Social and Environmental Determinants of Cycling Accidents Involving Fatalities and Serious Injuries

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Summary

The purpose of this study is to investigate the built and social environmental determinants of killed of seriously injured (KSI) cycling accidents in London, UK (2010-2015). Drawing on previous studies, we examined the association between KSI accidents and an extensive list of factors including: land use, road type, traffic volume, cyclist proportions, road visibility, distance to speed cameras, population density, and area-level deprivation. We found significant associations between KSI accidents and road/land use characteristics, while proximity to speed cameras protected against accidents. However, the proportion of cyclists on the road (even after controlling for the cyclist counts) did not have a protective effect, but appeared to have a detrimental impact.

KEYWORDS: cycling, accidents, road network analysis, health geography, transportation policy

1. Introduction

Policies to promote cycling has been taken up as a priority investment area for urban transformation across many local governments in Europe and North America (European Commision 2014). The benefits of cycling are well-documented in the public health literature: a review to assess the health impact of cycling found consistent scientific consensus on the strong association between cycling and fitness level and moderate benefits for the reduction of cardiovascular disease risks (Oja et al. 2011). However, cyclists also have an increased exposure to road accidents (Panis 2011), and geospatial research to investigate the social and environmental determinants of cycling accidents can help to ameliorate the risks of cycling and maximize the benefits of urban cycling policies.

To address the concern of cycling safety, our study is designed to examine the socio-environmental correlates of cycling accidents involving cyclists that were killed or seriously injured (KSI). Given that higher numbers of cyclist traffic has been cited as a significant protective factor against cycling accidents (Robinson 2005), we are particularly interested in whether cyclist traffic has a protective effect in a variety of settings. In addition to examining factors related to road/traffic characteristics,

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we also examined social factors that may impact on inhibitory control, in particular proximity to speed cameras or alcohol establishments. We have 2 research questions:

1) Is there an association between the social/environmental characteristics of the road segments and the risk of KSI cycling accidents?

2) Does proximity to alcohol selling outlets increase the risk of KSI accidents? Does proximity to speed cameras buffer against KSI accidents?

2. Methods

Cycling accidents data for the years 2005-2015 were obtained from Transport for London (TFL). TFL manages its traffic and accidents data through the ACCSTATS database, which is updated through the UK national Police accidents records. We used road segments as the unit of analysis in our study, and covered a total of n=233,549 road segments across the Greater London Area.

2.1 Dependent and Independent Variables

The outcome of our analyses is concerned with the number of KSI accidents associated with each road segment. Unlike minor accidents, KSI accidents are almost always represented in official statistics since police and ambulatory services are involved. Since KSI accidents are rare events, i.e. the majority of road segments did not have any KSI accidents (98.9%) with only 1.03% with 1 accident, and 0.07% associated with 2 or more accidents, we have created a binary outcome variable (i.e. no accidents versus at least one KSI accident).

To capture the complexity of the urban transport environment, we examine the effects of a wide range of built environmental and socio-environmental characteristics. For built environmental predictors of KSI, we include land use (i.e. green space and commercial density), road type, visibility (proxied by sinuosity), traffic volume (separate for motorcycle, car, and large goods vehicles), and the proportion of cycle traffic to motor traffic. Socio-environmental predictors included distance to speed cameras, alcohol establishments, the Index of Multiple Deprivation, and population density.

2.2 GIS

Utilising ArcGIS, we began by removing motorways from our road network because no cycling occurs on them. Each segment was assigned the traffic counts of the traffic monitoring point that it was closest to based on Euclidean distance. Euclidean distance was also utilised for the proximity to a speed camera variable and was calculated based on the centroid of each line segment. Sinuosity, which is the measure of the deviation of a line from the shortest path, was determined by dividing the total length of a segment by its shortest path. Buffers of 750 meters were created around each individual segment and used as the area of observation to calculate the area in square meters of green space around each segment as well as a count of alcohol and commercial establishments. Population density was calculated for each individual LSOA, and along with the Index of Multiple Deprivation ranking was joined to the road network. The final step was spatially joining the KSI accidents to the road segment they occurred on.

