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Can mixed-methods help us better understand congestion on Low Traffic Neighbourhood boundary roads?

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A R T I C L E I N F O

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A B S T R A C T

Low Traffic Neighbourhoods (LTNs) aim to improve conditions for walking, wheeling and cycling by restricting motor vehicle movements on residential streets while maintaining access to all addresses. Despite generally positive evidence, LTNs faced backlash, often linked to concerns that motor traffic from inside LTNs is displaced onto surrounding 'boundary roads'. In this paper, we bring together large-scale sensor data and spatially-transcribed interview data from a case-study LTN to discuss how mixed methods analysis can help to ease the LTN controversy by revealing the multiple ways in which the 'problem' of congestion is understood.

By integrating quantitative evidence of changes in congestion associated with LTN implementation with residents' perceptions and experiences of the same scheme, we discuss how and why these diverge, revealing the complexity of capturing what congestion is. We argue that concerns about congestion are influenced not only by changes in traffic volumes, but also by how these changes are framed in public discourse. We consider dissonances between what 'counts' for residents and what is counted in quantitative data, and how what is (in)visible to residents affects their perceptions of congestion. We also highlight the limitations of each method and the importance of integrating multiple forms of evidence.

The paper helps nuancing perspectives on congestion and its role in LTN debates, while also providing guidance on mixed methods approaches to evaluating transport policies. We recommend that these should combine attention to localised impacts with a broader evaluation framework that reflects the long-term public health and climate goals of LTNs.

1. Introduction

Despite solid evidence of negative societal, health and environmental impacts of widespread car use (Miner et al., 2024; Walker et al., 2022), measures to discourage car use and encourage active modes (walking, wheeling and cycling) generated controversy around the world (Field et al., 2018; Nello-Deakin, 2025). Under pressure to implement changes whilst facing backlash, policymakers seek clear 'objective' evidence about intervention impacts.[1] However, members of the public routinely contest what 'counts' as data, so evidence itself has become a key flashpoint (Chen et al., 2023; Merkley and Loewen, 2021; Powell, 2024a). Authorities and academics are criticised, often by residents living in or near to interventions, for ignoring their subjective experiences in favour of measured and 'objective' evidence (Verbeek, 2018).

Low Traffic Neighbourhoods (LTNs) have been one recent focus for such backlash in the UK. LTNs restrict motor vehicle movements on residential streets, and despite research revealing generally positive impacts (Thomas and Aldred, 2024), concerns are often raised that traffic from inside LTNs is displaced onto the surrounding 'boundary roads' creating more congestion (Harker, 2025). Booker (2023: 192) comments that:

'[Some] academic research has said that LTNs work as they are leading to measurable reductions in motor vehicles and air pollution in the LTNs, with little average change in traffic or air pollution on LTN boundary roads (Thomas and Aldred, 2024; Yang et al., 2022). […]

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[1] Yet datafication of policy decisions is challenged by austerity and limited resources (Verlinghieri et al., 2023, 2024).

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Some community groups dispute these results claiming that they can see the increase in traffic [on boundary roads] with their own eyes. This perfectly encapsulates the tension of whose knowledge is superior.'

Booker's (2023) comment on what knowledge counts reflects a tension with which we are very familiar, as a mixed methods team conducting a [details of research project, redacted for review].[2] Criticisms emerged in interviews with residents, often contrasting with our quantitative analysis congestion.

In this paper, using the debate over LTN boundary roads as a key example of the unfolding controversy over trustworthy data in transport planning, we reflect on lessons from a 3,5 years project evaluating LTNs in London, and consider whether and how mixed methods triangulation can help to reconcile conflicting evidence in the LTN debate and, in particular, derive new insights into our understanding of congestion. Examining our emerging findings, we discuss similarities and differences between qualitatively elicited perceptions and experiences of boundary road congestion by residents, and our own quantitative measures. Further than making a direct contribution to the growing evidence base on LTNs and studies of congestion, we contribute to enriching the debate on the use of mixed methods in transport research.

2. Research and literature context

2.1. The LTNs controversy

Street reallocation measures aimed at reducing car use, such as school streets, superblocks, pedestrianisations, are increasingly and effectively used in several cities worldwide. In the UK, LTNs became a popular measure since the covid-19 measure. LTN schemes use bollards, planters, and cameras ('modal filters': see Fig. 1) to remove through motor traffic from sets of residential streets, while retaining motor vehicle access to all homes. Similarly to other street reallocation measures, they seek to make active travel safer and more pleasant, while making journeys by car somewhat less convenient - i.e. combining elements of 'carrot' and 'stick' (Laverty et al., 2021).

Fig. 1. Automatic Number Plate Recognition (ANPR) enforced modal filter in a LTN.

As happened for example for measures introduced in other countries (Nello-Deakin, 2022), emerging evidence suggests that LTNs are effective in achieving these objectives. Controlled longitudinal studies of London LTNs indicate increased levels of walking and cycling amongst LTN residents (Aldred et al., 2024; Goodman et al., 2020a) alongside a reduction in car ownership and/or car use (Aldred et al., 2024; Goodman et al., 2020b, 2023). There is also evidence that numbers of road traffic injuries fall inside LTN areas, with no evidence of injuries being displaced outside the LTN (Goodman et al., 2021).

Again, similarly to international experiences of contestation in response to streetscape transformations to reduce car use (Featherstone et al., 2005; Field et al., 2018; Hickman and Huaylla Sallo, 2022; Nello-Deakin, 2025; Nieuwenhuijsen, 2020), despite evidence of their benefits, a dominant media narrative has been that LTNs are highly controversial and polarising (Mason, 2021; Powell, 2024a). UK media headlines commonly use conflict imagery to describe LTNs and responses to them, including words like 'hate', 'row', 'battle', and 'war', reinforcing and generating division (Larrington-Spencer et al., 2021). Right-wing newspapers particularly combine this language with a focus on personal narratives rather than quantitative data (Powell, 2024a). Many LTN schemes, particularly outside London, have been cancelled or removed, because of some level of public opposition. Yet, in spite of notable public protest, evidence suggests that LTNs are somewhat popular: while a large UK survey conducted in August 2021 found that in popularity terms LTNs ranked only seventh out of eight net zero policies, 53 % of respondents were in support of them compared to 27 % opposed (Poortinga et al., 2023). A more recent report by the Department for Transport also found LTNs to be generally popular amongst residents living in them (Ipsos, 2024).

Much opposition to LTNs centres on their impact on congestion on 'boundary roads'. The idea is that rather than reducing overall levels of motor vehicle traffic in the area, LTNs simply displace traffic and associated harms onto boundary roads. Analysing consultation responses from Birmingham, Pritchett et al. (2024: 8) found that "modal filters were perceived to simply shift congestion from one road to another". This is characterised as especially unfair because areas experiencing potential displacement typically already have much higher motor traffic volumes, and are often believed to be poorer than areas receiving LTNs, although in London this appears not to be the case (Aldred et al., 2021).

