TRANSPORT FINDINGS

Cycling Injury Risk in London: Impacts of Road Characteristics and Infrastructure

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Keywords: road characteristics, risk, cycling, infrastructure, injury, route environment

10.32866/001c.18226

Findings

This study of cycling injury risk in London examines impacts of road characteristics and environment, including different types of cycling infrastructure. It controlled for exposure by using a case-crossover method alongside an algorithm developed by Transport for London to predict cyclist routes. When compared to no infrastructure, this study found that protected cycle infrastructure reduced odds of injury by 40-65% in the morning commute, whereas advisory lanes increased injury odds by 34%. Junctions were found to increase injury odds threefold; higher pedestrian density also increased injury odds. This study supports growing evidence of a 'safety in numbers' effect.

Research Questions

Road safety interventions have traditionally been prioritised by looking at absolute number of casualties at different locations. Whilst this helps practitioners identify dangerous locations, it will not capture the relative risk per user of different types of infrastructure or route environment.

To assess how characteristics of the route environment affect injury risk for each individual road user, we need to control for exposure (Vandenbulcke, Thomas, and Int Panis 2014; Vanparijs et al. 2015). Epidemiological methods offer ways of doing this. Case-control studies control for exposure by comparing aggregate injury locations to aggregate control locations, with control locations selected from modelled or measured flow data (Miller et al. 2017; Aldred et al. 2018; Meuleners et al. 2019).

By contrast, in case-crossover studies each person serves as their own control, reducing intrapersonal confounding. Control points are selected from a person's route prior to injury, as in Teschke et al. (2012). This study uses a similar method, however, using a cycling route prediction algorithm to generate cyclist routes rather than recall.

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Methods and Data

Britain's database for police-reported traffic incidents, Stats19, was used to identify cycle injury locations, with casualty home postcode data provided via Transport for London (TfL). Between 2016-2018, 13,700 cycling injuries were reported to police in London. After removing non-London residents and incorrect home postcodes, 11,936 injuries remained.

As we only had home postcode data rather than journey origins, we could only use injuries sustained where a person's home was likely the starting point. For the purposes of routing, their trip needed to be for utility purposes (A to B; i.e. not a weekend leisure ride which might not follow typical utility routing patterns). Morning commuter travel fits both requirements. Therefore, only collisions occurring between 7-10am on weekdays and involving people over 16 were used. This left a total of 2,876 injury points, most of which (86.7%, or 2,494) were slight injuries. 375 were serious and 7 were fatal.

Routes were predicted between home and injury locations on TfL's Cynemon network (which contains all roads and other routes that can legally be cycled) using the Network Analyst tool in ArcGIS. The route prediction tool was programmed to use Cynemon generalised costs for commuters, which places route directness above other factors such as infrastructure and traffic volumes. Cynemon is a cycling assignment model which has primarily been developed to support appraisal of cycling interventions and formation of cycling policy. As such, Cynemon can estimate cyclist routes, flows and journey times.

A control point was introduced for each 3km of a cyclist's route, i.e. 1 point for routes under 3km, 2 points for routes 3-6km. This method resulted in 5,754 control points, i.e. almost double the number of injury points - which was the target. 80% of control points were for routes under 12km (67% for under 9km). Control points were then selected at random points along the route by using the Random Point Generator tool in ArcGIS. Figure 1 shows the location of these points across Greater London.

Table 1 shows route environment datasets used and sources. Figure 2 illustrates cycling infrastructure in London, taken from the TfL Cycle Infrastructure Database, separated into different types of infrastructure, and Figure 3 provides a composite image of different facility types.

The cycling flow data uses 2016 AM peak hour (08:00-09:00) link flows from Cynemon, which have been calibrated and validated using observed counts. Aggregate temporal and seasonal factors from Strava data were applied to the Cynemon flows to increase precision and better align with the injury data. Temporal factors derived from London Travel Demand Survey (LTDS) data were applied to the pedestrian and traffic flow data. Traffic speed data was obtained from Trafficmaster via DfT: this uses data from GPS-enabled vehicles to generate average flows at peak and off-peak times.

