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# Is cycling infrastructure in London safe and equitable? Evidence from the cycling infrastructure database

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ABSTRACT

*Introduction:* We describe and analyse a new, open dataset of surveyed cycling infrastructure in London UK. We demonstrate its potential to contribute to research and evidence-based policy development through a spatial analysis of infrastructure provision in London, before evaluating administrative boroughs on their infrastructure mix and compliance with UK Cycle Infrastructure Design Standards.
*Methods:* We processed and cleaned the 233,596 records in the London Cycling Infrastructure Database (CID) that contains nine infrastructure types. To support comparison between London boroughs, infrastructure provision was normalised to borough area, population size and level of commuter cycling. We generated variables capturing cyclist separation from motor vehicles and estimated cycle lane compliance for such segregation against design standards.
*Results:* Each CID record contains the infrastructure survey date, spatial location, infrastructure-specific variables and accompanying photographs. Traffic calming assets are numerous and distributed throughout London. Cyclist signals, crossings, Advanced Stop Lanes and cycle lanes and tracks are less numerous and more commonly seen in inner rather than outer London. Normalisation by area and population did not change these spatial patterns. Six percent of on-road cycle lane length is physically segregated from vehicles. Estimated compliance with UK design standards was notably higher for inner London boroughs with 66% exceeding mean compliance compared to just 24% of outer London boroughs.
*Conclusions:* In this first systematic description and analysis of the CID we have demonstrated its potential to quantitively and qualitatively compare infrastructure and a method to estimate compliance against design standards. We found that cycling infrastructure is not distributed equally across London and may not be of the quality that provides safe space for cycling. Such datasets are critical assets to evaluate infrastructure and guide health and transport policies.

## 1. Introduction

Enabling more cycling is important as it is one of the healthiest, safest (Khreis et al., 2016; Woodcock et al., 2014) and potentially

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most equitable (Pereira et al., 2017) forms of transport, leisure and exercise. Cycling generates numerous benefits for individuals and society, representing one of the simplest and most effective solutions to crises ranging from climate change (Woodcock et al., 2009) to the obesity epidemic (Rasmussen et al., 2018). Increased physical activity associated with cycling uptake can improve physical and mental health, reduce motor vehicle usage, congestion, air and noise pollution and health costs (Götschi et al., 2020; Laird et al., 2018). The COVID-19 pandemic has profoundly impacted transport, leisure and exercise and disrupted historical patterns of cycling and motor vehicle use (De Vos, 2020; Hadjidemetriou et al., 2020; Hong et al., 2020a; Li et al., 2021). Some pandemic impacts may become sustained societal shifts, presenting new opportunities to embed active travel and greater cycling participation (Budd and Ison, 2020; Laverty et al., 2020; Musselwhite et al., 2021; Tirachini and Cats, 2020).

To enable more cycling, cycling networks and routes must be safe, coherent, direct, comfortable and attractive (DfT, 2020a). Dedicated cycling infrastructure has a central role to play in delivering these key principles. Cycle lanes and segregated cycle paths are cited by people as factors that would encourage them to cycle (DfT, 2020b) and dedicated infrastructure may address the significant perceived and actual safety concerns that deter many from cycling (e.g. DfT, 2020c; Félix et al., 2019; Lorenc et al., 2008; Pooley et al., 2013). However, evaluating infrastructure, to determine whether it is safe, coherent, direct, comfortable and attractive, is hindered by a lack of high-quality infrastructure data (Reid and Ada, 2010). In many studies this data is partial, sporadic and contains a fraction of the infrastructure available (e.g. a few kilometres) (Reid and Ada, 2010). It is complicated by differences or inconsistency in infrastructure design (Reynolds et al., 2009) and failure to describe infrastructure characteristics (Mulvaney et al., 2015). This can be compounded by the fact that much infrastructure data is held locally by planners and not publicly accessible (Hong et al., 2020b; Schoner and Levinson, 2014).

High-quality, complete, open, infrastructure datasets such as the London Cycling Infrastructure Database (CID) could improve the quality of evaluation and thus the evidence base for infrastructure effectiveness. Cycling infrastructure in London has developed over many years influenced by geography, politics, priorities and investment (Golbuff and Aldred, 2011; Di Gregorio and Palmieri, 2016). Ninety-five percent of London roads are managed by local government (33 London boroughs). Transport for London (TfL) manages most main roads and is responsible for delivering the Mayor of London's Transport Strategy including the implementation of strategic schemes such as Cycle Superhighways, which aim to provide direct, quality cycling highways connecting key parts of the city (TfL, 2022). The CID surveys all physical cycling infrastructure in London. Created by TfL in 2019, its ambition is to 'address barriers to cycling by providing Londoners with clear and accurate information about cycling infrastructure, helping them plan cycle journeys with confidence' and to 'help TfL and the boroughs to plan future cycling investment' (TfL, 2019a). This data was systematically collected and coded through on-site surveying and provided complete, contemporary, coverage (TfL, 2019b, 2020a). The CID is available as open data (TfL, 2019c) and collaboration with OpenStreetMap aims to ensure that it becomes a dynamic dataset (OSM Wiki contributors, 2020). We believe this new, open dataset is a highly valuable cycling infrastructure resource.

This paper explores this new cycling infrastructure database for the first time and demonstrates its potential to support research and influence policy and planning. After describing the database in detail, we present a data analysis comparing variation in cycling infrastructure provision across London's boroughs. We compare boroughs according to the distribution, type, quantity and quality of infrastructure, adjusting for factors such as geographical area, population size and amount of cycle commuting. We also evaluate on-road cycle lane separation from motor vehicles and estimate compliance of this separation with new UK Cycle Infrastructure Design Guidance (DfT, 2020a).

## 2. Methods

### 2.1. Data

The London CID contains cycling infrastructure data derived from systematic physical surveys conducted between 2017 and 2019 (TfL, 2019a). The CID data were accessed via the TfL cycling open data portal (TfL, 2019c). We created an R package named CycleInfraLnd (Tait and Lovelace, 2019) to import the data into R in the standard simple features class (Pebesma, 2018). The CycleInfraLnd package presents the cycling infrastructure as a data frame, with latitude and longitude coordinates represented in a 'geometry' column for each of the 233,596 cycling infrastructure observations in the CID.

The 2019 Greater London boundary was used to spatially limit all datasets to within London to coincide with the final year of CID survey. Inner and outer London boroughs were defined by the London Plan (GLA, 2021). To support borough-level comparison when characterising infrastructure provision, we adjusted for geographical area, population size and level of commuter cycling. The population estimates (mid-2019) (ONS, 2020a), geographical boundaries and areas (ONS, 2020b) for each of the 33 London boroughs were obtained from the Office for National Statistics. The Propensity to Cycle Tool uses individuals' home origin and employment destinations from the 2011 Census and a cycling routing algorithm to estimate the number of commuter cycling trips using each segment on the route network (Lovelace et al., 2017). We took these route network level data and split it by borough boundaries. Where the network crossed a boundary, we created two segments. We calculated the total distance cycled by commuters per working day on each borough segment by multiplying the segment length by the number of commuter cyclists using that segment per working day. Finally, we calculated the estimated annual total distance cycled by commuters by multiplying the previous figure by 400 (one outbound and one inbound trip for 200 working days of the year). Historical road speed limit data, required to assess compliance of cycle lanes with UK design standards, was obtained from OpenStreetMap for January 2019 (Geofabrik, 2019; OSM contributors, 2017).

### 2.2. *Analysis of the cycling infrastructure database*

We examined all CID datasets for errors and missing values. Minor spelling mistakes were corrected and missing infrastructure values were examined and corrected manually where possible, for example by using a combination of google maps and CID infrastructure images.

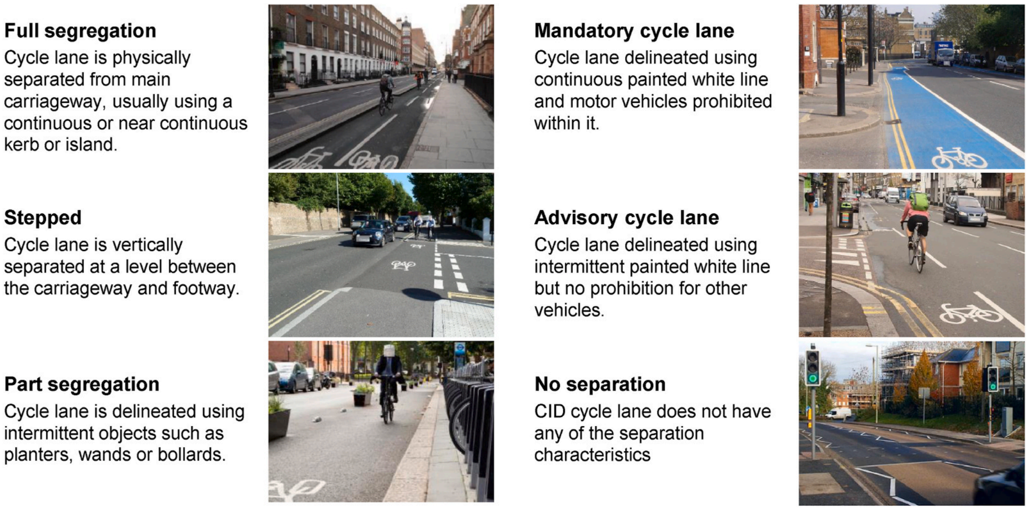
We spatially joined all CID observations with borough boundaries to ensure they were labelled with the correct borough (ONS, 2020c). Where an observation did not have a pre-existing borough label or there was a mismatch between the pre-existing and spatially-joined borough, these were corrected. Observations were examined to ensure they contained a single infrastructure item per row of data. Where a single row represented more than one infrastructure item, for example, multiple cycle crossings at a junction, it was replaced by multiple, new, single observations. We calculated the dimension of those CID observations that have linear spatial data. We performed a detailed analysis of the five CID datasets most obviously related to providing safe space for cycling. These are: Advanced Stop Lines (ASL) that provide protective space at traffic signals, crossings for cyclists, signals for cyclists, physical traffic calming and cycle lanes and tracks. Observations were aggregated to borough level and joined to datasets containing geographical area, estimated population and estimated total annual commuter cycle distance. To support borough-level comparison we calculated counts (length for cycle lanes and tracks) by area (square kilometre), per 100,000 head of population and per 100,000 km estimated total annual commuter cycling.

### 2.3. *Determining on-road cycle lane separation from motor vehicles*

On-road cycle lanes in the CID have multiple variables that define their separation from motor vehicles. Each on-road cycle lane observation was assigned the ‘highest’ level of separation ordered as follows: full segregation, stepped, partial segregation, mandatory cycle lane, advisory cycle lane and no separation (Fig. 1). We categorised the cycle lanes by whether they were shared bus lanes, contraflow cycle lanes or general cycle lanes.

### 2.4. *Estimating on-road cycle lane compliance with UK Cycle Infrastructure Design Guidance (LTN 1/20)*

The UK Cycle Infrastructure Design Guidance (LTN 1/20) provides clear recommendations for designing cycle lanes to protect cyclists from motor vehicles on highways (DfT, 2020a). Full segregation is considered suitable in most road conditions whilst stepped or part segregation is appropriate when the road speed limit is 30 mph or less (see Fig. 1 depictions). Mandatory and advisory cycle



**Full segregation**
Cycle lane is physically separated from main carriageway, usually using a continuous or near continuous kerb or island.

**Stepped**
Cycle lane is vertically separated at a level between the carriageway and footway.

**Part segregation**
Cycle lane is delineated using intermittent objects such as planters, wands or bollards.

**Mandatory cycle lane**
Cycle lane delineated using continuous painted white line and motor vehicles prohibited within it.