So far, there is relatively little evidence of boundary road disbenefits. A study analysing local authority monitoring data from 46 London schemes found no systematic change in motor traffic on boundary roads, albeit with large variation: around half saw increases, half decreases (Thomas and Aldred, 2024). Smaller-scale studies analysing quantitative data on traffic and/or pollution have typically found mixed, neutral, or positive impacts on boundary roads. A study of three Islington schemes in London found improvements in traffic levels and NO_2 on boundary roads (Yang et al., 2022). In Oxford, a recent noise-focused study of Cowley LTN found that "one of the displacement sites displays a minor decrease in noise and one shows a minor increase" (Leach et al., 2024: 19). A study of three LTNs in Southwark, London, found that motor traffic levels remained unchanged on boundary roads, with one exception where there was an increase on weekdays and at our peak hours (Xiao et al., 2023). At present, there have been no studies that have specifically focused on the impact of LTNs on congestion, as opposed to traffic volumes, on boundary roads.

2.2. Congestion

Why are beliefs about congestion displacement so strong in eliciting controversy about LTNs, when the evidence, at least so far, suggests impacts are positive or at least mixed? One answer might be the imposing yet slippery nature of the 'congestion problem'. Congestion frequently recurs in press photos depicting a queue of motor vehicles. Technological firms like Inrix monetise millions of hypothetical 'lost minutes' to generate enormous costs attached to such queues, producing

[2] Our study considers and evaluates several impacts related to LTNs schemes, including in terms of road injury, air pollution, journey times, and residents' views and perceptions of schemes in general (Furlong et al., 2025). Given the centrality of congestion in the debate on LTNs, this paper focuses only on this aspect of schemes.

a sense of congestion as *the* overriding transport problem. Yet as Rooney (2016: 24) writes, this forceful certainty is illusory, because "[r]oads are political and economic spaces […] and the solutions proposed depend on the problem one sees—and on the world view one holds. Congestion is not a stable concept". Far from congestion being a self-evident technical fact, there is still no single agreed method of measuring it (Afrin and Yodo, 2020), and many methodological and conceptual challenges remain. Congestion can be measured as, for instance, proportion of roadway speed under a given level, or as the ratio of capacity to vehicle numbers. Surprisingly, most discussions on congestion fail to mention the absolute growth in vehicle numbers, which in the UK, for example, has more than doubled in the last 30 years (Department for Transport, 2023).

In broad terms, the existence of congestion implies that the current roadway capacity for vehicles is at odds with the amount of drivers seeking to travel on that roadway (Lay, 2012). Interventions to reduce congestion may aim to increase capacity (road widening, adjusting signal timings to favour motorists, etc.) or reduce demand on the network generally or at a specific time and/or place (e.g. providing alternative services, road pricing). Following the 2003 London Congestion charge, user responses included 'peak spreading' where some travel moved to the less congested and uncharged inter or pre-peak periods. How one views this response depends on how one views the congestion 'problem'. For a market economist, congestion is a (mis) pricing problem, and charging has meant that peak spreading has helped address this by making a 7 am start cheaper than a 9 am one. From an environmental planner's perspective, it is less positive, because the 'problem' of congestion is understood more in terms of harms such as pollution, carbon emissions, sedentary behaviour and road injuries, none of which are improved by a proportion of drivers travelling earlier in the morning.

Typically around half of congestion is 'recurrent', a very regular occurrence on a given road at a given time of the week, rather than the more sporadic delays resulting from roadworks or road collisions (Afrin and Yodo, 2020). Despite this, the public tends to see congestion (or 'traffic') as exogenous to drivers. Guiver's (2007: 246) focus group study found that "congestion is the most talked about effect of car travel, but it is referred to as an impedance to car travel not a result of it". Similarly, when we interviewed residents in our project, growth in vehicle numbers was never mentioned when talking about LTNs and congestion. In another qualitative study, residents in Outer London often understood the harms of car use but simultaneously saw traffic demand was unchangeable, implying that the only modifiable element in the push-pull congestion relationship is roadway capacity (Aldred, 2019). In this framing, restricting roadway capacity is self-defeating; if traffic remains the same, restricting where it goes only increases congestion, associated harms for drivers (delays) and for wider society (noise, air pollution, etc.). From this perspective, measures such as LTNs, which seek to reduce car use and encourage modal shift by making some car journeys more circuitous, are inevitably futile. If their documented ability to reduce car use is denied, they can only displace traffic and therefore be blamed for the negative externalities of car use.

2.3. Mixed methods in evaluating transport interventions

Understandings of congestion (including on boundary roads) varies depending on whether one prioritises quantitative or qualitative data. Traditionally, qualitative and quantitative methods have a degree of 'incompatibility' as they look at different aspects of reality, quantitative research being more focused on the 'what' and qualitative more on the 'why' and 'how' (Bryman, 1984). Despite such 'incongruence', mixed method research commonly aims to *integrate* the mixed data (Uprichard and Dawney, 2019) – an approach which loosely refers to the synthesising of both types of data to analyse together rather than separately (Fetters et al., 2013).

Integration does not necessarily imply *confirmation* in the findings from the quantitative and qualitative analysis; rather, *expansion* and *discordance* can also occur when the different approaches address different aspects of a particular issue or where there is disagreement or incongruence between the findings (Fetters et al., 2013). In cases of discordance, a reconciliation via further work is possible but not always desirable due to the complexity of the object of study (Moffatt et al., 2006; Uprichard and Dawney, 2019).

One reason for proposing a mixed methods approach in transport research is that existing evaluations of interventions, which are often quantitative and focused on economic impacts, may overemphasise the strategic benefits of projects (e.g. aggregated journey times saving) (Steele and Legacy, 2017) whilst overlooking social impacts and unintended consequences on specific groups (e.g. marginalised or 'hard to reach' communities) or locations. These may be better captured by research at a more refined scale - often qualitative - such as changes in perceived safety when travelling to school (Lucas et al., 2022). While this need for more mixed methods transport research is well understood, it has not always translated into practice. For example, to date, we are not aware of any mixed methods studies of congestion.

Further than integrating this multiscalar approach to projects' evaluation, mixed methods can help transport research and planning to move beyond aggregated or generalisable *quantitative* evidence and integrate it with highly localised, *social* impacts of any project (see Mottee et al., 2020). In the case of LTNs, for instance, an assessment of congestion on aggregated boundary roads data might reveal no systematic effects, yet could conceal the differential effects and experiences of congestion amongst residents. For example, parents are likely to travel at particular times of the day (i.e. school drop-off/pick-up), people with health conditions may be more significantly impacted by smaller changes in air quality, or those that live in close proximity to major roads might already experience the negative externalities associated with congestion. These experiences of congestion are more likely to be revealed in qualitative research.

Integrative mixed methods research can reveal how micro-scale environmental characteristics can shape environmental perceptions and, potentially, travel behaviour. For example, Moran et al. (2017) used it to associate measured characteristics of walking routes and perceptions of barriers/facilitators to walking. Other research integrated datasets to show dissonances between perceived and measured impacts (Orstad et al., 2017). Understanding such perceptions can paint a more detailed picture of what transport impacts mean to those affected and can detail mitigation strategies, though one must be careful of the social justice implications of prioritising perceived over measured evidence (Verbeek, 2018).

Aware of these different challenges of mixed methods research in transport, our research integrates an aggregated measure of observed behaviour (travel times) over a large number of journeys, i.e. a quantitative assessment of congestion on boundary roads, with micro-scale qualitative data from resident interviews. We then reflect on the lessons learned from this mixed methods approach, producing the first available mixed methods study of congestion.

3. Case study and methods

3.1. Case study area

Our case study LTN was implemented in December 2021 and, after 18-month trial, was made permanent as a slightly smaller version. It is located in a residential area in Inner London, which had previously received traffic calming and greening measures but still had significant 'through traffic' of motor vehicles between the East and West boundary roads.