2.3 Statistical Analyses

Since our unit of analysis are not spatially independent (e.g. road segments are clustered into neighbourhoods that are affected by a common set of neighbourhood attributes such as land use, social deprivation, population density, or traffic volume), multilevel modelling is used to account for the spatial autocorrelation of KSI. In our multilevel model, our level 1 units (233,549 road segments) are nested within level-2 groups (neighbourhoods proxied by 4671 UK census LSOAs for the Greater London Area), and random intercepts are included that allow each neighbourhood context to vary (Larsen & Merlo 2005). Given that the dependent variable has a binomial distribution, where probability of getting one or more KSI accident can be modelled using multilevel logistic regression (through a logit link function) summarized as

$$log[\frac{p_{ij}}{1-p_{ij}}] = (\beta_0 + u_{0j}) + \beta_1 X_{ij} + \varepsilon$$

where the i^{th} road segment is nested in the j^{th} neighbourhood, β_0 is the intercept (with u_{oj} random intercept), and β_1 is the slope of road-segment specific independent variable X. Quartiles were created for two-wheeled motor vehicles, cars, large goods vehicles, proximity to speed cameras, sinuosity, green space, population density and proportion of cyclists to motor traffic, while a z-score was calculated for the number of alcohol and commercial establishments. The models were estimated using the *lme4* library in RStudio with the *glmer* package.

3. Results

Over the period of 2004-2015, 4733 KSI accidents were recorded across the Greater London Area. The availability of data narrowed our study focus to the last 5 years of monitoring, which had 2552 KSI accidents (Figure 1), this ensured temporal compatibility of accidents with the road network and its attributes. Nesting based on spatial neighbourhoods demonstrated that there are significant differences between LSOAs. 38.62% of the variation in KSI accidents is attributable to the LSOA effect. Table 1 summarises the results of the multilevel logistic regression model which identified the environmental and social factors associated with serious cycling accidents. After controlling for the length of road segments and number of cyclists on each segment, KSI accidents were found in roads that 1) had higher levels of 2-wheeled motor traffic, 2) had curvier roads (low sinuosity), 3) were adjacent to high amounts of green space, 4) were adjacent to areas with high population density, 5) were adjacent to high level of commercial density, 6) were dual carriageways (as opposed to single carriageways), 7) had low traffic of large goods vehicles, 8) were further away from speed cameras, and 9) higher proportions of cyclist to motor vehicles traffic. There was no significant association between area-level socioeconomic status (i.e. the Index of Multiple Deprivation) and the presence of alcohol establishments with KSI accidents, so they were removed from the final model. See Figure 2 for forest plot of odds ratios for selected factors.