**Advisory cycle lane**
Cycle lane delineated using intermittent painted white line but no prohibition for other vehicles.

**No separation**
CID cycle lane does not have any of the separation characteristics

**Fig. 1.** Categorisation of CID on-road cycle lane separation from motor vehicles (images taken from TfL, 2019b).

lanes are considered better than no cycle lane but only under certain circumstances: the road speed limit is 20 mph or less, exceedance of this speed limit is minimal and traffic volumes are below a certain threshold (DfT, 2020a). Data on traffic volumes and speed limit exceedance is not available for most roads in London so for this analysis we assumed that these thresholds were not breached.

To associate cycle lane separation with the speed limit of that road, we needed to join the CID to OpenStreetMap speed limit data. As OpenStreetMap speed limit data is represented as a single line, we enlarged this to a road 'zone' allowing 3.65 m for lane width (Highways England, 2020) and 6 m for potential OpenStreetMap positional inaccuracy (Haklay, 2010) each side of the line. Cycle lanes that were within (67%) or touching (13%) a road zone were allocated that road zone speed limit (facilitated by spatial joins). All cycle lane segments were then tested for compliance with LTN 1/20 level of protection standards and judged as being compliant if they met the criteria in Table S1. This identified 2738 (18%) cycle lanes where it was unknown as to whether the cycle lane was compliant (actual number of cycle lanes with unknown speed limits was 3158). These 2738 cycle lanes were visually inspected with OpenStreetMap data to establish whether a speed limit could be attributed to the cycle lane. Where it could, speed limit data was attributed and where it could not it was left as "Unknown". This approach resulted in 2335 (15%) observations where it was unknown as to whether the separation was appropriate.

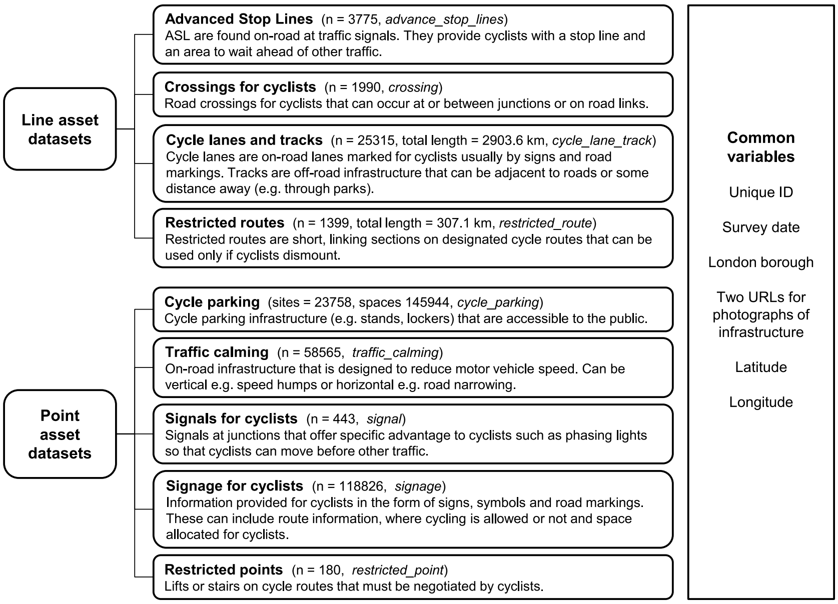
More details about all the methods described above can be found in the Supplementary materials.

## 3. Results

### 3.1. Description of the cycling infrastructure database

The CID consists of nine datasets each containing a different type of linear or point physical cycling infrastructure (Fig. 2). There are seven variables present in every dataset: a unique identifier, survey date, borough location, two URLs for photographs of the infrastructure and coordinates of the location. Each dataset contains further variables that are unique and relevant to the infrastructure type and these are detailed in Table S2.

In total the CID datasets contained 234,251 observations, each representing an individual infrastructure object, after applying the processing steps outlined in the previous section. The majority are signage (51%) or traffic calming (25%) whilst restricted points



**Advanced Stop Lines** (n = 3775, *advance_stop_lines*)
ASL are found on-road at traffic signals. They provide cyclists with a stop line and an area to wait ahead of other traffic.

**Crossings for cyclists** (n = 1990, *crossing*)
Road crossings for cyclists that can occur at or between junctions or on road links.

**Cycle lanes and tracks** (n = 25315, total length = 2903.6 km, *cycle_lane_track*)
Cycle lanes are on-road lanes marked for cyclists usually by signs and road markings. Tracks are off-road infrastructure that can be adjacent to roads or some distance away (e.g. through parks).

**Restricted routes** (n = 1399, total length = 307.1 km, *restricted_route*)
Restricted routes are short, linking sections on designated cycle routes that can be used only if cyclists dismount.

**Cycle parking** (sites = 23758, spaces 145944, *cycle_parking*)
Cycle parking infrastructure (e.g. stands, lockers) that are accessible to the public.

**Traffic calming** (n = 58565, *traffic_calming*)
On-road infrastructure that is designed to reduce motor vehicle speed. Can be vertical e.g. speed humps or horizontal e.g. road narrowing.

**Signals for cyclists** (n = 443, *signal*)
Signals at junctions that offer specific advantage to cyclists such as phasing lights so that cyclists can move before other traffic.

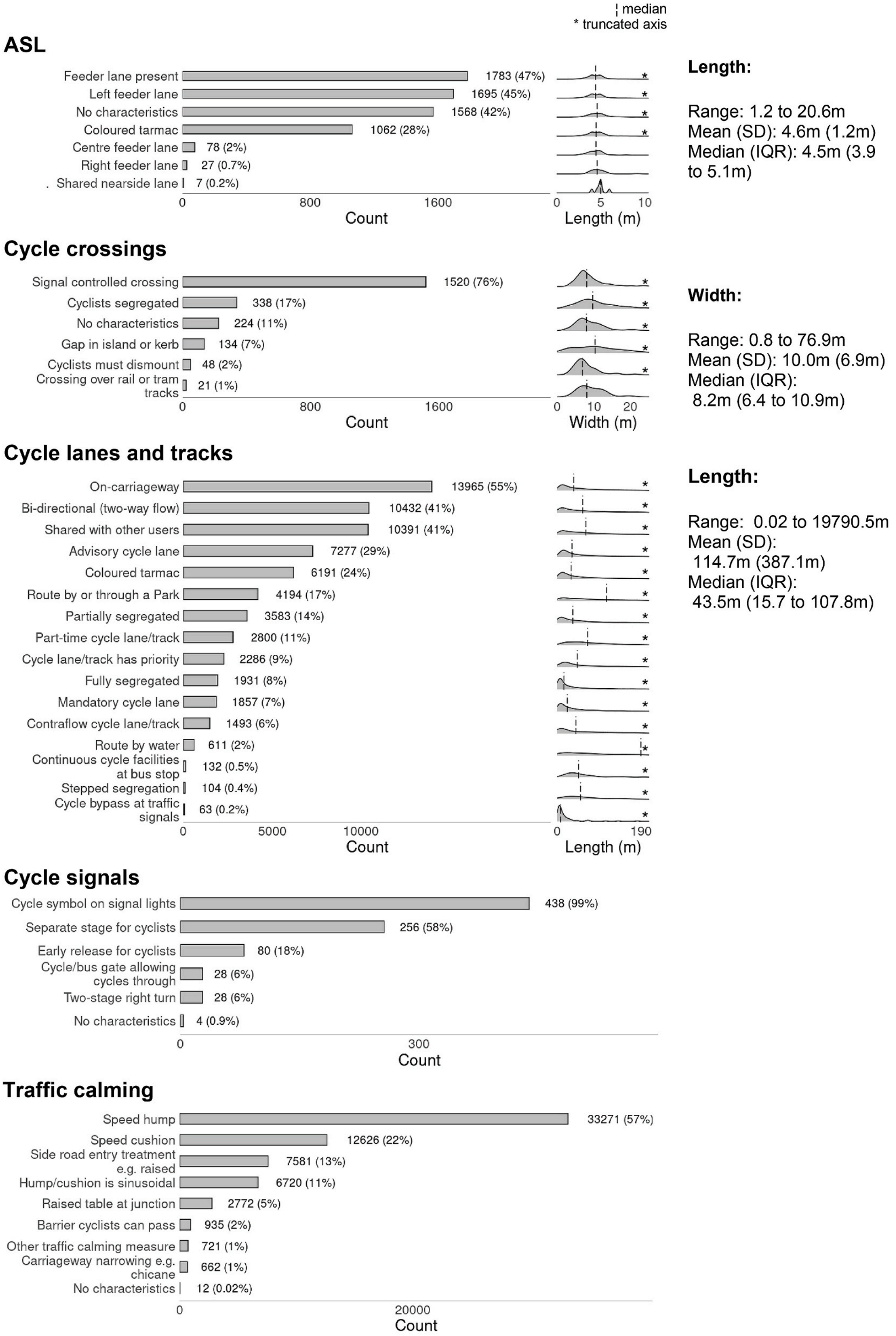
**Signage for cyclists** (n = 118826, *signage*)
Information provided for cyclists in the form of signs, symbols and road markings. These can include route information, where cycling is allowed or not and space allocated for cyclists.

**Restricted points** (n = 180, *restricted_point*)
Lifts or stairs on cycle routes that must be negotiated by cyclists.

**Fig. 2. An overview of the nine CID datasets (number of observations and *dataset name*) and their common variables [a].**

[a] Descriptions sourced from TfL (2019b). Number of observations reflects the count following data cleansing described in the Methods section. On-carriageway line asset spatial data is aligned to the kerb except for crossings, which run perpendicular to the kerb, and cycle lanes that continue through a junction. It represents where the infrastructure starts and ends according to road markings. Off-carriageway line asset spatial data is aligned to actual position where possible and represents the central location on the footway or path. Point assets are spatially located as close as possible to their physical location. Co-located assets, e.g. multiple signs on a single signpost, are recorded as separate assets.

**Table 1**
Characterisation of infrastructure data by variables: bar charts of counts (%), and smoothed histograms with summary statistics of linear CID data.



(0.1%) and signals (0.2%) are the least common. Infrastructure was surveyed between January 6, 2017 and September 2, 2019 with 76% surveyed in 2017, 24% in 2018 and 0.01% in 2019. Despite regular modifications to the online CID data repository, it appears that no new data has been added since September 2, 2019. All 33 London boroughs are present in the nine datasets apart from 10 boroughs (signals) and six boroughs (restricted points). Most observations (98%) have two photographs and coordinates are present for all observations. The CID only includes one-dimensional linear information, for example, the length but not the width of cycle lanes.

In the remainder of this section we focus on the CID infrastructure most important in providing safe space for cycling namely the ASL, crossings, cycle lanes and tracks, signals and traffic calming datasets.

### *3.2. Description of specific infrastructure datasets*

The ASL, crossings, cycle lanes and tracks, signals and traffic calming datasets are characterised in Table 1. Further descriptions of this infrastructure can be found in tables A1-A.6.

The most common characteristic of ASL is a feeder lane (47%), predominantly on the left (45%). Only seven ASL have more than one feeder lane (Table A1). Most cyclist crossings are signal controlled (76%) and nearly a fifth segregate cyclists from other users (17%). Some crossings have multiple characteristics (Table A3); for example, 45 crossings (2%) are signal-controlled, have cyclist segregation and a gap in the island or kerb. Crossing width varies depending on characteristics, crossings with gaps in kerbs or islands (required for wider crossings) have the highest median value (10.3 m). Fifty-five percent (944.0 km) of cycle lanes and track are on-road (Table A4). The most frequent cycle lane and track characteristics are bi-directional flow (41%, 1911.4 km) and sharing with buses or a footway (41%, 1896.2 km). Unlike ASL, cycle lane and track length varies considerably by characteristic with water routes and park routes having the longest medians (189.6 km and 111.5 km). Only four signals have no characteristics whilst 99% have a cycle symbol on the traffic lights (Table A5). The majority have a separate cyclist lighting phase (58%). Speed humps (57%) and cushions (22%) are the prevalent traffic calming infrastructure. Only nine percent of humps and three percent of cushions are sinusoidal, the shape that is most comfortable for cyclists (Table A6). Just 15 traffic calming observations (0.03%) have more than one characteristic.