Fig. 2 below maps the boundary roads that are used in this analysis, with letters for each road from A to E. Note that roads C and E are two-way roads – journey time data has been collected in both directions on each of these roads. Roads A, B and D are one-way.

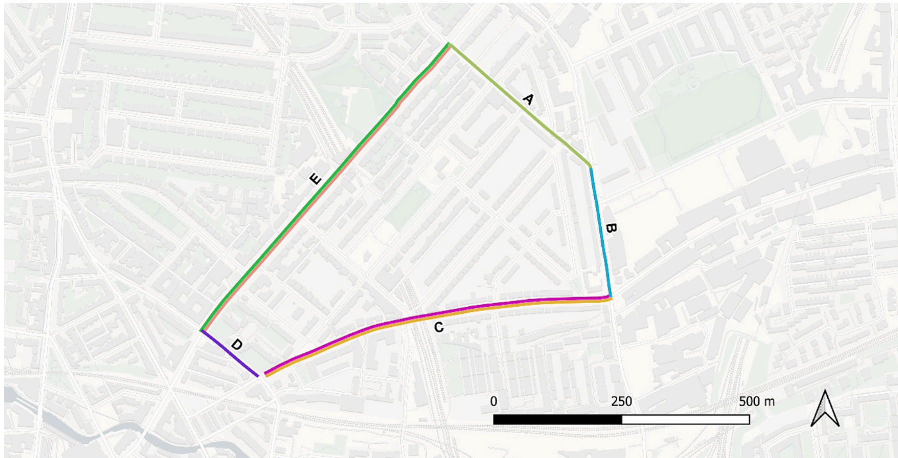

Fig. 2. Numbered boundary roads used in our study.

3.2. Studying boundary roads

There is no agreed definition of what constitutes a boundary road for an LTN and there are likely to be discrepancies between how local authorities, academic researchers and residents might define it. Local authorities often do not explain their own definitions of LTN boundaries in their monitoring and evaluation of schemes, which means that definitions may also be inconsistent from one local authority to another. Similarly, as our qualitative interviews show, residents may not 'see' a particular road as a boundary (e.g. because of its distance from a modally-filtered road) and therefore may not equate changes in congestion with the LTN itself. Others may not even be aware of the concept, while others, given the widespread controversy over boundary roads, may highlight the effects on many nearby roads by using a broader definition.

In our 'LTNs in London' study, following the definition employed by Thomas and Aldred (2024), we have defined boundary roads in terms of the nearest external road to each LTN scheme, which might, in principle, experience traffic displacement, based on our own qualitative assessment of alternative routes drivers would likely take to navigate around the LTN.[3] In short, boundary roads were those which provided logical diversions around the modally filtered LTN area. We accept, of course, that displacement, could occur on more distant roads but believe it reasonable to assume that any such impacts would be significantly smaller than those on our identified boundary roads. In addition, across all of the LTNs in the wider study, we have to employ a consistent definition, even if we accept the extent to which impacts might extend beyond the nearest adjacent roads could vary across LTNs (Furlong et al., 2023). The qualitative data used for the study (see below) refers to the same roads and it is a subset of a broader set of interview data covering a wider area and scope.

3.3. Methodology

Having worked as a team for over 3,5 years on a project evaluating 5 LTN schemes in London (and matched control sites), our approach to mixed methods has refined over time and has been based on sustained dialogue between our qualitative and quantitative research teams. Each month, we have discussed our research progress and findings, continuously reflecting on the potential integrations and incongruences in the datasets and related learning for the project. The idea for this specific paper and focus on boundary roads emerged as part of those conversations.

Our quantitative team had been collecting data on congestion across 5 LTN schemes as the impacts of LTNs on congestion was one of our key research questions. Congestion was considered a key outcome in our quantitative research as it is, alongside journey times, arguably more meaningful and relevant to residents than the number of vehicles. Congestion also emerged as a theme in the over 140 go-along interviews we conducted with residents in 3 of our case study schemes. We therefore decided to combine the two datasets with a focus on a single case study for which we had both quantitative and qualitative data, to deepen and enrich our understanding of LTNs and congestion and examine the issue from different viewpoints (perceived and measured transport effects) and scales (aggregated and micro-scale).

To integrate the data related to the case study, we mapped the qualitative and quantitative results to explore similarities and differences between residents' perceptions and experiences and the quantified changes in congestion. The comparison that emerged from it gave us a better understanding of congestion on boundary roads and how people's perceptions might vary from measured congestion. We discussed these themes from our perspective as researchers, but also considering what we learnt, through a comprehensive quantitative study of LTN impacts, 140 interviews with London residents living in LTNs, over 30 interviews with policymakers implementing schemes in the UK, and 6 focus groups with disabled residents (Larrington-Spencer et al., Under review PHR journal). The detailed methods we used and results of the analysis are presented below.

3.4. Quantitative understandings of traffic changes on boundary roads

As part of the quantitative strand of the LTNs in London project, we have measured changes in congestion on boundary roads across case studies LTNs and matched control areas. In our wider study, we examined whether LTN boundary roads showed evidence of a change in congestion relative to matched control areas. The results point towards a significant increase in congestion on boundary areas in the first year after LTN implementation. In line with the theories about LTNs needing time to 'bed in', by the second and third years after implementation, we find that the negative impacts are dissipated (Furlong et al., Submitted). In this paper, we only examine whether the LTN boundary roads showed evidence of change in congestion in absolute terms (i.e. an uncontrolled comparison), because we believed this would mirror most closely how residents formulate their perceptions of congestion impacts.

[3] In practice, this was not always possible. In the LTN scheme included in this study, we selected boundary roads based on the original plans for the LTN, which differed somewhat to the LTN implemented. The boundary roads on which we measure congestion in our quantitative analysis are therefore the ones we 'expected', meaning that in some cases they are not the very closest potential boundary road but the second closest one.

As discussed, there are many ways to quantitatively measure congestion, including measuring time spent not moving (or in a queue) or estimating delay relative to journey time in free-flow or urban-peak roadway conditions (Victoria Transport Policy Institute, 2016). In our case, we use the simpler 5mph definition instead: a congested trip is defined as those where the average speed across a road segment is less than 5 miles per hour. This reflects the relatively slow average journey times in London as a whole – data shows average bus speeds of 9.3 mph (2023/24) and PM peak vehicle speeds of 7.9 mph (Central London) and 10.7 mph (Inner London) between 2010 and 2020 (Transport for London, 2021).

To measure congestion, we divided the boundary roads into segments split at major and some minor road junctions. These were typically around 500 m in length, although this varied by the density of junctions. We then used Google API to route journeys on those segments and estimate driving time in live traffic conditions. This driving time, combined with the distance, allows us to calculate the journey speed and therefore congestion. We used Google API to estimate driving times in live traffic conditions before and after the LTN was implemented, allowing us to make before-and-after comparisons between the before-LTN period (mid-June to mid-December 2021) and the post-LTN period (mid-June to mid-December 2022 and the same period in 2023). More details on the methodology adopted are presented in Appendix 2.

3.5. Qualitative understanding of traffic changes on boundary roads

As part of the qualitative component of the project, we sought to understand resident experiences of living inside LTNs or on the boundary roads in three case study LTNs. Our detailed methodology is provided in Appendix 1.