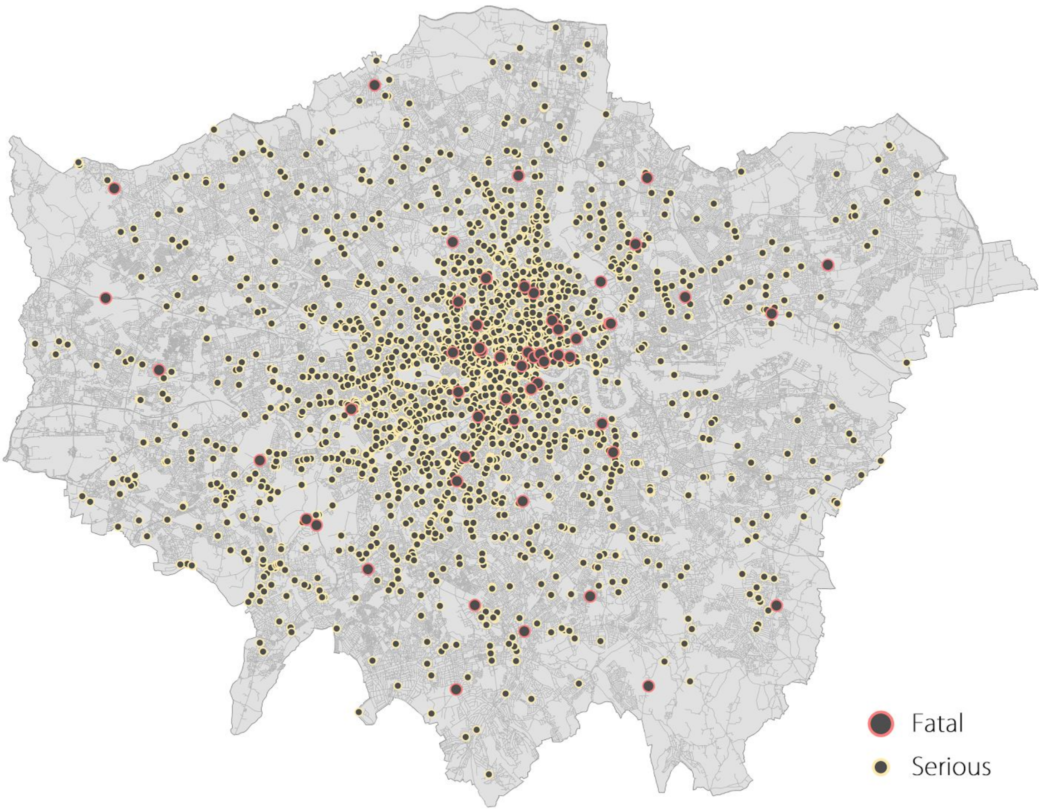

Figure 1 Location of KSI Cycling Accidents, 2010 - 2015

Table 1 Multilevel Logistic Regression Model: factors associated with serious cycling accidents

	Odds Ratio	Std. Error	Pr(>|z|)	
(Intercept)	0.00	0.15	< 0.0001	***
Nature: Enclosed Traffic Area Link	0.00	< 0.0001	0.97	
Nature: Roundabout	0.85	0.17	0.34	
Nature: Single Carriageway	0.41	0.07	< 0.0001	***
Nature: Slip Road	0.93	0.18	0.67	
Nature: Traffic Island Link	0.46	0.19	0.00	***
Nature: Traffic Island Link At Junction	0.80	0.11	0.03	*
Length	1.00	0.00	< 0.0001	***
Two-Wheeled Motor Vehicles - Q2	1.49	0.12	0.00	**
Two-Wheeled Motor Vehicles - Q3	2.35	0.15	0.00	***
Two-Wheeled Motor Vehicles - Q4	2.76	0.17	0.00	***
Cars - Q2	1.03	0.12	0.80	
Cars - Q3	0.98	0.15	0.88	
Cars - Q4	0.91	0.17	0.60	
Large Goods Vehicles - Q2	0.69	0.15	0.02	*
Large Goods Vehicles - Q3	0.74	0.18	0.10	.
Large Goods Vehicles - Q4	0.78	0.21	0.22	
Proximity to Speed Camera - Q2	0.85	0.06	0.00	**
Proximity to Speed Camera - Q3	0.81	0.06	0.00	**
Proximity to Speed Camera - Q4	0.70	0.08	0.00	***
Sinuosity - Q2	1.74	0.06	< 0.0001	***
Sinuosity - Q3	1.36	0.06	0.00	***
Sinuosity - Q4	0.00	< 0.0001	0.95	
Green Space - Q2	0.92	0.06	0.15	
Green Space - Q3	0.87	0.06	0.03	*
Green Space - Q4	1.17	0.06	0.01	**
Population Density - Q2	0.99	0.09	0.87	
Population Density - Q3	1.30	0.08	0.00	**
Population Density - Q4	1.66	0.08	0.00	***
Commercial Locations - z score	1.13	0.02	0.00	***
Proportion of Cyclists to Motor Traffic - Q2	1.80	0.10	0.00	***
Proportion of Cyclists to Motor Traffic - Q3	2.56	0.10	< 0.0001	***
Proportion of Cyclists to Motor Traffic - Q4	4.16	0.10	< 0.0001	***
Log Number of Cyclists	1.00	0.00	0.75	

Reference group is Nature: Dual Carriageway and the first quartile for all other variables. Quartiles are ranked from the lowest values in Quartile 1 to the highest values in Quartile 4.