For cycle lanes and tracks, length appears to be a more appropriate measure than count due to the extreme variation in length between observations. For example, 55% of observations are on-road but these account for 33% of total length. This is explained by the varying nature of on-road cycle lanes, necessitating new observations when they change, for example, from segregated to advisory cycle lanes (Table A4). Length rather than count will be used in subsequent analyses.

Cycle lanes and tracks vary by whether they are on or off-road (Fig. 3, Table A4). Unsurprisingly, certain characteristics are almost exclusively found off-road e.g. water or park routes whilst others are predominantly found on-road e.g. mandatory, advisory, contraflow or priority cycle lanes. Advisory cycle lanes, a cheap form of infrastructure, has the greatest on-road length (489.2 km) whilst Bi-directional tracks have the longest off-road length (1885.4 km).

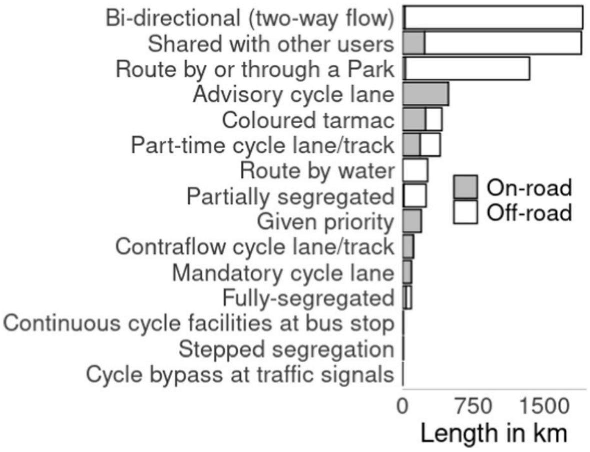


**Fig. 3.** Comparison of characteristics of on-road cycle lanes and off-road cycle tracks.

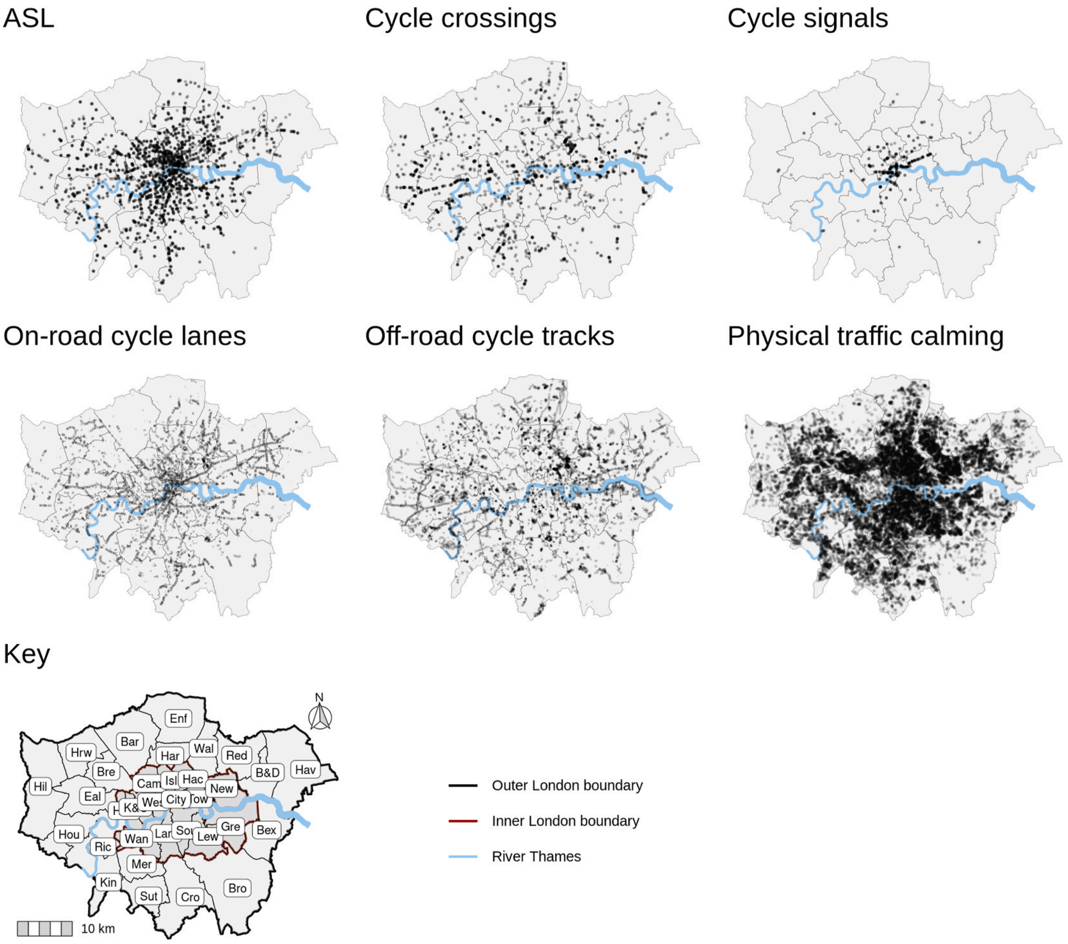


**Fig. 4.** Spatial distribution of infrastructure across London.
Bro = Bromley, Cam = Camden (I), City = City of London (I), Cro = Croydon, Eal = Ealing, Enf = Enfield, Gre = Greenwich (I), Hac = Hackney (I), H&F = Hammersmith & Fulham (I), Har = Haringey, Hrw = Harrow, Hav = Havering, Hil = Hillingdon, Hou = Hounslow, Isl = Islington (I), K&C = Kensington & Chelsea (I), Kin = Kingston upon Thames, Lam = Lambeth (I), Lew = Lewisham (I), Mer = Merton, New = Newham (I), Red = Redbridge, Ric = Richmond upon Thames, Sou = Southwark (I), Sut = Sutton, Tow = Tower Hamlets (I), Wal = Waltham Forest, Wan = Wandsworth (I), Wes = Westminster (I), (I) = Inner London borough.

### 3.3. Spatial distribution

The five types of infrastructure are not uniformly distributed across London (Fig. 4). ASL and signals are predominantly located in inner London whilst traffic calming measures are distributed throughout London, particularly in areas of high residential density. On-road cycle lanes correspond to arterial roads and strategic cycling infrastructure (such as the Cycle Superhighways that provide high-quality cycle routes) whereas off-road cycle tracks frequently correspond to areas of green space. Certain locations, particularly boroughs in outer London, appear to have very little cycling infrastructure.

### 3.4. Borough-level analysis

Comparison of boroughs by absolute amount of infrastructure shows that there is considerable variation (Table 2). Signals are the only type of infrastructure that has no representation in some boroughs (n = 10). Signals, ASL and traffic calming show the greatest variation in values between boroughs. Most boroughs (n = 25) have more off-road than on-road cycle lane length. Examining individual boroughs, we can see that there is no consistent pattern as boroughs with a large amount of one type of infrastructure do not necessarily have large amounts of other types of infrastructure and vice versa.

The maps displaying absolute infrastructure by boroughs (Fig. 5, column 1) show that ASL are predominantly located in the inner London boroughs of Lambeth, Southwark, Camden, Westminster and Wandsworth whilst signals are almost exclusively found in the inner London boroughs of Westminster, Tower Hamlets, City, Lambeth and Southwark. The highest numbers of traffic calming measures are found in Southwark and Lambeth (boroughs with high population density) along with Lewisham, Newham and Hackney (all inner London). Hillingdon, Hounslow (outer) and Newham (inner) have the highest number of crossings. Croydon, Barking and Dagenham and Waltham Forest (outer) and Lambeth and Southwark (inner) have the greatest amount of on-road cycle lanes whilst Richmond upon Thames, Hounslow, Enfield, Ealing (outer) and Newham (inner) have the greatest amount of off-road cycle tracks.

**Table 2**
Borough raw count or length of infrastructure: Summary statistics and individual borough data.

| | ASL | Crossings | Signals | Traffic calming | Cycle lanes and tracks | |
|---|---|---|---|---|---|---|
| | | | | | On-road | Off-road |
| **Summary statistics** | | | | | | |
| Range | 6–336 | 16–140 | 0–96 | 182–3604 | 5.8–58.3 km | 1–112.7 km |
| Mean (SD) | 114.4 (79) | 60.3 (31.9) | 13.4 (22.9) | 1774.7 (946.4) | 28.6 km (12.0 km) | 59.4 km (30.1 km) |
| Median (IQR) | 94 (57–146) | 54 (42–71) | 2 (0–16) | 1513 (1024–2558) | 28.8 km (20.9–34.0 km) | 58.8 km (43.8–81.3 km) |
| **Inner London boroughs** | | | | | | |
| Camden | 259 | 19 | 36 | 1681 | 35.8 km | 10.9 km |
| City of London | 122 | 16 | 58 | 182 | 20.8 km | 1.0 km |
| Greenwich | 113 | 93 | 0 | 2834 | 32.2 km | 87.6 km |
| Hackney | 188 | 58 | 25 | 2923 | 32.8 km | 60.7 km |
| Hammersmith & Fulham | 81 | 51 | 3 | 1362 | 31.8 km | 36.9 km |
| Islington | 165 | 22 | 16 | 2108 | 30.6 km | 12.1 km |
| Kensington & Chelsea | 89 | 17 | 5 | 360 | 12.5 km | 15.4 km |
| Lambet | 336 | 46 | 44 | 2989 | 49.6 km | 45 km |
| Lewisham | 126 | 49 | 1 | 3604 | 27.2 km | 59.3 km |
| Newham | 146 | 139 | 0 | 3103 | 31.1 km | 108.1 km |
| Southwark | 274 | 71 | 44 | 3542 | 40.3 km | 51.3 km |
| Tower Hamlets | 100 | 41 | 59 | 2320 | 28.5 km | 73.6 km |
| Wandsworth | 228 | 59 | 17 | 2001 | 34.0 km | 55.3 km |
| Westminster | 229 | 48 | 96 | 716 | 34.1 km | 22 km |
| **Outer London boroughs** | | | | | | |
| Barking & Dagenham | 76 | 54 | 0 | 1539 | 49.4 km | 58.8 km |
| Barnet | 6 | 36 | 0 | 377 | 6.6 km | 64.7 km |
| Bexley | 6 | 42 | 0 | 1015 | 13.8 km | 71.0 km |
| Brent | 92 | 38 | 1 | 2921 | 13.5 km | 55.0 km |
| Bromley | 51 | 45 | 2 | 795 | 21.4 km | 90.9 km |
| Croydon | 122 | 67 | 2 | 2167 | 58.3 km | 57.9 km |
| Ealing | 157 | 60 | 1 | 2879 | 38.8 km | 96.5 km |
| Enfield | 38 | 78 | 5 | 1513 | 17.0 km | 100.2 km |
| Haringey | 85 | 60 | 0 | 2156 | 23.2 km | 65.6 km |
| Harrow | 42 | 45 | 6 | 1318 | 32.0 km | 34.5 km |
| Havering | 47 | 48 | 0 | 1024 | 25.4 km | 71.1 km |
| Hillingdon | 57 | 140 | 4 | 920 | 20.9 km | 81.3 km |
| Hounslow | 99 | 139 | 0 | 1365 | 33.6 km | 107.0 km |
| Kingston upon Thames | 68 | 67 | 4 | 1300 | 28.8 km | 21.5 km |
| Merton | 94 | 78 | 2 | 1269 | 20.9 km | 44.1 km |
| Redbridge | 48 | 37 | 1 | 1381 | 24.5 km | 88.9 km |
| Richmond upon Thames | 78 | 92 | 0 | 930 | 24.3 km | 112.7 km |
| Sutton | 30 | 76 | 0 | 1413 | 5.8 km | 54.8 km |
| Waltham Forest | 123 | 59 | 11 | 2558 | 44.2 km | 43.8 km |