Participants were asked to take part in a go-along interview and take the interviewer around their local LTN and to discuss their experiences as they went. It is important to note that we did not ask explicit questions on boundary roads; participants chose the interview route and which roads to cover in the conversation. For this paper we consider in detail 21 interviews collected in 2022, i.e. after the LTN had been implemented, bringing however also broader learning from the wider project. Interviews were audio recorded and GPS tracked to develop detailed spatial transcripts.

The analysis of the interview data could take multiple pathways. As expected from LTNs controversies, levels of traffic on boundary roads emerged as key topic (see Appendix 1). We therefore developed analysis using spatial transcripts to specifically look at participant comments regarding traffic changes on boundary roads (Fig. 5). In our case, visually bringing in all participants' responses allow us to look at emerging patterns across the datasets, including areas in the LTN that were considered critical by multiple participants, as detailed in the next sections.

4. Findings and discussion

4.1. Quantitative findings

Below, we present the percentage of trips, aggregated from road segments to road level, that are congested, pre-LTN implementation (Fig. 3) versus post-implementation (Fig. 4). For example, on road A, one can observe that in the pre-implementation period, some 12.9 % of journeys were congested compared to 19.1 % in the post-implementation period.

Figs. 3 and 4 show the percentage of trips congested on each road, before and after LTN implementations, respectively. Table 1 also presents the change in the percentage of trips congested from pre-implementation to post-implementation. Before the LTN was implemented, only road A had a significant number of congested trips, 12.9 %, with the rest of the roads all being less than 3.5 %. Following the

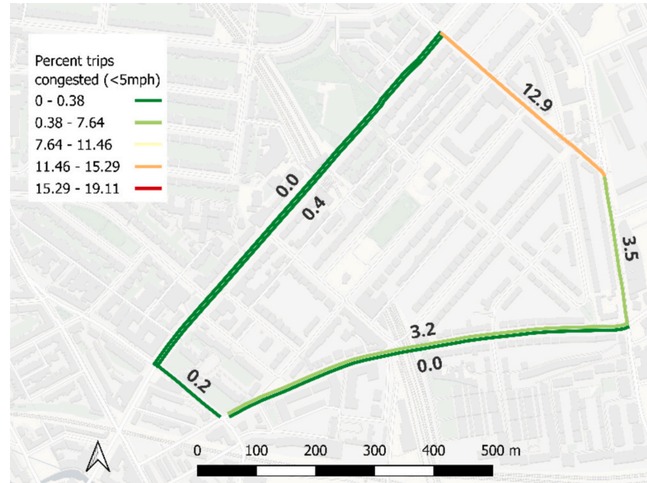

Fig. 3. Percentage of trips congested on each road pre-LTN implementation.

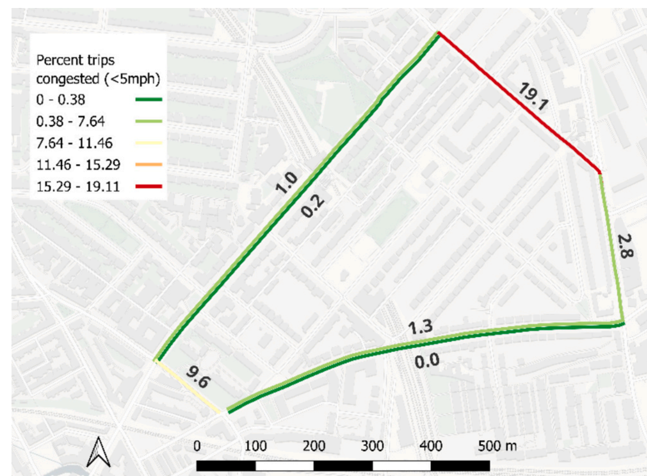

Fig. 4. Percentage of trips congested on each road post-LTN implementation.

implementation of the LTN, roads A and D both have much higher congestion levels than any other roads.

In terms of changes in congestion, the percentage of congested journeys remains broadly consistent on most roads following the implementation of the LTN. Except for two roads (Roads A and D), the percentage point change falls between −1.9 and + 1.0, suggesting that the LTN has had little discernible impact on congestion across most boundary roads.

On Road A, the proportion of congested journeys increased from 12.9 % pre-implementation to 19.1 % post-implementation, making it the most congested road both before and after the LTN was introduced. Despite this, it is not the road with the largest increase in congestion. On Road D, the percentage of congested journeys rose by 9.3 percentage points, from just 0.2 % to 9.6 % post-implementation. This represents a shift from virtually no congestion, according to our measure, to being the second-most congested boundary road.

4.2. Qualitative findings

Fig. 5 shows the spatial transcript reporting analysed participants' perceptions of changes in motor traffic in the LTN area and on the boundary roads, as attributed, at least partially (see later), to the implementation of the LTN.

For comments clustered around road E, which is an A-road, participants tended to consider that the road has "always been super busy"

Table 1
A summary of congestion across LTN roads, pre- and post-LTN implementation.

		Pre-LTN implementation			Post-LTN implementation			Pre- to post-LTN
		Journeys	Congested		Journeys	Congested		
Road	Direction	N	N	Per cent	N	N	Per cent	Change (percent congested)
A	One-way	840	108	12.86	1680	321	19.11	6.25
B	One-way	840	29	3.45	1680	47	2.80	−0.65
C	Westbound	821	0	0.00	1642	0	0.00	0.00
C	Eastbound	773	25	3.23	1546	20	1.29	−1.94
D	One-way	840	2	0.24	1680	161	9.58	9.35
E	South-westbound	840	0	0.00	1680	17	1.01	1.01
E	North-eastbound	840	3	0.36	1680	4	0.24	−0.12

(P13) and that they "don't think there's any difference [pre- and post-LTN intervention] to be honest with you" (P20). The comments on clustered around C, were more mixed. Whilst some participants felt that "this is where, you know, the traffic has all been basically pushed" (P10), other participants felt that "it seems to be the same [level of motor traffic]" (P3) and they "haven't noticed any [change in motor traffic]" (P6). Overall, relatively few reflections were made on these boundary roads, perhaps because the focus was largely on road A, but also because participants often tended to focus most of the go-along within the LTN area as the environment felt more facilitative to them for walking and talking. Importantly, boundary road congestion was only raised by some participants and was only one of many topics of discussion covered. Participants focused mostly on interior roads changes,[4] some ignored boundary roads, and not every participant walked there.

The cluster near road A identifies it as the most important place within go-along interviews for participants who considered changes in traffic levels and congestion a key topic to talk about. Participants who walked and talked about road A tended to consider that "this is one of the roads that has become much, much busier" (P1) and that "[traffic is] often backed up to the end there" (P7). Participants considered that motor traffic "has increased, definitely" (P8) and that "at the moment all they [residents of the road] see is an increase in car numbers" (P7), estimating that they had seen "at least 30%, 40% increase in volume [of vehicles]".

Whilst those participants who talked about it attributed the perceived increase in traffic volume on this road to the LTN, they also identified other factors that they believed were entangled, including regular roadworks in the area. For example, P10, like many other participants, identified there being "loads of roadworks" and P12 felt they were "an ongoing thing, never ending". P17 felt such roadworks "make it even [in addition to the LTN] worse, because it makes the traffic even slower". The recent reconfiguration of the road -which had changed from two vehicles lanes to a bus lane, cycle lane, and vehicles lane- was also considered a complimentary factor in the levels of congestion. For example, P10 discussed how "there's a lot more traffic, but that is also partly because they have made this bus lane much wider. So now there's only one lane of traffic", P8 who lives on the road similarly considered that "a lot of [traffic] is simply to do with the fact that there is just one lane now where it used to be two".