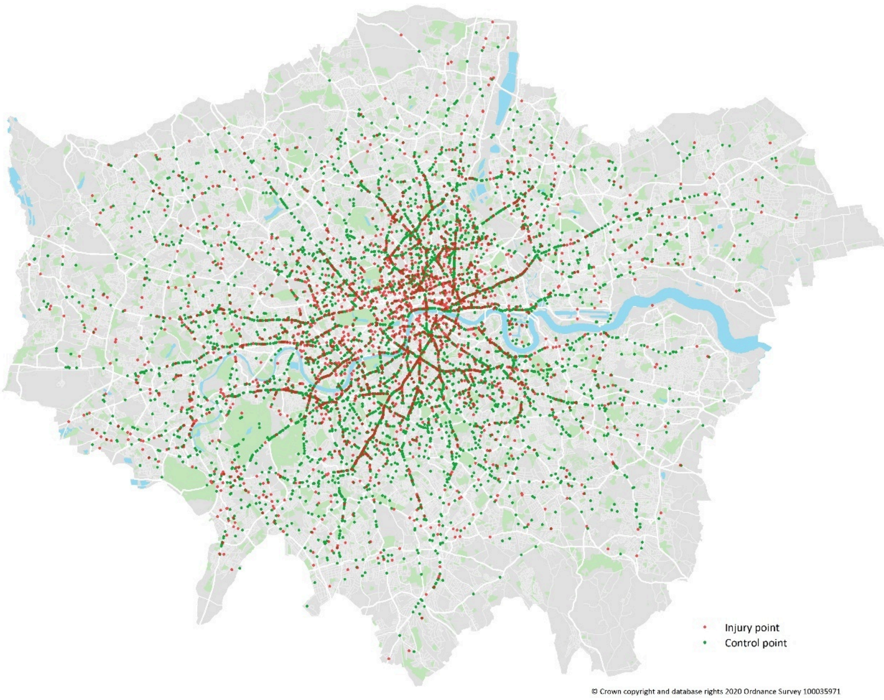

Figure 1: Control and injury points

Table 1: Data sources

Variable	Categories	Dataset (source)
Area	Central/Inner/Outer London	Greater London Authority boundary data
Road type	4 classes	ITN network (Ordnance Survey)
Intersection	yes/no	ITN network (Ordnance Survey)
Speed limit	20mph/>20mph	Digital speed limit map (TfL)
Bus lane	yes/no	Bus lane database (TfL)
Bus stop	yes/no	Bus stop database (TfL)
Speed (mph)	Log transformed morning peak speeds	Trafficmaster (DfT)
Cycle infrastructure: mandatory cycle lane, advisory cycle lane, on/off carriageway, partially or light kerb-separated cycle lane/track, kerb-separated cycle lane/track, stepped cycle lane/track	yes/no	Cycle Infrastructure Database (TfL)
Cycle flow (per hour)	Log transformed flows	Cynemon (TfL)
Traffic flow (per hour)	Log transformed flows	Highway Assignment Model (TfL)
Pedestrian density (metres walked per square metre, per hour)	Log transformed pedestrian density	LTDS (TfL)

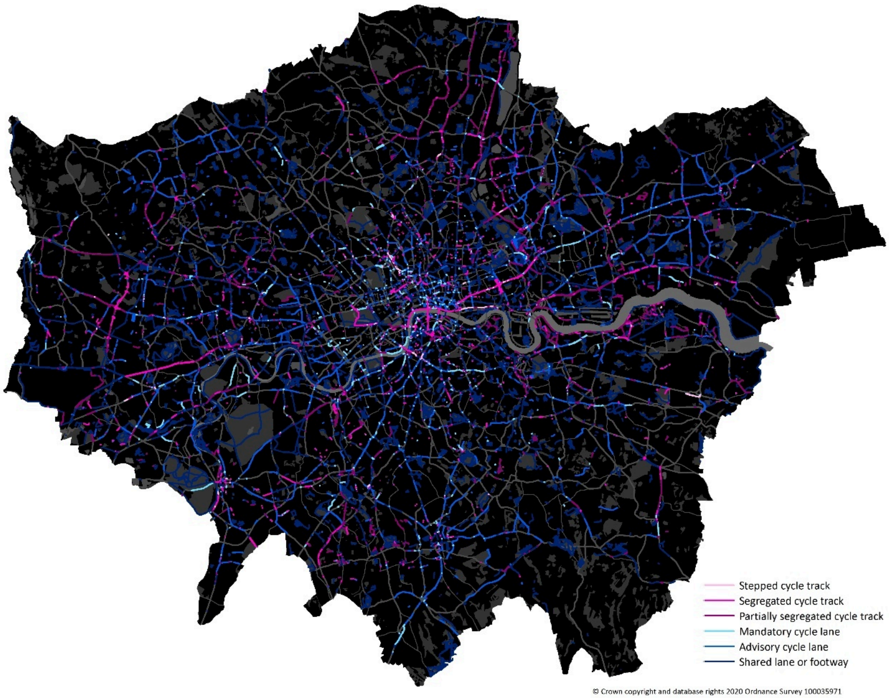

Figure 2: Cycle infrastructure in London

Figure 3: types of cycle infrastructure (source: London Cycle Design Standards)