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

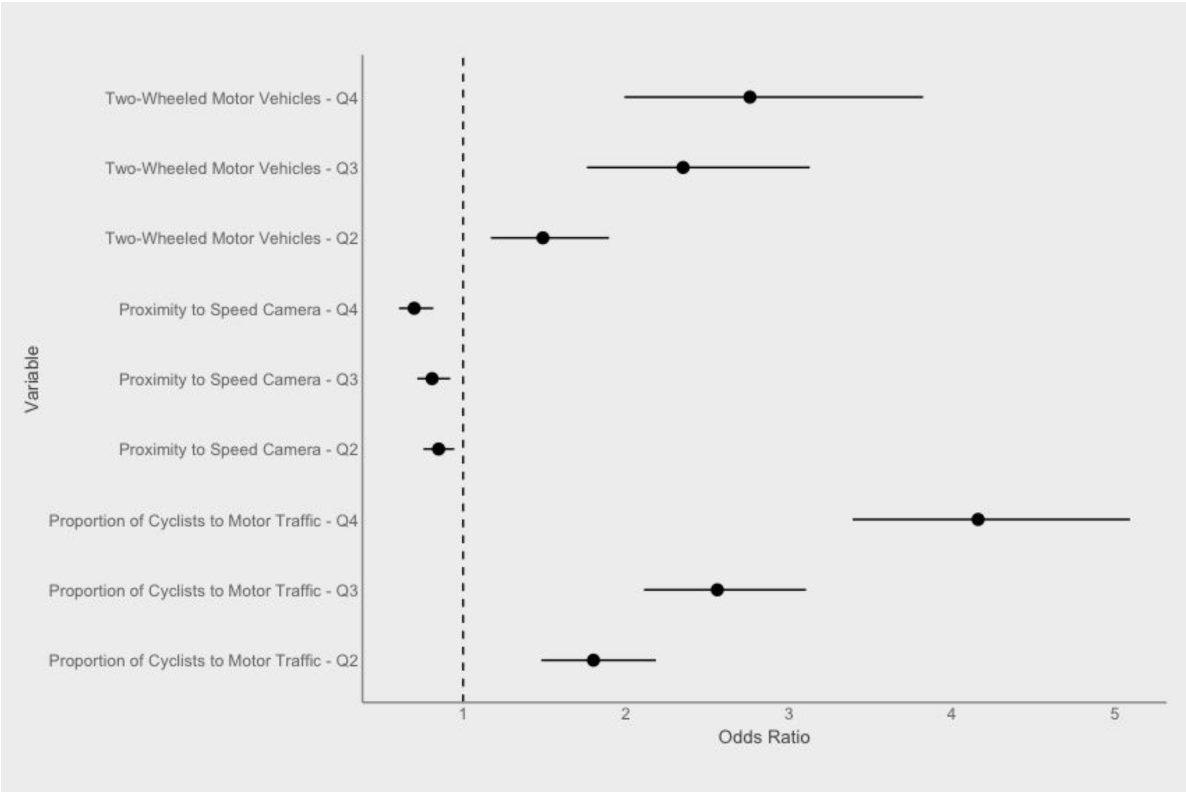

Figure 2 Odd ratios of at least 1 KSI accident with 95% confidence interval (dotted line) for selected social and environmental factors (all variables are compared to reference group, Q1)

4. Discussion and Future Work

Our study has identified road characteristics (i.e. dual carriageways, high sinuosity, and high two-wheeled motor vehicle traffic) and land use characteristics (i.e. high commercial and population density) associated with increased risk of KSI accidents (Figure 3). Proximity to speed cameras was also associated with reduced risk of KSI accidents. These socio-environmental characteristics point to the potential for novel urban design interventions to reduce KSI accidents. For example, increasing the use of speed cameras on dual carriageway roads.