4.3. *Mixing and integrating findings*

Mixed methods research requires comparing our qualitative and quantitative results seeking integration. Doing so we find that, in some respects, there is congruence between the two datasets. First, on most of the roads where there is little observed change in congestion (i.e. low before and low after) relatively few comments are made about traffic or congestion by participants. Second, multiple residents bring to attention the perceived changes in congestion on road A, which is also reflected in the quantitative data – this road had the highest proportion of congested journeys both before and after the LTN was implemented.

However, the way several participants focus on road A as the critical problematic site for congestion, is to an extent incongruent with the quantitative data which shows that road A already had high levels of congestion, relative to other roads, before the LTN was implemented. Moreover, the quantitative data shows the largest *increase* in congestion on road D, and yet no participant commented about this change. This is despite road D being a major arterial route leading away from the area. Rather, it was almost entirely road A where participants felt that changes were problematic and needed mitigations.

There are several potential explanations on why such different views on the congestion 'problem' might have happened which invite us to make some more general reflections on boundary road congestion.

4.3.1. *What 'counts' versus what is counted*

One set of reflections the data invites is around what 'counts' for residents as a basis for forming their views, versus our quantitative approach to the same topic.

First, when a LTN is implemented people may often start to pay more attention than usual to traffic in their area. As authors have remarked, urban processes are invisible only until moments of crisis or change bring them forward (Kaika, 2004). This reflects LTN implementation being accompanied by local authorities sending out comms materials, plus the impact of citizens' groups complaints and of local and national media attention to the topic. Thus, a *generalised increased salience of the congestion 'problem'*, means residents start paying more attention to the phenomenon. This in turns may mean that people start noticing congestion that once they did not pay as much attention to, as happened for road A.

Secondly, in relation to the previous point, given also the increase in the salience of congestion, participants may be more likely to be publicly vocal about places where *congestion has increased*, as compared to places where it has gone down/stayed the same. As evident in Fig. 5, changes to congestion were also widely discussed in the LTN area, here in neutral or positive terms. Positive comments about reductions in congestion, however, rarely emerge in the public LTNs dispute, whilst complaints about increases in congestion on boundary road have become emblematic and central to the LTNs controversy, often obscuring other important impacts associated with schemes. This could plausibly reflect both a general tendency for 'problems' to be more noticeable and noted than 'non-problems' (Johnson et al., 2006; Tversky and Kahneman, 1991), and also a LTN-specific effect whereby *congestion increases are salient* because this fits with a broader discourse around road reallocation and LTNs which, as discussed in the literature review, are considered as inevitably causing congestion (Aldred and Verlinghieri, 2020; Powell, 2024b; Thomas and Aldred, 2024).

Thirdly, as others have highlighted (Orstad et al., 2017), perception formation is a complex process where recalling change over time can be challenging, especially in relation to controversial topics. The increased salience of congestion may also manifest as residents being in general more likely to be influenced by *current levels* of congestion at the time of

[4] These are object of other quantitative monitoring which our study covers [reference deleted for review] but which, for reason of space, are not covered in this paper.

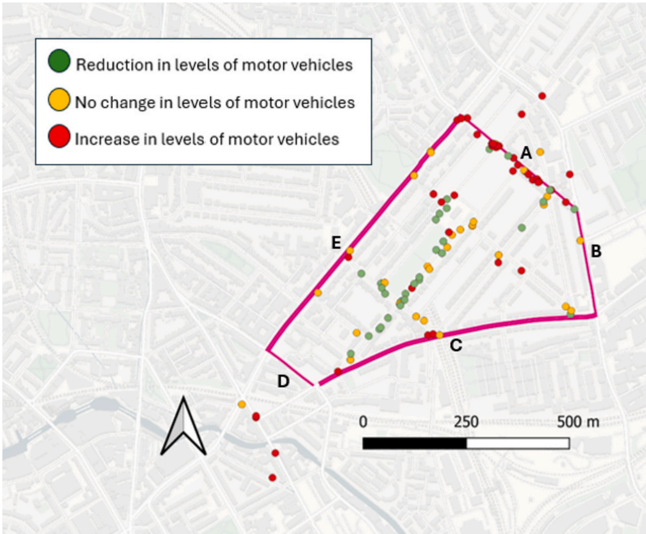

Fig. 5. Spatial transcript of perceptions of motor vehicle traffic changes by all participants.

our interview (i.e. post LTN implementation) rather than by *trends in congestion levels*. The latter trends are far more difficult to observe, especially where residents were not paying as much attention to congestion on boundary roads before the LTN was implemented. This may in part explain why participants paid so much more attention to how the LTN had affected congestion on road A (where the post-LTN absolute level of congestion was higher, but the post-LTN change in congestion was lower) than on road D (where the level of congestion was lower, but the change in congestion was higher).

Finally, it is worth reflecting that *residents cannot have a bird's eye view of their area*, nor weight all roads equally. Apart from some exceptional cases, for example someone regularly visiting all address in the area for work, residents generally notice and therefore are concerned with changes observed in areas 'where they go', rather than 'anywhere equally' in the LTN. Although our recruitment leaflets were distributed equally across all the study area, most participants who took part lived closer to road A, which is the more densely populated side of the scheme. A further potential explanation for why road A is talked about than road D is that it was a road participants used more frequently. Moreover, the location of road D, further away from new filters and a shorter segment, might mean that participants did not feel this was part of the scheme or a boundary road itself, and therefore they might have felt the road was not relevant to the interview. This is different from our quantitative approach which treats all boundary roads equally, rather than considering where residents go – and highlights a limitation that is important to consider when interpreting findings.

4.3.2. What is visible, what is invisible?

Another important point that these datasets allow us to notice is around the (in)visibility of congestion and its causes in relation to residents' perceptions and experiences.

First, as discussed elsewhere in relation to our wider study (Verlinghieri et al., Under review), which explanation of congestion participants consider most plausible may link to which discourses they are exposed in relation to the congestion 'problem', in general, and the LTN, in particular, including with their pre-formed views on the scheme (s). This is particularly relevant for roads where – as is not unusual in London – multiple things have changed in close succession. In the data considered for this paper, some participants attributed congestion on road A to the bus and cycle lane implemented on that road in 2019–2020; others attributed it to the LTN implemented nearby in 2021; and others still attributed it to the widespread roadworks on local roads across 2021–2022. All these explanations are prima facie plausible, and our quantitative data provides some support for all three.[5] Studies considering residents' views on pedestrianization measures in Barcelona similarly showed how these were influenced by personal characteristics, including their mobility habits, sociodemographic background, and the specific level of traffic calming of the street they live on (Nello-Deakin et al., 2024).

Second, congestion might be more 'visible' than other scheme outcomes, some of which, such as the hundreds of injuries averted due to LTN implementation in London (Furlong et al., 2025), will be completely 'invisible'. A queuing line of cars is a visual phenomenon and is likely to be easier for residents to observe than 'total vehicle volumes', which is how the local authority measures traffic impacts in their Monitoring and Evaluation reports. Although, specifically to this case study, only some residents noticed only congestion whilst other considered a variety of other impacts, interesting discrepancies about the visual presence vs actual congestion recur. For example, an existing council report from the same area highlighted a 24 % decrease in traffic on road A between June 2018 and June 2022, plausibly reflecting the conversion of one general lane of traffic into a bus lane. On the same road, our data shows considerable congestion in 2021 that gets worse in 2022. This provides an example of how a road reallocation measures such as bus lanes or LTNs may achieve a reduction in total car volumes without necessarily reducing levels of congestion.