Road classes were 'A', 'B', 'C' and 'Other'. A roads are primary roads, which include TfL-managed 'red routes', carrying up to 30% of London's traffic despite only making up 5% of roads. B roads are secondary roads, while C roads tend to connect local roads with A or B roads, and 'Other' roads include residential and private roads.

We performed statistical analysis using similar methodology to Aldred et al. (2018), with binary logistic regression modelling to predict whether a location was an injury or control point. Coefficients (odds ratios) were produced for each variable after controlling for other factors. This indicated whether the variable increased or decreased cycling injury odds and a corresponding significance level (we chose $p<0.05$ as our threshold). All analysis was undertaken in the statistical package R (https://www.r-project.org/) and the mixed-effects models were fitted using the 'glmer' function (https://www.rdocumentation.org/packages/lme4/versions/1.1-25/topics/glmer).

Findings

Table 2 provides descriptive statistics for route environment characteristics included in the final model, alongside the proportion of points for each characteristic that represent injury sites. Across all points, this proportion is 33.3%, so any value higher than this means an over-representation of injury points for that variable category.

Coefficients related to whether a point was in Inner, Outer, or Central London do not reflect differences in the 'real' risks in each area. Apparent higher risk in Inner and Central areas is an artefact of the method as control points, by definition, lie closer to home than work. Instead, we included this variable to control for possible differences between these areas not included in the table below.

Table 3 presents the results of the two models, alongside univariate odds ratios. Model 1 controlled for road characteristics whilst model 2 also controlled for road user flows (other cyclists, pedestrians, motor traffic). Variables for which $p=>0.1$ were removed before re-running the models, which made no substantive difference to results.

Cycling at intersections increases injury odds threefold. This is in line with literature on intersections (e.g. Quddus 2008; Harris et al. 2013) and the odds ratio is similar to Aldred et al's London study (2018). B roads were relatively risky compared both to residential streets and A roads. These findings differ from Teschke et al. (2012) and Aldred et al. (2018).

Kerb separated cycle infrastructure reduced injury odds substantially; by 40% compared to no infrastructure. Stepped tracks were even more protective, reducing injury odds by 65%, albeit with large confidence intervals due to low numbers (0.15-0.85, CI 95%). These findings are in line with Teschke et al. (2012) and in London, Li, Graham, and Liu (2017). By contrast, painted cycle lanes did not reduce injury. Mandatory painted lanes did not lead to any risk reduction and advisory lanes (which motor vehicles are legally permitted to enter) increased injury odds by over 30%.

Table 2: Descriptive statistics, route environment characteristics

Variable	Categories	Injury	Control	% Injury points
Area	Central	777	975	44.3%
	Inner	1298	2762	32.0%
	Outer	801	2017	28.4%
Road type	A Road	1750	3788	31.6%
	B Road	320	329	49.3%
	C Road	303	672	31.1%
	Other	503	965	34.3%
Intersection	No	544	2471	18.0%
	Yes	2332	3283	41.5%
20mph limit	No	1707	3536	32.6%
	Yes	1169	2218	34.5%
Bus lane	No	2341	4332	35.1%
	Yes	535	1422	27.3%
Bus stop	No	2745	5186	34.6%
	Yes	131	568	18.7%
Speed (miles per hour)	0-10	716	1062	40.3%
	10-20	1986	4152	32.4%
	20-30	164	491	25.0%
	30-40	10	49	16.9%
Kerb-separated cycle lane / track	No	2797	5505	33.7%
	Yes	79	249	24.1%
Partially or light separated cycle lane / track	No	2794	5556	33.5%
	Yes	82	198	29.3%
Stepped cycle lane / track	No	2869	5710	33.4%
	Yes	7	44	13.7%
Mandatory cycle lane	No	2784	5544	33.4%
	Yes	92	210	30.5%
Advisory cycle lane	No	2294	4825	32.2%
	Yes	582	929	38.5%
Cycle flow (cyclists per hour)	0-100	2081	3859	35.0%
	100-250	611	1370	30.8%
	250-500	169	456	27.0%
	>500	15	69	17.9%
Traffic flow (motor vehicles per hour)	0-250	654	1300	33.5%
	250-500	998	2003	33.3%
	500-750	574	1160	33.1%
	750-1000	334	620	35.0%
	>1000	316	671	32.0%
Pedestrian density (metres walked per square metre, per hour)	0-3	1990	4273	31.8%
	3-6	528	974	35.2%
	6-9	173	271	39.0%
	9-12	76	112	40.4%