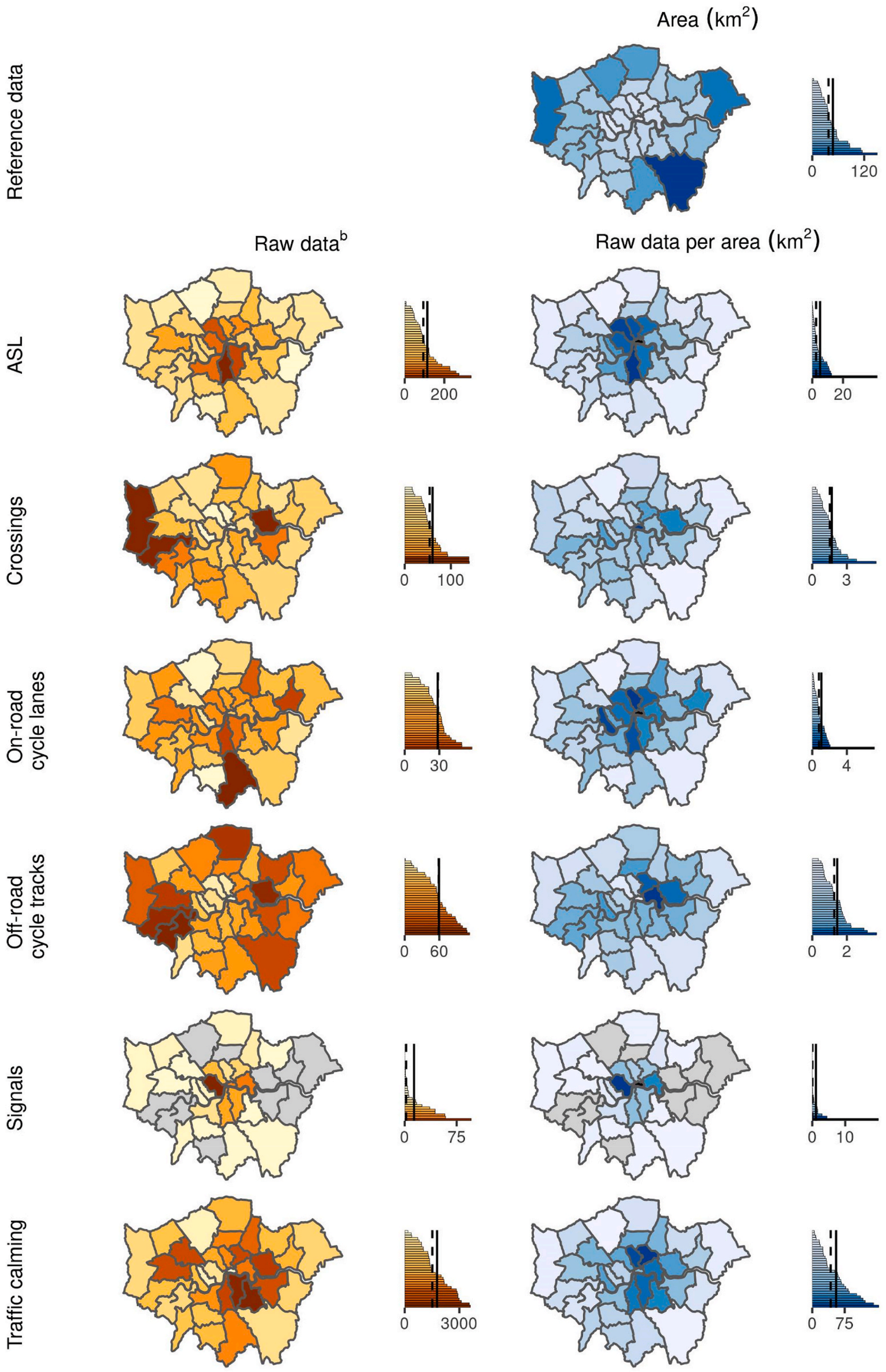


**Fig. 5.** Visualisations of borough-level cycling infrastructure as raw data and normalised to borough geographical area, population size and commuter cycling (bar chart key: dashed line = median, solid line = mean).
a. The City of London can be an extreme outlier when normalised to borough area and population size due to it being small with a low population. When it is an extreme outlier it is coloured black. b. Raw data is in counts apart from cycle lanes and tracks which is in length (kilometre) c. Estimated amount of commuting cycling in the borough in million kilometres per year.

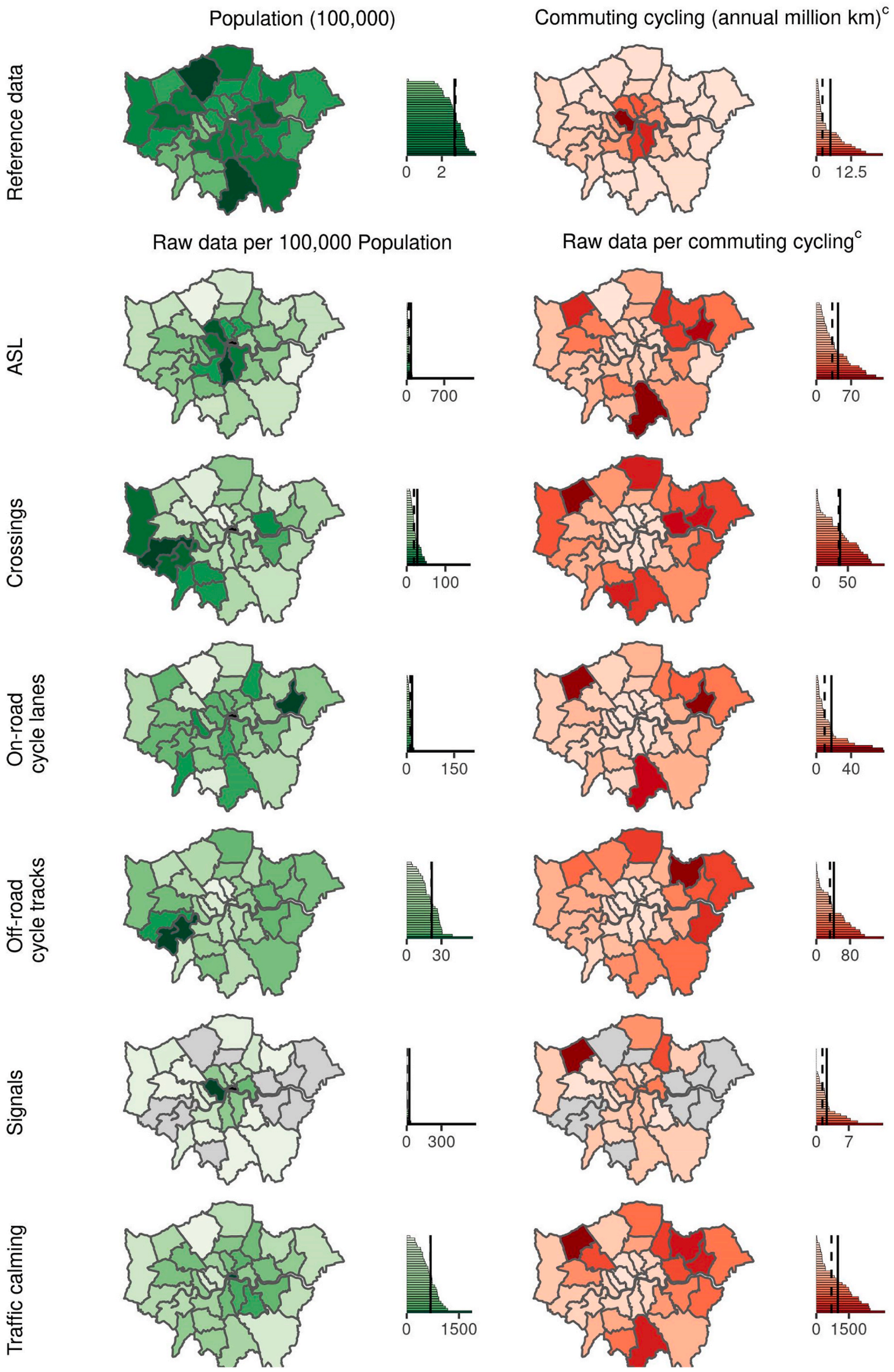


**Fig. 5.** (*continued*).

**Table 3**
CID on-road cycle lane length by highest degree of separation from motor vehicles.

| Highest degree of cyclist separation from motor vehicles | CID cycle lane length in kilometre | | |
|---|---|---|---|
| | Total (Percentage) | Shared bus lane (Percentage of total length of that degree of separation) | Contraflow cycle lane (Percentage of total length of that degree of separation) |
| Full segregation | 39.2 (4) | 0.3 (0.8) | 5.8 (15) |
| Stepped | 0.7 (0.1) | 0.0 (0) | 0.0 (0) |
| Part-segregation | 15.7 (2) | 0.3 (2) | 3.3 (21) |
| Mandatory cycle lane | 85.3 (9) | 0.9 (1) | 9.9 (12) |
| Advisory cycle lane | 487.0 (52) | 2.5 (0.5) | 20.8 (4) |
| No separation | 316.1 (34) | 232.0 (73) | 72.7 (23) |
| Total | 944.0 | 236.4 | 112.5 |

When the absolute data is adjusted (normalised) by borough area and population size (Fig. 5, columns 2 and 3), different patterns emerge. The City of London (the smallest, least populated borough) has the highest density of infrastructure by area and population except for traffic calming (by area) and off-road cycle tracks. For the other 32 boroughs, normalising the raw data by area or population does not tend to alter patterns seen for ASL and signals but does increase the density of this infrastructure in inner London.

Normalisation does appear to reduce variation between boroughs for the other infrastructure types. For example, when normalised by area Hillingdon is no longer the darkest borough for crossings nor is Croydon for on-road cycle lanes, whilst normalising by population size results in greater similarity in colour for crossings in south-western boroughs and off-road cycle tracks in eastern and far-western boroughs. This reduced variability in colour suggests that provision of infrastructure by borough is more equal when normalised by area and population than when evaluated using absolute numbers.