Finally, slow-moving cars in congestion will likely be more 'visible' than 'uncongested' cycles and buses travelling though quickly. In part this is because congested cars will remain in view for longer and, especially compared to cycles, have a more prominent sound and olfactory presence. It may also tie into what is most salient in terms of wider LTN discourses: the 'LTNs and journey delays' discourse relates almost exclusively to delays to motor vehicle rather than delays to cycles.

4.3.3. What can mixed methods add to our understanding of congestion?

Examining the reasons for such incongruence helps highlighting the limitations of both datasets and improving our understanding of congestion. As Rooney (2016) and others have pointed out, congestion and other such concepts are inherently political. Framing a problem as 'congestion' has different implications to framing it as one of 'air pollution', with different implications. Reducing congestion might or might not reduce air pollution, and vice versa. Other analysis that we have conducted has found that changes to car journey times are not always in line with changes in congestion (Furlong et al., Submitted). Rather than looking for 'the' definition of congestion, it may be more fruitful to ensure that the definition used in a particular case is clear and that congestion data is presented alongside other outcomes about which people care, which are sometimes assumed to track congestion yet may not do so. As with studies of large transport infrastructures (Lucas et al., 2022), our qualitative data points complement the aggregate view of congestion by highlighting potential localised problems. In our specific case, the data suggest that road A was the focus of concern, at least for one group of residents, and therefore it is perhaps here that measures should be taken to mitigate the negative impacts of the scheme. More generally, this finding reiterates the importance of complementing aggregated assessments of congestion impacts with analysis of disaggregated impacts by road segment.

This is particularly important as aggregated quantitative evidence alone, which is generally used by research and policy to assess the

[5] It supports the 'bus and cycle lane' explanation in that congestion was already high on this road pre-LTN implementation; it supports the 'LTN' explanation in that congestion increased further after LTN implementation; and it supports the 'roadworks' explanation in that exploratory analyses (not shown) indicated that periods of major roadworks in this area were indeed generally associated with increases in congestion.

success of schemes and consider desirable mitigation measures, may be misaligned with the concerns of residents. For example, in our case, a quantitative analysis that averages all boundary roads might conclude that the area as a whole experienced a 'modest average increase' in congestion, misrepresenting the distribution and extremes of impacts.

A quantitative assessment of perceptions, for example through a representative survey of residents, could complement this approach. This could be particularly important in mitigating a potential shift from a global perspective of scheme evaluation, which is key to ensuring that schemes achieve their desired health and environmental impacts, to a hyper-local focus. As we have seen in our case, the residents interviewed do not even seem to notice the increase in congestion on road D. However, this does not mean that others may not find it worrying, or that such an increase should not be considered.

5. Conclusion

By aiming to integrate quantitative and qualitative evaluations of changes in congestion on boundary road, we were able to derive some important hypothesis contributing to the growing evidence base on LTNs and, more in general, congestion study, as well as learning points for mixed methods research.

The data allowed us to reflect upon and unpack the complexity of concerns around the congestion 'problem', revealing differences between what seems to count for residents at different points in time might be different from what is considered in monitoring or evaluation or in other datafication exercises. Particularly, we reflected on how residents' perceptions might be shaped by discourses on the scheme which might increase the salience of congestion in residents' concerns and their primary focus on increases rather than decreases in congestion. We also discussed the difficulty residents might find in observing trends in congestion levels vs current levels of congestion, as well as prioritise localised focus on specific familiar routes/roads to a bird's eye view on an area.

Furthermore, we considered issues of (in)visibility in residents' perceptions and experiences. What aspects of the LTNs are made visible and, particularly, which cause of congestion is believed more plausible is likely to be linked to participants' pre-existing believes and to which discourses they are exposed. Similarly, congestion is likely to be more noticeable than changes in vehicle volumes or smoother public transport or cycling journeys, creating a further incongruence between what is measured and what is experienced.

These findings provide insights for research on congestion and transport policy. First, we show that spatially disaggregated evidence on congestion impacts is a useful complement to quantitative evidence, but that it can vary widely geographically and temporally and should therefore be considered carefully. For example, what our data shows is that, perhaps surprisingly, effects that might emerge as concerning in quantitative terms might not be relevant to many residents' experiences or not even being noted, and that a threshold of congestion might be what matters more than the actual increase before /after a scheme.

Given the overall complexity of defining congestion, residents' concerns about increasing levels of congestion should be taken into account when designing, testing and implementing road reallocation policies. Taking them into account means also considering how such perceptions are likely to be far from universal or area-wide and are likely to be shaped by *what 'counts'* for those residents and what is salient and *visible* to them. This in turn is shaped by evolving public discourses and controversies (Powell, 2024b). This means that residents from different areas, backgrounds, demographics, needs and views should be adequately involved in the discussion. We have argued elsewhere how such discussion should particularly consider access frictions between different mobility needs, especially when involving disabled people (Larrington-Spencer et al., Under review Disability Studies Quarterly). Similarly, local authorities' measurements of traffic volumes may only tell part of the story and will benefit from being complemented by other methods of analysis.

We are aware that, as the controversy around street reallocation schemes complexifies, ways in which data play a role are changing. In the UK, authorities appear to be very aware of the limitations of traditional monitoring and evaluation methods, with a recent report for the UK Department for Transport finding that policymakers recognise that "traditional approaches were insufficient to capture key outcomes" (Aldred and Lawlor, 2024: 44). The introduction of new methods to capture the variety of scheme' associated impacts, including the use of video-cameras to replace traditional manual traffic counts, and the combination of traditional quantitative measurement with other forms of qualitative, quantitative and/or spatial data such as attitudinal surveys, focus groups and map-based online engagement is a welcome move to provide better and more nuanced depiction of changes and impacts, which we hope will be informed also by our findings.[6] Such move might be particularly key in anticipating and addressing shortcomings of measures, which in turn is likely to reduce controversy and opposition over time. Finally, there are some important limitations to our research which are hopefully useful also to these new methods being introduced more widely. Firstly, as research shows, the timeline alongside which impacts such as but not limited to congestion are assessed is crucial. As schemes bed in, effects are likely to change or reduce, which might not be reflected in the one-time picture captured in interviews or online engagement or even in repeated interviews or longitudinal measurements.[7] The quantitative data presented in this paper, which are only a portion of the data we collected, are likely to show a different picture if analysed taking into account a longer time frame than the one we selected for this study.

Secondly, to an extent emerged from the interviews themselves, a focus on a single area-level impact, such as congestion on one road segment, risks missing capturing the full-range changes related to ambitious road reallocation measures that, although hyperlocal in focus, target global challenges such as climate change or a pressing health epidemic. As others highlighted (Larrington-Spencer et al., 2021), a repeated focus on localised issues will fuel controversy and dangerously distract from a due discussion on a vision of improved public life and health which underpins these interventions. As much as qualitative data can help further detail aggregated data and nuanced understanding of local impacts, a focus only on such micro-scale effects fails to capture other important changes related to schemes.

