	678.5	−541.21429	−31.70	1199	−299	−30.95
Hackney	Boundary	10,624	10,753	129	1.54	10,521	225	4.20
	Internal	1130	613	−517	−33.92	1168	−306	−35.54
Hammersmith and Fulham	Boundary	10,963	11,074	111	1.54	10,521	370	5.12
	Internal	1219.71429	662	−557.71429	−33.29	1199	−321	−31.91
Islington	Boundary	10,462	10,441	−21	−0.30	9896	234	3.98
	Internal	1228	697.5	−530.5	−31.45	1180	−292	−30.28
Lambeth	Boundary	11,075	10,879	−196	1.07	10,542	219	3.98
	Internal	1185	648	−537	−28.50	1183	−272	−30.02
Newham	Boundary	11133.8571	11215.5	81.6428571	0.72	10,637	233	3.98
	Internal	1206	652	−554	−33.92	1186	−310	−32.05
Newham/WF	Boundary	11,116	11,114	−2	1.21	10,558	242	4.20
	Internal	1262.5	702.5	−560	−34.38	1249	−343	−32.71
Southwark	Boundary	11142.7143	11,357	214.285714	1.39	10,682	242	4.10
	Internal	1166	648	−518	−32.25	1145	−298	−31.22
Waltham Forest	Boundary	11166.3571	11,401	234.642857	0.47	10,662	233	3.98
	Internal	1325	702	−623	−36.19	1320	−377	−36.37
Walford Road Scheme	Boundary	11,244	11,401	157	1.07	10,908	211	3.98
	Internal	1209.71429	655	−554.71429	−33.29	1193	−321	−31.91
Non-Standard Counts	Boundary	10,624	11,005	381	3.74	10,420	551	6.65
	Internal	1167.5	642	−525.5	−34.29	1140	−321	−32.16
Borough Road Classification	Boundary	11,298	11,446	148	2.12	10,861	410	5.12
	Internal	1257	690.5	−566.5	−31.00	1235	−299	−30.36
ATA Road Classification	Boundary	11,116	11,357	241	0.93	10,558	242	4.20
	Internal	1196.5	625.571429	−570.92857	−39.41	1193	−369	−38.24
External counts included (borough definitions)	Boundary	10897.5	11039.5	142	1.07	10,523	279	4.15
	Internal	1216.71429	670.5	−546.21429	−32.21	1193	−308	−31.23

MEANS

Excluded Values	Road Type	Baseline	After Observed	Difference from Baseline	% Difference from Baseline	After Predicted	Difference from Predicted	Difference as a % Change from Baseline
Brent	Boundary	11,663	11,532	−131	−1.12	11,404	127	1.09
	Internal	1810	894	−916	−50.61	1775	−881	−48.68
Camden	Boundary	11,752	11,601	−152	−1.29	11,519	82	0.70
	Internal	1796	932	−864	−48.09	1754	−821	−45.73
Enfield	Boundary	11,136	10,945	−190	−1.71	10,820	125	1.12
	Internal	1785	944	−841	−47.11	1748	−803	−45.00
Greenwich	Boundary	11,767	11,551	−216	−1.83	11,495	56	0.48
	Internal	1779	937	−842	−47.33	1745	−808	−45.43
Hackney	Boundary	11,874	11,821	−53	−0.45	11,765	56	0.47
	Internal	1658	876	−781	−47.14	1650	−774	−46.70
Hammersmith and Fulham	Boundary	11,587	11,524	−63	−0.55	11,323	201	1.73
	Internal	1780	930	−850	−47.75	1745	−815	−45.79
Islington	Boundary	11,530	11,055	−475	−4.12	10,928	126	1.10
	Internal	1775	953	−822	−46.29	1705	−752	−42.37
Lambeth	Boundary	11,660	11,488	−173	−1.48	11,435	52	0.45
	Internal	1732	921	−811	−46.83	1713	−792	−45.73
Newham	Boundary	11,799	11,529	−270	−2.29	11,520	9	0.08
	Internal	1760	933	−827	−46.97	1725	−792	−45.01
Newham/WF	Boundary	11,753	11,553	−200	−1.70	11,489	64	0.54
	Internal	1848	963	−886	−47.92	1811	−849	−45.91
Southwark	Boundary	12,095	11,834	−261	−2.16	11,845	−11	−0.09
	Internal	1736	900	−835	−48.13	1708	−807	−46.51
Waltham Forest	Boundary	11,899	11,662	−237	−1.99	11,635	27	0.23
	Internal	1886	973	−913	−48.41	1848	−875	−46.40
Walford Road Scheme	Boundary	11,941	11,738	−203	−1.70	11,707	31	0.26
	Internal	1780	930	−850	−47.76	1747	−817	−45.88
Non-Standard Counts	Boundary	11,010	11,081	71	0.65	10,817	264	2.40
	Internal	1770	895	−875	−49.43	1747	−852	−48.13