Commuter cycling is predominantly undertaken through inner London boroughs (Fig. 5 column 4). When the raw data is normalised to the estimate of annual commuter cycling an inverse pattern is seen with low infrastructure density in inner London, most

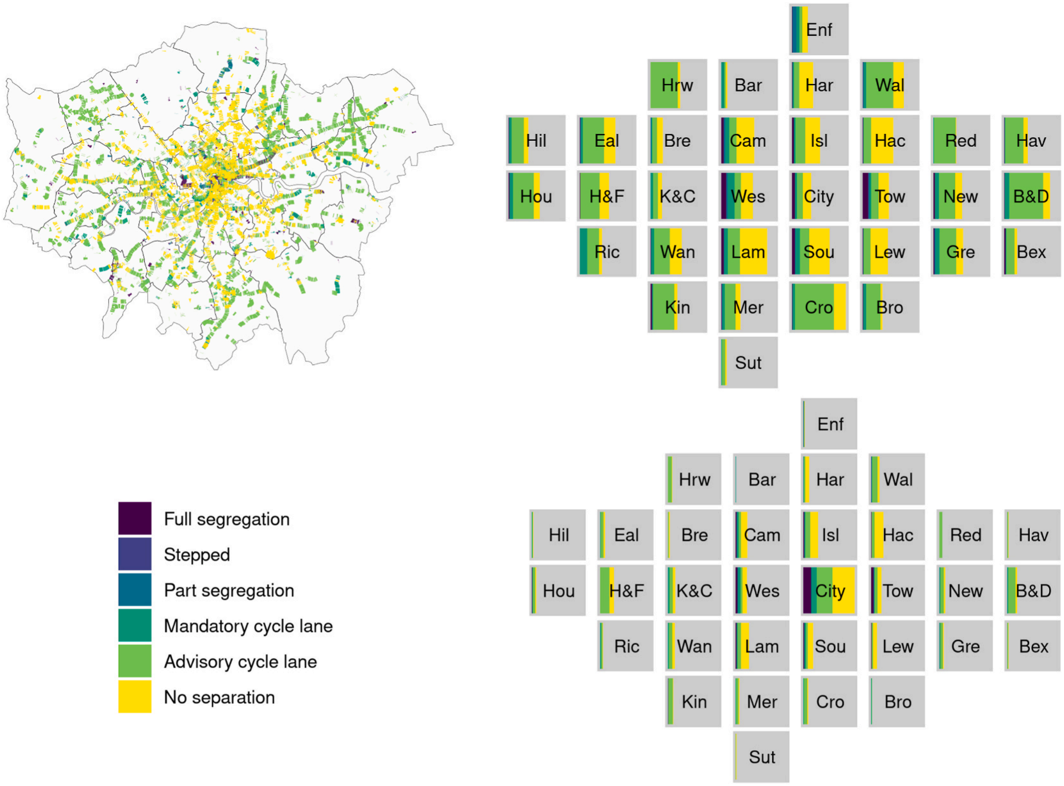


**Fig. 6.** Highest degree of separation of CID on-road cycle lanes from motor vehicles:
Spatial distribution (left) and spatially arranged (After the flood, 2019a; After the flood, 2019b) borough bar charts showing length in kilometre (top right) and length by borough area in kilometre per square kilometre (bottom right).

markedly for crossings, cycle lanes and tracks and traffic calming. For outer London boroughs there appears to be greater variability between boroughs than seen for the other normalisations. For example, Croydon has a much higher density of ASL whilst Harrow has a high density of crossings, on-road cycle lanes, signals and traffic calming.

### *3.5. CID on-road cycle lane separation from motor vehicles*

In the CID, on-road cycle lanes are characterised by their degree of separation from motor vehicles ranging from physical partition (full, stepped or part-segregation) to painted partition (mandatory or advisory cycle lanes) or no separation (see Fig. 1). Analysis of the highest level of separation shows that advisory cycle lanes account for the greatest length of CID cycle lane separation (487 km, 52%, Table 3). Just 6% (55.6 km) of cycle lane length is physically segregated whilst 61% (572.3 km) is mandatory or advisory cycle lanes. 316.1 km (34%) of CID cycle lanes have no separation with the majority of these being shared bus lanes (73%) or contraflow cycle lanes (23%) (Figure A1).

There are clear spatial patterns to the distribution of separated cycle lanes in London (Fig. 6, Table A7). Physically segregated infrastructure tends to match the strategic cycling infrastructure (for example, parts of Cycle Superhighways 2, 3 and 6 correspond to purple lines running east-west, Fig. 6, left). Such infrastructure is more centrally located as illustrated by the purple bars in Westminster, City of London and Tower Hamlets (Fig. 6, top right). Croydon has the greatest total length of on-road cycle lanes with some separation (45.4 km) whilst Sutton has the least (4.3 km). All London boroughs contain cycle lanes where the highest separation is full segregation, but the amount varies from 21 m (Brent) to 6.0 km (Tower Hamlets). 31 boroughs have part-segregation but vary in length from 7 m (Barnet) to 4.3 km (Enfield). Fully segregated lanes are predominantly found in inner London boroughs whereas advisory cycle lanes are predominantly found in outer London boroughs. When the length of on-road cycle lanes are adjusted for geographical borough area (Fig. 6, bottom right), the City of London has the greatest density of cycle lanes with some form of separation (4.1 km per

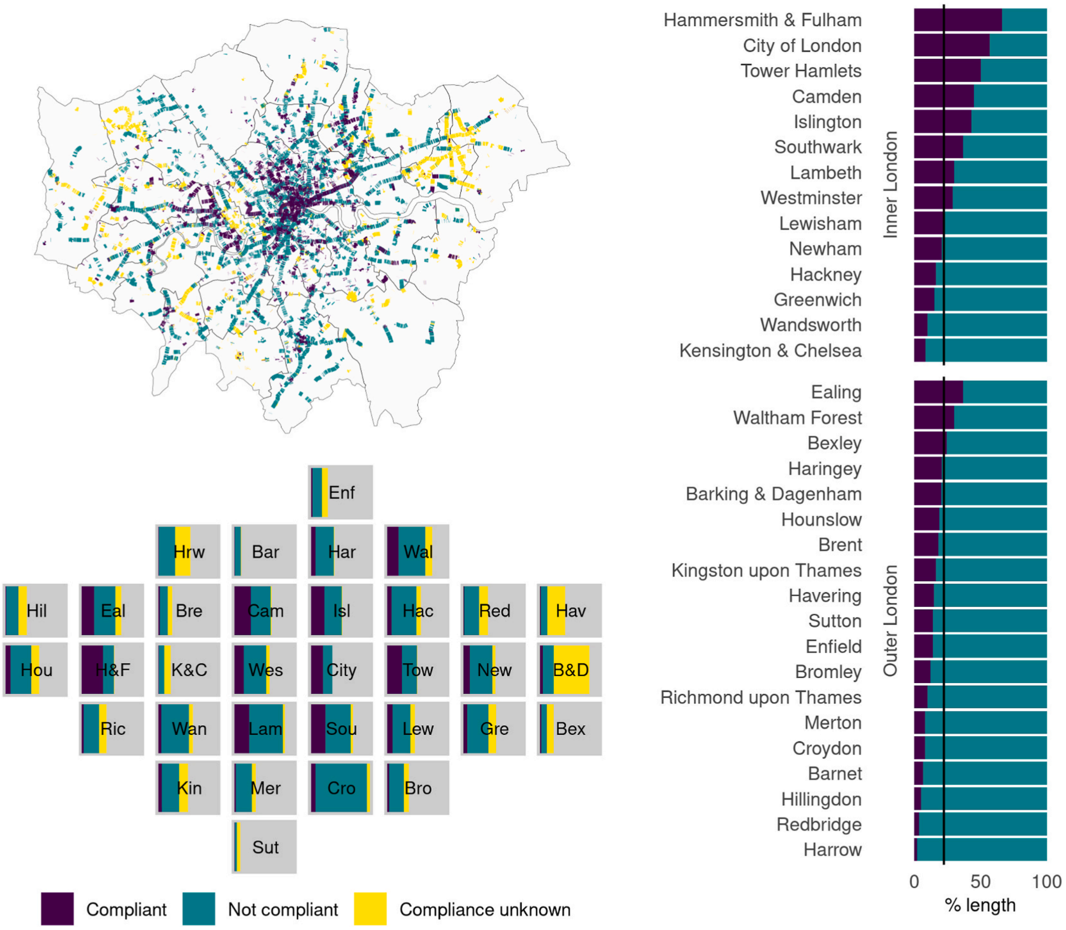


**Fig. 7.** Estimated compliance of on-road cycle lanes with LTN 1/20: Spatial distribution (top left), spatially arranged (After the flood, 2019a; After the flood, 2019b) borough bar charts showing length in kilometre (bottom left) and percentage of length by borough where speed limit is known (right, solid line = mean).

square km) whilst Barnet has the least (0.05 km per square km). The highest densities are found in the City of London for fully segregated (1.1 km per square km), Waltham Forest for stepped (0.009 km per square km) and Camden for part-segregated (0.08 km per square km).

### *3.6. Estimated CID on-road cycle lane compliance with UK Cycle Infrastructure Design Guidance*

Compliance of CID on-road cycle lanes with UK Cycle Infrastructure Design Standard LTN 1/20 (DfT, 2020a) was estimated using degree of separation from motor vehicles and road speed limit data. This revealed 20% of the total length of CID on-road cycle lanes were compliant (196.4 km). 59% of length was not compliant (565.8 km) and compliance was unknown (due to missing speed limit data) in 21% (197.5 km) (Table A8). This demonstrates that whilst the physical separation from motor vehicles is modest (only 6% of CID cycle lane length is physically segregated), the separation can be appropriate if the road speed limit is low.

There are clear spatial patterns to compliance (Fig. 7). Compliant cycle lanes (purple) tend to be in inner London and follow the strategic cycling infrastructure whilst non-compliant lanes (turquoise) are distributed throughout London. Those where compliance is unknown are mainly located in outer London reflecting the low availability of OpenStreetMap speed limit data in these areas. Hammersmith and Fulham has the greatest compliance (65%) whilst Harrow has the least (2%, Table A8). Less than one percent of cycle lanes in shared bus lanes are compliant (Figure A2) which is unsurprisingly since these tend to have no separation (Figure A1). If we focus on those cycle lanes with known speed limits then the mean borough estimated compliance is 22% with 64% (9/14) of inner but only 16% (3/20) of outer London boroughs exceeding this mean (Fig. 7, right). Even if we remove cycle lanes in shared bus lanes (mean compliance 32%) the proportions exceeding the mean only change for outer London (21%, 4/19, Figure A3). Kensington & Chelsea and Wandsworth have low levels of estimated compliance despite having high levels of commuting cycling (Fig. 5, column 4) and conversely Ealing, Waltham Forest and Bexley have high levels of compliance despite having low levels of commuting cycling.

## 4. Discussion

### *4.1. Summary of findings*

Analysis of the CID shows that the quantity and quality of infrastructure is not equal across London. Boroughs vary in their provision with none having consistently high or low levels of all types. Outer London has less infrastructure providing safe space for cycling than inner London. This pattern persists even when normalised for area and population but is inverted when normalised for commuter cycling. Traffic calming is the most common infrastructure type whilst cyclist signals are absent in 30% of boroughs. Just six percent of on-road cycle lane length is physically segregated and this is predominantly found in inner London. Estimated compliance with the appropriate level of protection for cyclists in cycle lanes (LTN 1/20) is greatest in inner London where 64% of inner London boroughs exceed the mean compliance of 22% compared to 16% of outer London boroughs. Estimated compliance is greater than perhaps the modest levels of physical segregation would predict due to low road speed limits making non-physical separation acceptable.

### *4.2. Interpretation of key findings*

High levels of traffic calming measures, particularly in residential areas, are unsurprising given their role is protecting all road users rather than just cyclists (Elvik, 2001). The absence of cyclist signals in many boroughs and the low levels of these and ASL is concerning as junctions are known to be especially risky for cyclists in London (Adams and Aldred, 2020; Aldred et al., 2018). This variation in provision may be explained by historical infrastructure design guidance, where traffic calming was prioritised (DfT, 2008; Golbuff and Aldred, 2011), coupled with their lower costs - £10,000 - £15,000 per kilometre for traffic calming versus £0.24 - £1.61 million for junction remodelling and £1.45 million per km for fully segregated cycle lanes (Taylor and Hiblin, 2017).

Given these high costs, it is unsurprising that London's on-road cycle lane provision is low with little segregation for cyclists. Only 6.4% of London's total road length contains CID cycle lanes (944 km out of 14,754 km non-motorway highways) with just 0.4% physically segregated from motor vehicles and only 1.3% compliant with LTN 1/20 (DfT, 2020d). Whilst comparisons are challenging due to limited detailed infrastructure data, some cities have a much greater provision. For example, Seville, a city with a similar population density, has 164 km of segregated cycle lanes (Marqués et al., 2015) compared to just 56 km in London. Such segregation is important, preferred by many users (Aldred et al., 2017) and reduces the risk of cyclist injury (Adams and Aldred, 2020).