CRediT authorship contribution statement

Ersilia Verlinghieri: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Harriet Larrington-Spencer:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jamie Furlong:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rachel Aldred:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Anna Goodman:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

[6] Particularly, several UK local authorities utilised platforms such as 'Commonplace' or 'Story Mapper' where residents could leave comments related to specific places, which allow the public to leave comments that relate to specific places, both as engagement and evaluation tool (Aldred and Lawlor, 2024).

[7] As part of our project, the same residents were interviewed twice.

Declaration of competing interest

AG lives in a former LTN in South London. It is not one of the LTNs studied in this paper. From time to time, AG volunteers in a personal capacity with local healthy streets and safe routes to school groups.

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Appendix 1. Analysing spatial transcripts

We recruited our participants by flyering all residences within or surrounding the case study LTNs, and selected to include a diversity of demographics – for example, disability, ethnicity, age, gender, car ownership – and multiple positions on their local LTN, namely support, oppose, and ambivalent. Participants were asked to participate in a go-along interview, in which the interviewer accompanies the participant travelling through a particular socio-spatial environment, which in the case of this research was the participants' local LTN [reference redacted for review]. Selected participants were invited to participate by walking, wheeling using a mobility aid, or by cycling. The majority of participants walked, whilst one person used their mobility scooter. A number of go-alongs were more sedate, taking longer sitting breaks on benches in order to account for reduced mobility or fatigue of the participant. Across the case study LTNs we conducted 21 go-along interviews in Summer 2022.

With consent from participants, go-along interviews were audio recorded, as well as GPS tracked. In addition to the audio recordings enabling transcription for qualitative analysis (see papers where we use this data [references redacted for review]), tracking GPS also enabled us to develop spatial transcripts, which bring together the qualitative data produced within go-alongs with spatial analysis to understand the role of place in producing perceptions, experiences and insights (Evans and Jones, 2011). This involves matching the transcript from the go-along interviews with the GPS track points of the go-along route (Jones and Evans, 2012; Martini, 2020). The full methodology for the development of transcripts is available from Martini (2020) and Jones and Evans (2012).

In our project we utilised two approaches to analysing interview spatial transcripts.

First, data can be combined to create a full spatial transcript of each participants' go-along route, in order to understand the spatiality of the content of their interview. The map in Fig. A1.1, for example, can be viewed within QGIS, with track points at 10 s intervals each with an associated popup box that shows what one participant was saying during the go-along at each of these locations. This method has been previously used in combination with quantitative data, for example comparing participants' reported exposure to air and noise pollution and their monitored exposure through wearable sensors (Marquart et al., 2022).

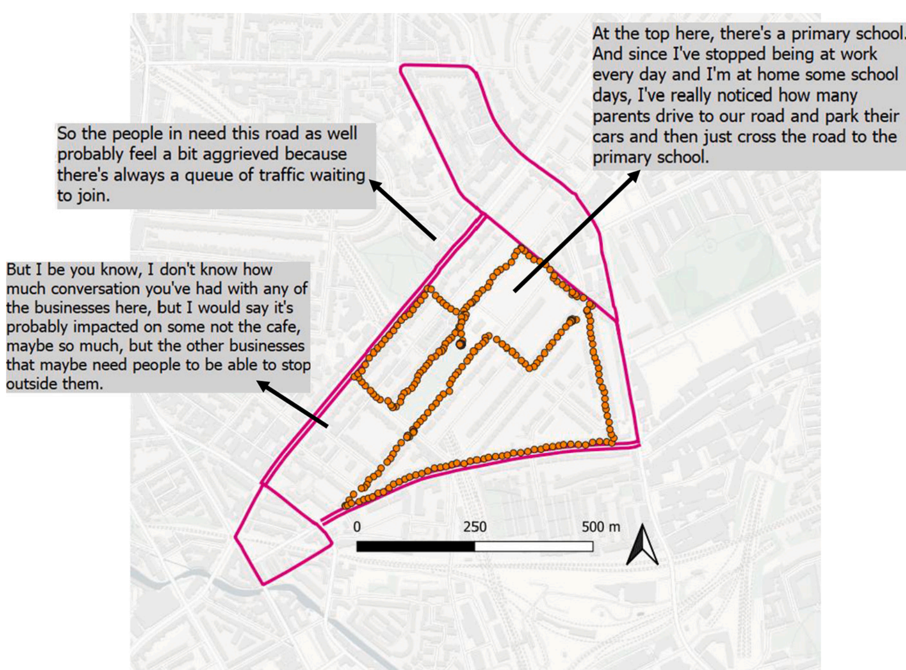

Fig. A1.1. Spatial transcript of an interview with a participant in a case study LTN.

A second approach consist in extracting place-based comments from all interviews and code these according to sentiment[8] of the experiences that participants identified (Fig. A1.2), therefore generating an aggregated map where individual participants place-based comments are aggregated to compose one map. This map is useful in identifying which locations within the study area are of major interest or concern to participants and nuance our coding approach to the interviews. For example, map in Fig. A1.2 worked as a reminder to pay particular attention towards comments made with relation to road A with relation to congestion, the signage for one of the traffic filters, and a particularly narrow junction.

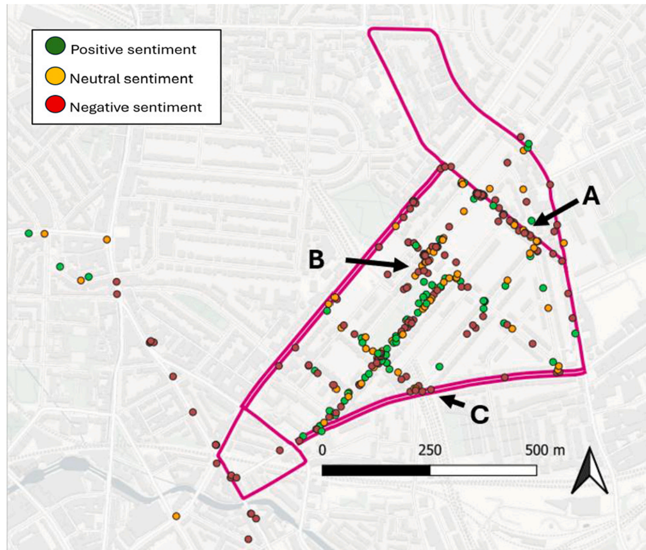

Fig. A1.2. Spatial transcript of place-based comments by research participants within one case study LTN, sentiment coded positive, neutral and negative.

Appendix 2. Quantifying congestion on boundary roads

To quantitative study congestion on boundary roads we used Google API real-time journey data.

To begin, we divided boundary roads for the LTN into segments between junctions/nodes, generally measuring between 250 m and 500 m. On each segment of road, in each direction (if the road is two-way), a unique journey is created from the start and end point of the segment. Using Google API, we have then routed each of these journeys, in real time, based on live traffic conditions, 30 times each week (24 journeys on Tuesdays and 6 journeys on Saturdays). Data has been collected since June 2021 and will be collected until October 2024. For each journey, at each time on each day, we have the estimated journey time, which combined with the distance, allows us to calculate the journey speed.