Variable	Categories	Injury	Control	% Injury points
	>12	109	124	46.8%
All points		2876	5754	33.3%

Table 3: Predictors of cycling injury in London when commuting in the morning

Variable	Categories	Univariate OR	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Region	Central	1.00	1.00	1.00
	Inner	0.59	0.62 (0.55, 0.71)***	0.57 (0.50, 0.65)***
	Outer	0.50	0.54 (0.47, 0.63)***	0.43 (0.37, 0.51)***
Road type	A Road	1.00	1.00	1.00
	B Road	2.11	2.14 (1.79, 2,55)***	1.91 (1.59, 2.30)***
	C road	0.98	1.10 (0.94, 1.29)	1.01 (0.85, 1.20)
	Other	1.13	1.30 (1.13, 1.49)***	0.95 (0.79, 1.13)
Intersection	No	1.00	1.00	1.00
	Yes	3.23	3.02 (2.70, 3.37)***	2.96 (2.65, 3.31)***
Bus Lane	No	1.00	1.00	1.00
	Yes	1.09	0.70 (0.62, 0.80)***	0.77 (0.67,0.87)***
Bus Stop	No	1.00	1.00	1.00
	Yes	0.70	0.52 (0.42, 0.64)***	0.53 (0.43, 0.65)***
Kerb separated cycle track	No	1.00	1.00	1.00
	Yes	0.62	0.54 (0.41,0.72)***	0.60 (0.45, 0.80)***
Stepped cycle track	No	1.00	1.00	1.00
	Yes	0.82	0.29 (0.12, 0.70)**	0.35 (0.15, 0.85)*
Advisory cycle lane	No	1.00	1.00	1.00
	Yes	1.32	1.21 (1.06, 1.37)**	1.34 (1.18, 1.52)***
Traffic speed	Change per 1 log_2 increase	-	0.75 (0.67, 0.82)***	0.73 (0.66, 0.81)***
Cycle flow	Change per 1 log_2 increase	-	-	0.87 (0.84, 0.90)***
Pedestrian density	Change per 1 log_2 increase	-	-	1.06 (1.01, 1.12)*
Traffic flow	Change per 1 log_2 increase	-	-	1.04 (0.99, 1.09)'

****p < 0.001, **p < 0.01, *p < 0.05, 'p < 0.1*

Bus lanes reduced injury odds, although less than protected cycle infrastructure. Bus stops were also, surprisingly, associated with reduced risk. Perhaps they provide a respite from parked cars, which increase risk (Teschke et al. 2012) but are not included in this study.

There is evidence of a 'safety in numbers' effect as an increase in cycle flow reduced injury odds (e.g. Jacobsen 2003; Marques and Hernández-Herrador 2017; Aldred et al. 2018). The study suggests that a doubling of cyclists in the morning commute reduces cycling injury odds by 13%.

Higher pedestrian density and traffic volume increased risk, although the latter was only borderline significant. A doubling in pedestrian density increased cycling injury odds by 6%. This finding reflects the increased risk of busy high streets, town centres or business hubs.

Counterintuitively, risk decreased as speed increased. When looking at the absolute numbers it appears that roads with speeds less than 10mph are more dangerous, indicating congestion could increase risk. However, an increase in speed is likely to increase severity of a given injury (Elvik 2013).

In conclusion, cycle infrastructure on main roads and junctions must be protected (kerb separated or stepped tracks, rather than painted lanes), particularly when there is high traffic and/or pedestrian activity.

Acknowledgements

A special gratitude goes to Transport for London and the Strategic Analysis department, as this study would not have been possible without its data and support. University College London provided a platform for this research which is also appreciated.

Submitted: October 29, 2020 AEDT, Accepted: December 08, 2020 AEDT

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