The greater provision of dedicated cycling infrastructure in certain boroughs and inner London could be explained by several factors. Central London has a concentration of functions, institutions and businesses whose population increases by 80% daily (Brown et al., 2020). Therefore, centrally located boroughs or those that facilitate transportation into central London, for example, Lambeth being orientated north-south into the centre, have been the focus of historical and current road and infrastructure development (Di Gregorio and Palmieri, 2016). However, this pattern is not the same for every inner London borough, for example, Kensington & Chelsea is a central London borough but has low levels of normalised infrastructure, segregation and compliance. Boroughs are autonomous political and highway entities and, as such, politics, priorities and investment influence their cycling infrastructure development (Deegan and Parkin, 2011; Deegan, 2016). For example, certain boroughs have had low engagement with cycling infrastructure (e.g. Kensington & Chelsea, Barnet) whilst others have focussed on specific infrastructure such as segregated routes (e.g. Tower Hamlets) (Deegan, 2016). This potentially explains the low LTN 1/20 compliance of Kensington & Chelsea compared to the high compliance of Tower Hamlets. Borough priorities such as traffic calming through speed limit reduction may have also affected compliance. For example, Ealing (outer London) has high LTN 1/20 compliance despite low cycle lane segregation due to a high density of 20 mph speed limits. Investment in borough cycling infrastructure is unequal (Martin et al., 2021) and usually subject to bidding processes (London Councils, 2014; Mayor's Question Time, 2020a). Finally, implementing cycling infrastructure can require engagement and collaboration between multiple highway authorities that can be difficult to achieve and may result in variable implementation (Deegan and Parkin, 2011). These aforementioned factors all contribute to the variation in infrastructure provision in London.

### 4.3. *Strengths and limitations*

This study provides the first systematic description and use of the CID with method development to influence policy and planning. Given its granularity, completeness and open-access nature, the CID is a highly valuable dataset for analysing cycling infrastructure. We demonstrated that normalisation of absolute infrastructure to borough area, population and cycle commuting enabled fairer comparison than absolute raw data. We have shown that this dataset, particularly when combined with geographical and demographic data, can generate new insights into cycling infrastructure quantity and quality and be used to compare administrative units within London. Developing an approach to combine the CID with other data has demonstrated that it can be used to evaluate infrastructure. Analysis at this level means that our findings can be meaningful to local government who can implement change as well as presenting an overview for those working strategically across London. Our supporting GitHub repository contains all the code used in the analysis (https://github.com/PublicHealthDataGeek/London_CID_analysis) and our CycleInfraLnd R package is freely available (Tait and Lovelace, 2019) . This enables other researchers or interested parties to access and utilise the CID data or our methods in their work in addition to facilitating transparency and reproducibility.

The main CID limitation is the last survey date being September 2, 2019 so it does not reflect infrastructure changes that have occurred since, for example, soon-to-be-completed MiniHolland programmes (DfT, 2020e) and COVID-related infrastructure (TfL, 2020b). The ONS borough population and commuter cycling estimates from the PCT use 2011 Census data. The commuter cycling estimates are based on individual origin-destination data providing road segment level granularity. However, cycling levels increased by 24% from 2012 to 2017 (TfL, 2018) and changed substantially during the COVID-19 pandemic (DfT, 2022). Furthermore, commuter cycling does not reflect leisure and non-commuting cycling and our assumption of bi-directional commuting cycling may result in overestimation, particularly in winter. These limitations could be overcome in future work by incorporating any new cycling and by developing a new approach to estimate multipurpose cycling participation at a borough-level.

Regarding the LTN 1/20 compliance estimates, our road speed limit data was obtained from OpenStreetMap but this may be unreliable. As Volunteered Geographical Information it is subject to quality issues and biases (Basiri et al., 2019) and known to be more complete in urban areas (Haklay, 2010) - something that our research also found. London road speed limits have changed since 2019 with most boroughs now having 20 mph speed limits on the majority of roads (Mayor's Question Time, 2020b). LTN 1/20 compliance guidance indicates that speed limit exceedance and motor vehicle flow should be considered. Unfortunately, data on actual road speeds and motor vehicle flow is not available at a granular level. This may have resulted in over-estimating compliance for mandatory and advisory cycle lanes and under-estimating compliance for cycle lanes with no separation. Furthermore, our buffering method and spatial joins could have misattributed speed limit data that may have affected whether a cycle lane could be compliant or not.

Whilst enabling comparison, aggregating data to administrative boroughs loses granularity and fails to capture the diversity within smaller spatial units. For example, Waltham Forest has a MiniHolland scheme introduced that has increased cycling (Aldred et al., 2019, 2021) but it fails to stand out as a borough in our results. Using aggregated spatial data does introduce two issues (Stewart Fotheringham and Rogerson, 1993). Firstly, borough boundaries are fixed but artificial and may not capture other factors influencing cycling infrastructure location e.g. main roads and cyclist route preferences. Secondly, infrastructure in one borough may influence infrastructure in another, for example, a junction located on a borough boundary.

### 4.4. *Implications and future research*

Accurate data on the location, type and characteristics of physical cycling infrastructure such as that provided by the CID is vital for research, policy and planning. The CID addresses issues previously identified in the literature on infrastructure datasets by providing complete, consistent, accurate, detailed, relevant and open-access cycling infrastructure data. Our paper provides the first estimates of compliance with official guidance for on-road cycle lane quality at the UK local government and, as far as we are aware, worldwide level. This highlights the need for more research into different guidance and compliance between cities at national and international levels, with reference to established principles of cycling infrastructure design (Parkin, 2018). Future research could combine the CID with additional datasets such as road traffic crashes, road characteristics, improved estimates of cycling participation, population and routing data. This means it has the potential to examine: the impact of infrastructure on cyclist safety and participation; compliance with other infrastructure design standards; the quality of cycle routes and networks; and inequalities and inequities in infrastructure provision, thus influencing transport and health policy.

We recommend that open inventories of cycling infrastructure such as the CID be considered a critical infrastructure asset in a similar way to other transport assets (Hall, 2019; Schooling et al., 2020). We advocate that open data on all new cycling infrastructure be captured in electronic format using the specification developed by TfL in conjunction with LTN 1/20 and should additionally include date of infrastructure implementation and two-dimensional geometry. This data standard should be mandated as a requirement to secure government funding (LTN 1/20 compliance is a requirement for government funding (DfT, 2020f)). Furthermore, we advocate that comprehensive, granular open data is available for road speed limits, actual road speeds and road traffic volumes.

Aspirations to increase cycling participation, particularly in areas of lower cycling such as outer London, are unlikely to be successful without an increase in infrastructure that promotes safe space for cycling both in quantity and quality. Ambitions to increase equity in cycling are unlikely to be achieved without an increase in infrastructure that supports more people to cycle (Le Gouais et al., 2021), such as physically segregated (Aldred et al., 2017) or LTN 1/20 compliant cycle lanes. Furthermore, opportunities to build on positive cycling changes seen during the COVID pandemic are unlikely to be maximised without concerted focus on high quality, cycling infrastructure. Knowing what cycling infrastructure exists and where, through collecting and analysing infrastructure data, can help realise these goals.

## 5. Conclusions

This is the first detailed description and analysis of a new, open and comprehensive dataset of cycling infrastructure in London, UK. Examining spatial patterns in infrastructure provision by London borough, we identified inequalities between boroughs even after considering relevant contextual factors such as borough size, population and amount of commuter cycling. When judged against compliance with UK Cycle Infrastructure Design Standards, only 20% (196.4 km) of London's cycle lanes were estimated to be compliant. This varies by borough but is higher in inner London. We have demonstrated that the CID (and thus other such datasets) can be used to evaluate cycling infrastructure quantitatively and qualitatively and highlight areas for intervention. This will enable greater research and more evidence-based policies and interventions to achieve goals in increasing cycling participation and equity. Furthermore, cycling research in general can benefit from such data to expand the evidence-base on cycling participation and equity. Open data on cycling infrastructure should be considered as a 'digital infrastructure asset' that is key to guiding sustainable transport and health policies.

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## Author statement

Caroline Tait - Conceptualization, Methodology, Software, Validation, Investigation, Data curation, Formal analysis, Visualization, Writing - Original Draft, Writing - Review and Editing. Dr Roger Beecham - Supervision. Dr Robin Lovelace - Supervision. Dr Stuart Barber - Supervision.

## Acknowledgments and Licenses

We would like to acknowledge CycleStreets as the PhD partner for the Doctoral Training Postgraduate Studentship. TfL data: Powered by TfL Open Data. Contains OS data © Crown copyright and database rights 2016 and Geomni UK Map data © and database rights [2019]. ONS data: Contains public sector information licensed under the Open Government Licence v3.0. OpenStreetMap data: Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org and contains Ordnance Survey data © Crown copyright and database right 2010-19. London squared data for spatial visualisation: Copyright 2019 After the Flood Ltd.

## Declaration of competing interest

No declared conflicts of interest.

## Data availability

The analysis code is available at https://github.com/PublicHealthDataGeek/London_CID_analysis. Data is open data.

## Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.jth.2022.101369.

## Appendix

**Table A.1**
Number of Advanced Stop Line feeder lanes

| Number of feeder lanes | Count |
|---|---|
| 1 | 1786 |
| 2 | 7 |

**Table A.2**
Detailed characterisation of Advanced Stop Lines using CID variables

| Total number | Characteristic | Number (% [a]) | Additional characteristics |
|---|---|---|---|
| 1568 | No characteristics | 1568 (100.0) | Not applicable |
| 1783 | Feeder lane present | 1 (0.06) | None |
| | | 1067 (59.8) | Feeder lane on left |
| | | 45 (2.5) | Feeder lane in centre |
| | | 15 (0.8) | Feeder lane on right |
| | | 1 (0.06) | Feeder lane on left and in Centre |
| | | 3 (0.2) | Feeder lane on left and Right |
| | | 609 (34.2) | Feeder lane on left and Coloured |
| | | 30 (1.7) | Feeder lane in centre and Coloured |
| | | 8 (0.4) | Feeder lane on right and Coloured |
| | | 2 (0.1) | Feeder lane on left, in Centre and Coloured |
| | | 1 (0.06) | Feeder lane on left, Right and Coloured |
| | | 1 (0.06) | Coloured |
| 1695 | Feeder Lane on Left | 11 (0.6) | None |
| | | 1067 (62.9) | Feeder lane present |
| | | 609 (35.9) | Feeder lane present and Coloured |
| | | 1 (0.06) | Feeder lane present and Feeder lane in Centre |
| | | 3 (0.2) | Feeder lane present and Feeder lane on Right |
| | | 2 (0.1) | Feeder lane present, Feeder lane in Centre and Coloured |
| | | 1 (0.06) | Feeder lane present, Feeder lane on Right and Coloured |
| | | 1 (0.06) | Coloured |
| 78 | Feeder Lane in Centre | 45 (64.3) | Feeder lane present |
| | | 30 (38.5) | Feeder lane present and Coloured |
| | | 1 (1.3) | Feeder lane present and Feeder lane on Left |
| | | 2 (2.6) | Feeder lane present, Feeder lane on Left, and Coloured |
| 27 | Feeder Lane on Right | 15 (55.6) | Feeder lane present |
| | | 8 (29.6) | Feeder lane present and Coloured |
| | | 3 (11.1) | Feeder lane present and Feeder lane on Left |
| | | 1 (3.7) | Feeder lane present, Feeder lane on Left and Coloured |
| 7 | Shared Nearside Lane (e.g. with buses) | 2 (28.6) | None |
| | | 5 (71.4) | Coloured |
| 1062 | Colour present [b] | 405 (38.1) | None |
| | | 5 (0.5) | Shared |
| | | 1 (0.09) | Feeder lane present |
| | | 1 (0.09) | Feeder lane on Left |
| | | 30 (2.8) | Feeder lane present and in Centre |
| | | 8 (0.8) | Feeder lane present and on Right |
| | | 609 (57.3) | Feeder lane present and on Left |
| | | 2 (0.2) | Feeder lane present, on Left and in Centre |
| | | 1 (0.09) | Feeder lane present, on Left and Right |

[a] Percentage calculated within characteristic group.