In our case study LTN, we have collected matched pre-LTN ('before') and post-LTN ('after') data for each journey on each road segment. To do so, we have taken data from a 28-week period in 2021 (pre-implementation) matched to the exact same period in 2022 (post-implementation) and 2023 (post-implementation). In total, this period comprised 7560 unique journeys in each year. There were some unique trips that have subsequently been excluded from the analysis. These are trips where there is a greater than 20 m difference between the distance of the journey and modal distance for that particular journey route across all the trips made. These have been excluded because, after manual inspections, we confirmed that these were cases where Google has re-routed at least part of the trip along a different road than the boundaries we are measuring. It is likely that these cases are caused by the road being temporarily closed or obstructed due to roadworks. While in a sense the journey times along the road segment is likely to reflect 'real-life' conditions, we cannot assign them to the boundary road if the actual journey is not taking place along that road. If a trip is excluded in one year, the equivalent trip is excluded from all years in the dataset. For example, if a trip was excluded on 20 July 2021 at 06:45, the same journey would be excluded on 19 July 2022 and 20 July 2023. In total, 450 trips were excluded (150 in each year), meaning there were a total of 22,230 trips included in the analysis (7410 in the pre-implementation year of 2021, and 7410 in each of the two years post-implementation. This method enables us to make a like-for-like comparison of speeds and congestion across the exact same journeys in the before and after periods.

[8] Positive sentiment: positive terminology/reduction in negative sentiment/change from bad to good/reduction of activities with negative implications i.e. pollution, ratrunning. For example: "There's a nursery on this corner here. So it's really nice that they probably having less pollution because there's not you know, there's not so much traffic here or here because this road was very busy and this nursery backs onto that that road."

Neutral sentiment: comments with no positive or negative framing/balanced comments/nuanced comments/descriptive place-based comments. For example: "Now what, what is attractive, obviously, putting the plants in - I've questions wondering who's watering them. I know the problem I've got keeping mine."

Negative sentiment: comments with negative terminology/reduction in positive sentiment/change from good to bad/increase in activities with negative connotations, i.e. rat running, pollution, revenue raising/comments on changing driving routes with negative interpretation. For example: "Right. Well, I mean, it is [the infrastructure] being responsible for reducing the traffic flow, making Camden what they love, which is money."

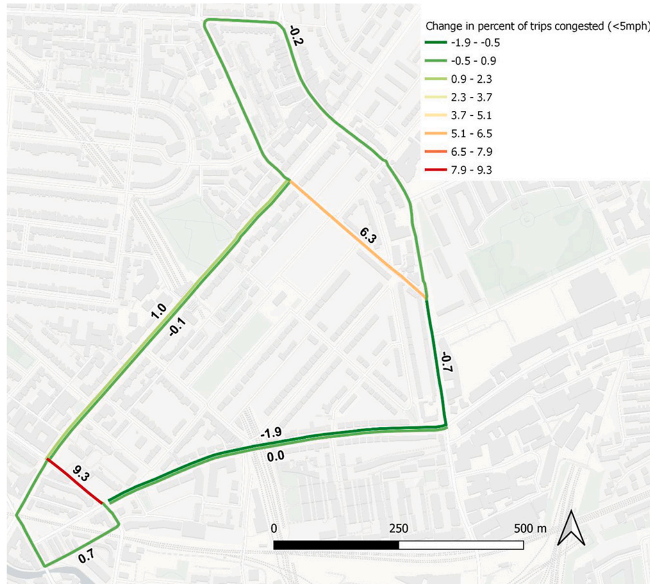

Fig. A2.1. Change in percent of trips congested (pre- to post-LTN implementation).

Quantitative methods details:

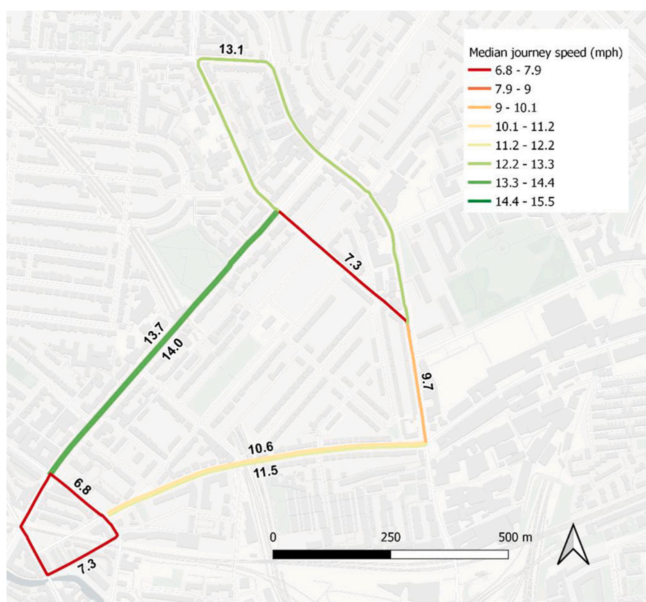

Fig. A2.2. Median journey speeds (pre-LTN implementation).

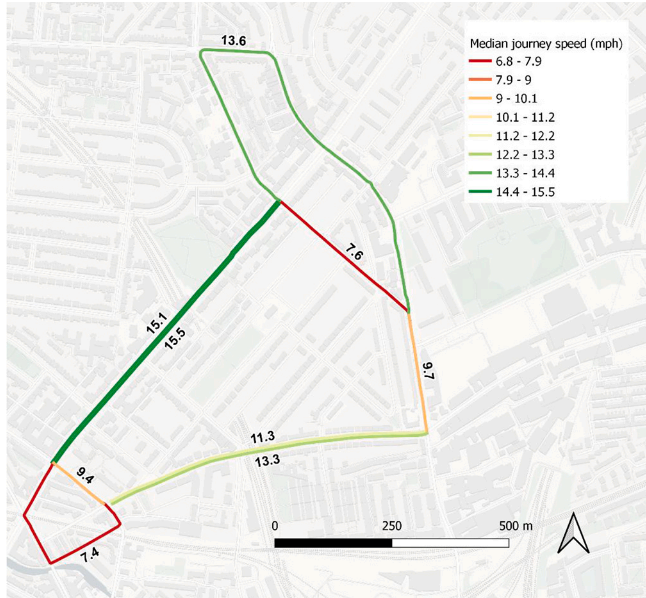

Fig. A2.3. Median journey speeds (post-LTN implementation).

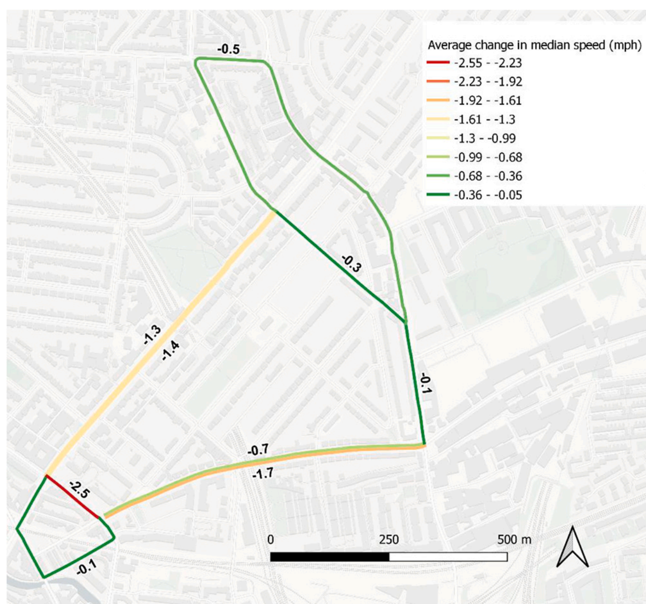

Fig. A2.4. Average change in median journey speeds (pre- to post-LTN implementation).

Data availability

The data used for this work will be deposited in an open access archive by October 2025. Please contact the corresponding author for information.

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