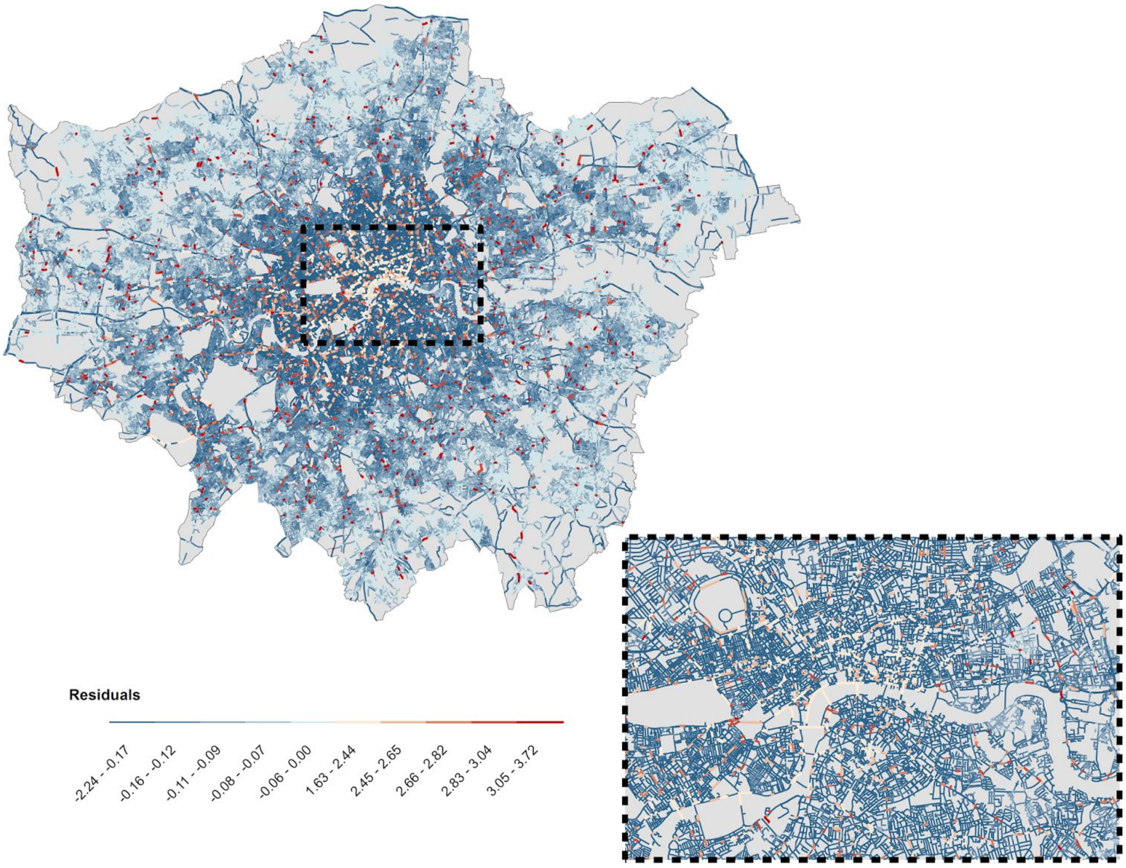

Figure 3 Residual value per road segment based on the results of the model, zoomed into Central London for clarity

The significance in the relationship between two-wheeled motor vehicle traffic and KSI accidents has important implications for policy-makers. There are a large number of companies in London that specialise in delivery and courier services, especially in the food service industry, and this number is continuing to grow. Most of these companies employ free-lance motorcyclists and in the United Kingdom a provisional licence is enough in order to ride a motorcycle or moped. For the majority of companies employing free-lancers, a provisional licence is enough to be hired. It can be argued that a more stringent policy ensuring a higher level of riding experience is required in order to allow riders to utilise two-wheeled motor vehicles.

While higher numbers of cyclist traffic has been cited as a significant protective factor against cycling accidents (Robinson 2005), we did not find cyclist traffic to be protective against KSI accidents. In fact, higher proportions of cyclist to motor vehicle traffic was associated with higher odds of KSI accidents even after controlling for the number of cyclist on each road segment, this was an unexpected finding. The divergence of our results from previous literature may be due to the unique mega-urban context of Greater London or the severe nature of the accidents. Increased cyclist traffic may be protective only for relatively minor accidents - further research into this matter is needed.

The major strengths of our study are 1) the inclusion of a broad range of social and environmental predictors of KSI accidents, 2) spatially referenced variables to account for neighbourhood-level effects, and 3) the use of KSI accidents as an outcome that are well represented by official statistics (compared to minor accidents). On the other hand, our use of a cross-sectional analysis precludes us from making strong inferences about the direction of causation. In our subsequent follow-up analyses, we will be analysing the data in a longitudinal manner (i.e. whether changes in the environment lead to changes in KSI accidents) to help clarify the causal mechanism for KSI accidents.

5. Biography

Anna Labetski is a first year PhD Candidate in the 3D Geoinformation group at TU Delft. She holds a Human Geography BA from the University of Toronto and an MSc in Geospatial Analysis from UCL. Her interests include statistics, open data, Python, spatial analysis and urban planning.

Antony Chum is an Assistant Professor in Human Geography at the University of Nottingham. His research interests are to understand the influence of built environments on human health and wellbeing, and to develop and evaluate strategies to build healthier cities and communities. He holds a PhD in Human Geography from (University of Toronto, 2012) and completed a Canadian Institute of Health Research Postdoctoral Fellowship in Health Equity Intervention at St Michael's Hospital in Canada.

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