[b] Actual colour is specified in the CID but for this table we indicate whether colour is present or not.

**Table A.3**
Detailed characterisation of crossings using CID variables

| Total number | Characteristic | Number (% [a]) | Additional characteristics |
|---|---|---|---|
| 224 | No characteristics | 224 (100.0) | None |
| 1520 | Signal-controlled Crossing | 1348 (88.7) | None |
| | | 100 (6.6) | Cyclist segregation |
| | | 2 (0.13) | Gap in island/kerb allowing cyclists through |
| | | 25 (1.6) | Pedestrian-Only Crossing (cyclists dismount) |
| | | 45 (3.0) | Cyclist segregation and Gap in island/kerb |
| 338 | Cyclists segregated from other users | 121 (35.8) | None |
| | | 72 (21.3) | Gap in island/kerb allowing cyclists through |
| | | 100 (29.6) | Signal-controlled |

(*continued on next page*)

**Table A.3** (*continued*)

| Total number | Characteristic | Number (% [a]) | Additional characteristics |
|---|---|---|---|
| | | 45 (13.3) | Signal-controlled and Gap in island/kerb |
| 134 | Gap in island/kerb allowing cyclists through | 15 (11.2) | None |
| | | 2 (1.5) | Signal-controlled |
| | | 72 (53.7) | Cyclist segregation |
| | | 45 (33.6) | Cyclist segregation and Signal-controlled |
| 48 | Pedestrian-Only Crossing (cyclists dismount) | 17 (35.4) | None |
| | | 25 (52.1) | Signal-controlled |
| | | 6 (12.5) | Crossing over rail or tram tracks |
| 21 | Crossing over rail or tram tracks | 15 (71.4) | None |
| | | 6 (28.6) | Pedestrian-Only Crossing (cyclists dismount) |

[a] Percentage calculated within characteristic group.

**Table A.4**
Detailed characterisation of cycle lane and track infrastructure in total and by on-road (cycle lanes) or off-road (cycle tracks) status using CID variables

| Characteristic | Total | | On road | | Off road | |
|---|---|---|---|---|---|---|
| | Count (%) | Length (%) | Count (%) | Length (%) | Count (%) | Length (%) |
| On carriageway | 13965 (55.2) | 944.0 km (32.5) | 13965 (55.2) | 944.0 km (32.5) | 11350 (44.8) | 1959.6 km (67.5) |
| Fully segregated | 1931 (7.6) | 93.7 km (3.2) | 1371 (71.0) | 39.2 km (41.8) | 560 (29.0) | 54.5 km (58.2) |
| Stepped | 104 (0.4) | 7.7 km (0.3) | 94 (90.4) | 7.1 km (91.4) | 10 (9.6) | 0.7 km (8.6) |
| Partially segregated | 3583 (14.2) | 251.1 km (8.6) | 349 (9.7) | 15.7 km (6.3) | 3234 (90.3) | 235.4 km (93.7) |
| Shared lane (buses or footway) | 10391 (41.0) | 1896.2 km (65.3) | 2845 (27.4) | 236.4 km (12.5) | 7546 (72.6) | 1659.8 km (87.5) |
| Mandatory cycle lane (painted line) | 1857 (7.3) | 95.5 km (3.3) | 1854 (99.8) | 95.5 km (100.0) | 3 (0.2) | 0 km (0.0) |
| Advisory cycle lane (painted line) | 7277 (28.7) | 490.0 km (16.9) | 7273 (99.9) | 489.2 km (99.8) | 4 (0.1) | 0.8 km (0.2) |
| Cycle lane/track has priority over other users | 2286 (9.0) | 200.9 km (6.9) | 2285 (100.0) | 200.9 km (100.0) | 1 (0.0) | 0 km (0.0) |
| Contraflow lane/track (not bi-directional) | 1493 (5.9) | 116.3 km (4.0) | 1463 (98.0) | 115.2 km (99.1) | 30 (2.0) | 1.1 km (0.9) |
| Bi-directional (two-way flow) | 10432 (41.2) | 1911.4 km (65.8) | 381 (3.7) | 26.1 km (1.4) | 10051 (96.3) | 1885.4 km (98.6) |
| Cycle bypass allowing cyclists to turn without stopping at traffic signals | 63 (0.2) | 1.6 km (0.1) | 5 (7.9) | 0.3 km (17.0) | 58 (92.1) | 1.4 km (83.0) |
| Continuous cycle facilities at bus stop | 132 (0.5) | 9.9 km (0.3) | 68 (51.5) | 4.3 km (43.6) | 64 (48.5) | 5.6 km (56.4) |
| Route through park | 4194 (16.6) | 1348.1 km (46.4) | 108 (2.6) | 30.1 km (2.2) | 4086 (97.4) | 1318.0 km (97.8) |
| Route by river, canal or water feature | 611 (2.4) | 268.0 km (9.2) | 0 (0.0) | 0 km (0.0) | 611 (100.0) | 268.0 km (100.0) |
| Part-time cycle lane/track | 2800 (11.1) | 400.9 km (13.8) | 2308 (82.4) | 188.4 km (47.0) | 492 (17.6) | 212.5 km (53.0) |
| Colour [a] | 6191 (24.5) | 419.8 km (14.5) | 4338 (70.1) | 246.3 km (58.7) | 1853 (29.9) | 173.6 km (41.3) |

[a] Actual colour is specified in the CID but for this table we indicate whether colour is present or not.

**Table A.5**
Detailed characterisation of cyclist signals using CID variables

| Total number | Characteristic | Number (% [a]) | Additional characteristics |
|---|---|---|---|
| 4 | No characteristics | 4 (100.0) | None |
| 438 | Cycle symbol on lights | 132 (30.1) | None |
| | | 186 (42.5) | Separate cyclist stage |
| | | 36 (8.2) | Early cyclist release |
| | | 8 (1.8) | Two-stage right turn |
| | | 2 (0.5) | Signal gate |
| | | 28 (6.4) | Separate cyclist stage and Early cyclist release |
| | | 16 (3.7) | Separate cyclist stage and Two-stage right turn |
| | | 15 (3.4) | Separate cyclist stage and Signal gate |
| | | 3 (0.7) | Early cyclist release and Two-stage right turn |
| | | 1 (0.2) | Early cyclist release and Signal gate |
| | | 10 (2.3) | Separate cyclist stage; Early cyclist release and Signal gate |
| | | 1 (0.2) | Separate cyclist stage; Early cyclist release and Two-stage right turn |

(*continued on next page*)

**Table A.5** (*continued*)

| Total number | Characteristic | Number (% [a]) | Additional characteristics |
|---|---|---|---|
| 256 | Separate stage for cyclists | 186 (72.6) | Cycle symbol on lights |
| | | 28 (10.9) | Cycle symbol on lights and Early release for cyclists |
| | | 16 (6.3) | Cycle symbol on lights and Two-stage right turn |
| | | 15 (5.9) | Cycle symbol on lights and Signal gate |
| | | 10 (3.9) | Cycle symbol on lights; Early cyclist release and Signal gate |
| | | 1 (0.4) | Cycle symbol on lights; Early cyclist release and Two-stage right turn |
| 80 | Early release for cyclists | 1 (1.3) | None |
| | | 36 (45.0) | Cycle symbol on lights |
| | | 28 (35.0) | Cycle symbol on lights and Separate cyclist stage |
| | | 10 (12.5) | Cycle symbol on lights; Separate cyclist stage and Signal gate |
| | | 1 (1.3) | Cycle symbol on lights; and Signal gate |
| | | 3 (3.8) | Cycle symbol on lights; and Two-stage right turn |
| | | 1 (1.3) | Cycle symbol on lights; Separate cyclist stage and Two-stage right turn |
| 28 | Two-stage right turn | 8 (28.6) | Cycle symbol on lights |
| | | 3 (10.7) | Cycle symbol on lights and Early cyclist release |
| | | 16 (57.1) | Cycle symbol on lights and Separate cyclist stage |
| | | 1 (3.6) | Cycle symbol on lights; Separate cyclist stage and Early cyclist release |
| 28 | Signal gate | 2 (7.1) | Cycle symbol on lights |
| | | 15 (53.6) | Cycle symbol on lights and Separate cyclist stage |
| | | 1 (3.6) | Cycle symbol on lights and Early cyclist release |
| | | 10 (35.7) | Cycle symbol on lights; Separate cyclist stage and Early cyclist release |

[a] Percentage calculated within characteristic group.

**Table A.6**
Detailed characterisation of traffic calming using CID variables

| Total number | Characteristic | Number (% [a]) | Additional characteristics |
|---|---|---|---|
| 12 | No characteristics | 12 (100.0) | None |
| 33271 | Hump | 26948 (81.0) | None |
| | | 6319 (19.0) | Sinusoidal shape |
| | | 1 (0.0) | Road narrowing |
| | | 3 (0.0) | Side entry treatment |
| 12626 | Cushion | 12217 (96.7) | None |
| | | 400 (3.2) | Sinusoidal shape |
| | | 8 (0.06) | Road narrowing |
| | | 1 (0.01) | Sinusoidal shape and Road narrowing |
| 7581 | Side entry treatment | 7576 (99.9) | None |
| | | 3 (0.04) | Hump |
| | | 2 (0.03) | Raised table at junction |
| 2772 | Raised table at junction | 2770 (99.9) | None |
| | | 2 (0.07) | Side entry treatment |
| 935 | Barrier | 935 (100.0) | None |
| 662 | Narrowing | 652 (98.5) | None |
| | | 8 (1.2) | Cushion |
| | | 1 (0.2) | Sinusoidal cushion |
| | | 1 (0.2) | Hump |
| 721 | Other traffic calming measure | 721 (100.0) | None |

[a] Percentage calculated within characteristic group.