(*continued on next page*)

Table C1 (*continued*)

MEDIANS								
Excluded Values	Road Type	Baseline	After Observed	Difference from Baseline	% Difference from Baseline	After Predicted	Difference from Predicted	% Difference from Predicted
Borough Road Classification	Boundary	12,266	12,093	−174	−1.42	12,002	91	0.74
	Internal	1846	1004	−842	−45.63	1799	−795	−43.08
ATA Road Classification	Boundary	11,516	11,333	−184	−1.60	11,210	123	1.07
	Internal	1807	876	−931	−51.52	1767	−891	−49.29
External counts included (borough definitions)	Boundary	11,726	11,546	−180	−1.53	11,433	114	0.97
	Internal	1773	931	−842	−47.51	1738	−807	−45.54

vehicles on each internal road.

This indicates that LTNs can contribute to wider traffic reduction objectives. It is encouraging to see on average so little change in boundary road traffic volumes. Perhaps the widely fluctuating Covid-19 trends (as well as the tendency of some authorities to introduce schemes in September following the annual August fall in congestion) have contributed to perceptions that such schemes make large contributions to boundary road traffic. And it may still be the case that despite relatively little changes in boundary road traffic, those car journeys which continue to be made as before take longer simply because cut-throughs are no longer available. This study only looked at motor traffic volumes, not journey times or trip distances (e.g. through a travel survey); different methods are needed to test and quantify changes in journey time or trip distances. For instance, Goodman et al. (2023) used Driver and Vehicle Licencing Agency data, which found a 6.4% decrease in distance driven per vehicle among those living in areas in Lambeth, South London, where LTNs were introduced.

Finally, it is important that boundary roads are not forgotten. They do experience often substantial traffic burdens, and just over half the boundary roads in this study saw increases over the monitoring periods (with just under half seeing a reduction). Tools are needed to reduce burdens on boundary roads, whether by traffic reduction and/or mitigation of its effects. A paper by Hajmohammadi and Heydecker (2002) found that the introduction of London's Ultra Low Emission Zone in April 2019 led to reductions in NO, NO_2, and NO_x concentrations both within the implementation zone and the wider low emission zone (LEZ) and Greater London area. LTNs represent one tool alongside many others (such as bus priority, pollution taxes, road charging, and/or car parking levies, which address different aspects of the problem and/or address different behavioural patterns) that may be needed to achieve the ambitious reductions in car use sought by many cities including London. Further research could explore and compare the impacts and different contributions of these tools alone or in combination.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: the research conducted here was funded through a grant obtained by climate action charity Possible. Possible did not have influence over the study design, analysis, or reporting of results here.

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Appendix A. Table of adjustment factors

Table A6 below shows the adjustment factors we used based on data provided to us by TfL, also presented graphically in Fig. 4. Each represents average daily motor vehicle traffic in the given month, in the functional area in question, by comparison to that in March 2019.

Appendix B. More details on included schemes

Table B1 provides a high-level summary of London boroughs with schemes that we considered including in the study. Note that Barking and Dagenham, Barnet, Bexley, Bromley, Haringey, Havering, Hillingdon, Kensington and Chelsea, Kingston, Redbridge, Richmond, and Wandsworth did not implement any schemes in this period that we defined as 'LTNs'. (Note that Havering and Wandsworth did implement schemes but removed them so quickly that no meaningful monitoring could take place).

Appendix C. Sensitivity analyses

Table C1

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