**Table A.7**
Borough length of CID on-road cycle lanes by highest degree of separation from motor vehicles (in descending order of full segregation length)

| Borough | CID cycle lane length in kilometres | | | | | |
|---|---|---|---|---|---|---|
| | Full segregation | Stepped | Part segregation | Mandatory cycle lane | Advisory cycle lane | No separation |
| Tower Hamlets [a] | 6.012 | 0.150 | 1.342 | 1.735 | 7.734 | 11.530 |
| Westminster [a] | 5.682 | 0 | 1.505 | 7.166 | 7.021 | 12.681 |
| City of London [a] | 3.077 | 0 | 0.140 | 2.205 | 6.347 | 9.063 |
| Southwark [a] | 3.037 | 0 | 0.516 | 5.133 | 9.802 | 21.861 |
| Camden [a] | 2.836 | 0 | 1.804 | 3.883 | 8.01.0 | 19.278 |
| Lambeth [a] | 2.829 | 0 | 0.627 | 3.378 | 13.714 | 29.057 |
| Islington [a] | 1.998 | 0 | 0.126 | 1.577 | 10.547 | 16.392 |
| Kingston upon Thames | 1.697 | 0.026 | 0.044 | 1.017 | 22.747 | 3.288 |
| Bexley | 1.520 | 0 | 0.161 | 0.358 | 9.143 | 2.654 |
| Newham [a] | 1.507 | 0 | 0.190 | 4.369 | 17.570 | 7.471 |
| Greenwich [a] | 1.005 | 0 | 1.140 | 4.294 | 17.953 | 7.812 |
| Merton | 0.861 | 0 | 0.146 | 2.627 | 12.085 | 5.193 |
| Hackney [a] | 0.723 | 0 | 0.010 | 0.576 | 7.511 | 24.008 |
| Ealing | 0.708 | 0 | 0.404 | 2.312 | 23.072 | 12.334 |

(*continued on next page*)

**Table A.7** (*continued*)

| Borough | CID cycle lane length in kilometres | | | | | |
|---|---|---|---|---|---|---|
| | Full segregation | Stepped | Part segregation | Mandatory cycle lane | Advisory cycle lane | No separation |
| Hounslow | 0.683 | 0 | 0.070 | 3.572 | 22.636 | 6.594 |
| Hammersmith & Fulham [a] | 0.513 | 0 | 0.071 | 0.136 | 20.876 | 10.227 |
| Lewisham [a] | 0.498 | 0 | 0.057 | 0.687 | 7.141 | 18.856 |
| Havering | 0.470 | 0.169 | 0.009 | 0.499 | 19.401 | 4.828 |
| Wandsworth [a] | 0.454 | 0 | 0.143 | 3.456 | 16.853 | 13.081 |
| Bromley | 0.386 | 0 | 0.024 | 3.242 | 15.317 | 2.398 |
| Haringey | 0.368 | 0 | 0.272 | 1.606 | 5.744 | 15.239 |
| Croydon | 0.354 | 0 | 0.163 | 2.859 | 42.05 | 12.906 |
| Enfield | 0.349 | 0 | 4.303 | 3.307 | 3.466 | 5.563 |
| Hillingdon | 0.288 | 0 | 0.008 | 2.454 | 13.301 | 4.851 |
| Barnet | 0.282 | 0 | 0.007 | 2.923 | 1.488 | 1.888 |
| Barking & Dagenham | 0.234 | 0 | 0.154 | 5.023 | 36.738 | 7.205 |
| Waltham Forest | 0.180 | 0.367 | 0.747 | 2.392 | 29.481 | 11.08 |
| Sutton | 0.179 | 0 | 0.098 | 0.471 | 3.583 | 1.501 |
| Redbridge | 0.167 | 0 | 0 | 0.248 | 23.365 | 0.755 |
| Kensington & Chelsea [a] | 0.147 | 0 | 0.022 | 2.838 | 5.191 | 4.280 |
| Harrow | 0.064 | 0 | 0.307 | 0.043 | 29.325 | 2.255 |
| Richmond upon Thames | 0.048 | 0 | 0 | 8.375 | 12.449 | 3.453 |
| Brent | 0.021 | 0 | 1.110 | 0.508 | 5.382 | 6.513 |

[a] Inner London boroughs.

**Table A.8**

Estimated borough compliance of CID on-road cycle lanes with LTN 1/20 (in descending order of Compliant percentage)

| Borough | Percentage (length in kilometres) | | |
|---|---|---|---|
| | Compliant | Non-compliant | Compliance unknown [b] |
| Hammersmith & Fulham [a] | 65 (21.1) | 33 (10.8) | 2 (0.6) |
| Camden [a] | 44 (16) | 54 (19.8) | 3 (0.9) |
| Tower Hamlets [a] | 49 (14.7) | 49 (14.7) | 2 (0.5) |
| Southwark [a] | 35 (14.7) | 60 (25.2) | 5 (2.1) |
| Lambeth [a] | 29 (14.6) | 67 (33.9) | 4 (1.9) |
| Islington [a] | 43 (13.4) | 56 (17.6) | 1 (0.2) |
| City of London [a] | 57 (12.2) | 43 (9.2) | 1 (0.1) |
| Ealing | 31 (12.2) | 53 (21) | 16 (6.2) |
| Waltham Forest | 26 (11.4) | 59 (26.6) | 15 (6.7) |
| Westminster [a] | 26 (9.1) | 64 (22.3) | 10 (3.4) |
| Newham [a] | 19 (6) | 72 (23) | 9 (3) |
| Lewisham [a] | 19 (5.2) | 64 (17.8) | 17 (4.8) |
| Hounslow | 14 (4.8) | 61 (20.7) | 25 (8.3) |
| Haringey | 20 (4.7) | 76 (18) | 3 (0.8) |
| Hackney [a] | 14 (4.7) | 73 (24.2) | 13 (4.5) |
| Croydon | 8 (4.6) | 87 (51.7) | 5 (2.9) |
| Greenwich [a] | 12 (3.8) | 65 (21.2) | 23 (7.4) |
| Kingston upon Thames | 11 (3.4) | 60 (17.6) | 29 (8.5) |
| Wandsworth [a] | 9 (3) | 79 (27.5) | 12 (4.2) |
| Barking & Dagenham | 6 (2.9) | 22 (11.2) | 72 (35.6) |
| Bromley | 10 (2.1) | 69 (14.9) | 21 (4.6) |
| Richmond upon Thames | 7 (1.7) | 62 (15.1) | 32 (7.8) |
| Brent | 12 (1.7) | 56 (7.7) | 32 (4.4) |
| Bexley | 12 (1.7) | 37 (5.2) | 51 (7.2) |
| Enfield | 9 (1.6) | 56 (9.7) | 34 (5.9) |
| Merton | 7 (1.4) | 74 (15.7) | 20 (4.2) |
| Havering | 4 (1.1) | 26 (6.5) | 70 (17.7) |
| Hillingdon | 3 (0.6) | 58 (12.2) | 39 (8.3) |
| Redbridge | 2 (0.6) | 61 (14.9) | 37 (9.1) |
| Kensington & Chelsea [a] | 4 (0.5) | 45 (5.6) | 51 (6.4) |
| Barnet | 6 (0.4) | 85 (5.7) | 9 (0.6) |
| Harrow | 1 (0.4) | 52 (16.7) | 47 (15.1) |
| Sutton | 6 (0.4) | 37 (2.2) | 57 (3.4) |
| TOTAL | 20 (196.4) | 59 (565.8) | 21 (197.5) |

[a] Inner London boroughs.

[b] Compliance unknown as speed limit data is not available.

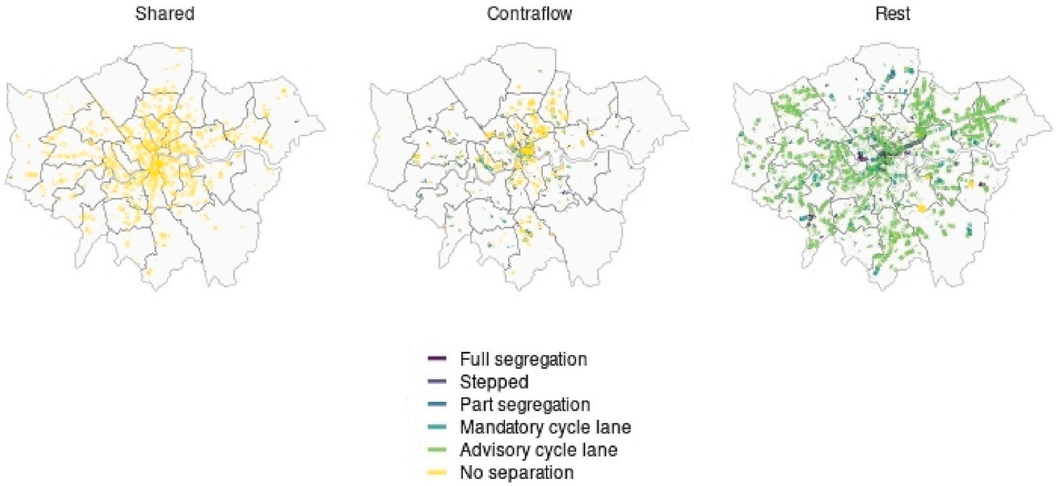

**Fig. A.1.** Degree of separation of CID on-road cycle lanes from motor vehicles by whether cycle lanes are shared, contraflow or neither ('Rest')

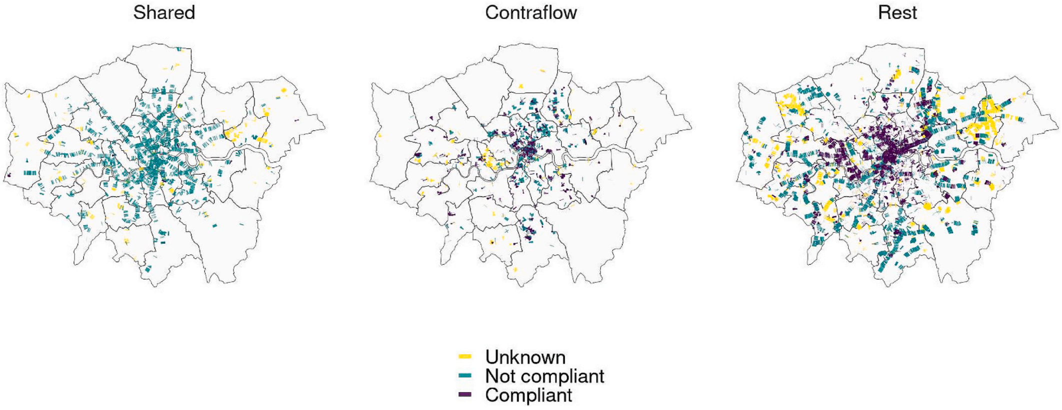

**Fig. A.2.** Estimated on-road CID cycle lane compliance with LTN 1/20 by whether cycle lanes are shared, contraflow or neither ('Rest')

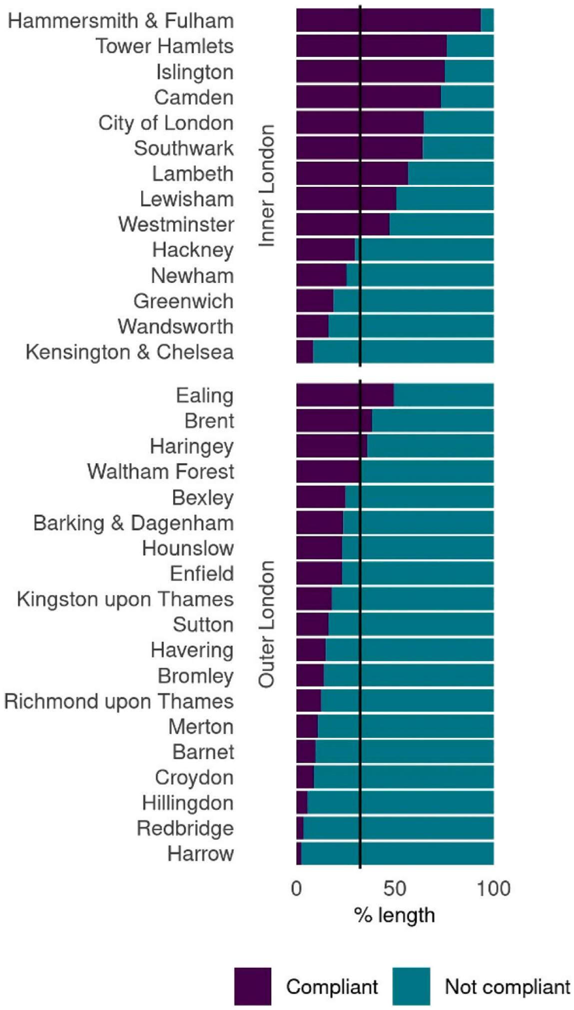

**Fig. A.3.** Estimated borough CID on-road cycle lane compliance with LTN 1/20 where speed limit is known and shared lanes are excluded (solid line = mean)

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