INFRASTRUCTURE AND SPATIAL EFFECTS ON THE FREQUENCY OF CYCLIST-MOTORIST COLLISIONS IN THE COPENHAGEN REGION

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INTRODUCTION

- Cycling answers the need for healthy and sustainable alternative transport in a world of depleted resources (e.g., Jacobsen, 2003; Elvik, 2009; Vandelbulcke et al., 2009; Buehler et al., 2011; de Nazelle et al., 2011)

- The debate between risks and benefits is vivid (e.g., de Hartog et al., 2010; Int Panis et al., 2010; Bos et al., 2013)

- The risk of crashes discourages people from cycling (e.g., Pucher et al., 1999; Parkin et al., 2007; Winters et al., 2011)

INTRODUCTION

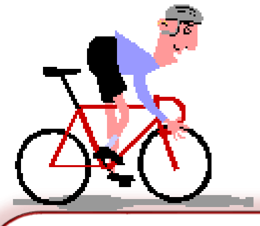
- Intersections are associated with a higher risk of cyclist-motorist crashes (e.g., Wang and Nihan, 2004; Quddus, 2008; Møller and Hels, 2008; Reynolds et al., 2009)

- Cycle facilities are related to a lower risk of cyclist-motorist crashes (e.g., Forester, 1994; Rodgers, 1997; Aultman-Hall and Hall, 1998; Pucher et al., 1999)

- Traffic conditions and congestion are linked to a higher risk of cyclist-motorist crashes (e.g., Li et al., 2007; Møller and Hels, 2008; Wang et al., 2009; Yiannakoulias et al., 2012)

INTRODUCTION

- Missing is a comprehensive analysis of cyclist-motorist crash frequency in a cycling nation with extensive infrastructure
- Missing is the consideration of spatial correlation in existing cycling crash frequency models



Research objective:

Modeling infrastructure and spatial effects on the crash frequency in the Greater Copenhagen Area at the zone-level

DATA

- Crash data from the National Crash Database maintained by the Danish Road Directorate compiled from police records:

	mean	stdev	min	25% pct.	median	75% pct.	max
total crashes	19.9	22.7	0	6	13	26	194
severe and fatal injury crashes	4.3	5.1	0	1	3	5	47
damage only and light injury crashes	15.6	18	0	5	10	21	136

Data sample:

5,349 cyclist-motorist collisions in the Greater Copenhagen Area between 2009 and 2013

DATA

- Network data for the Greater Copenhagen Area:

	mean	stdev	min	25% pct.	median	75% pct.	max
roads without cycling infrastructure	58.760	58.378	1.025	16.996	44.567	79.875	403.113
roads with painted bicycle lanes	0.372	0.776	0.128	0.147	0.360	0.490	5.362
roads with Copenhagen-style bicycle paths	6.124	4.327	0.670	2.973	5.534	8.369	26.238
roads with separated bicycle paths	22.511	21.570	1.241	4.905	18.043	32.518	135.831
footpaths	2.217	2.574	0.162	0.453	1.427	2.828	14.523
number of intersections	32.6	25.6	6	13	25	44	213

DATA

- Exposure data for the Greater Copenhagen Area:
  - Cycling traffic from the OTM model and the TU data
  - Traffic data from the LTM model

	mean	stdev	min	25% pct.	median	75% pct.	max
cycle-km	8633.1	6656.4	136.5	4348.9	7116.8	11281.0	62431.6
car-km	101489.5	101750.0	4438.3	34819.7	62181.3	135636.8	523432.6
van-km	10316.0	11010.9	476.6	3217.0	6113.1	14092.3	62341.0
truck-km	5049.1	5891.1	54.1	1354.7	2908.6	6587.1	32196.6

MODEL

- Poisson-based models of the number Y_i of crashes in zone i:

$$Y_i \sim Poisson(\mu_i)$$
$$\log(\mu_i) = \alpha + \boldsymbol{\beta X_i} + \nu_i + u_i$$

μ_i is the expected Poisson crash rate in zone i

$\boldsymbol{X_i}$ is the vector of explanatory variables for zone i

α and $\boldsymbol{\beta}$ are coefficients to be estimated

v_i captures the heterogeneity effects for zone i

u_i captures the spatially correlated effects for zone i

MODEL

- Poisson-gamma and Poisson-lognormal random effects:

$$\exp(\nu_i) \sim Gamma(\phi, \phi)$$

$$\nu_i \sim Normal(0, \tau_\nu^2)$$

- CAR spatial correlation effects:

$$u_i | u_j, i \neq j \sim N\left(\frac{\sum_j u_j w_{ij}}{w_{i+}}, \frac{\tau_u^2}{w_{i+}}\right)$$

τ_v and τ_u control the Poisson extravariation because of respectively heterogeneity and spatial correlation

w_{ij} are weights between zone *i* and *j,* with *j* being neighbor of *i and* w_{i+} being the sum of the weights of the neighbors

MODEL

- Bayesian estimation with the MCMC method
  - Two chains simulated with 25,000 iterations as burn-ins and 75,000 iterations as posterior mean and standard deviation calculation
  - uniform prior distribution assigned to *a*
  - non-informative normal prior distributions assigned to the *β's*
  - non-informative gamma prior distributions assigned to the *τ's*
  - several neighboring structures, with the best being by physical contiguity
- Model evaluation with the deviance information criterion

$$DIC = D\left(\overline{\theta}\right) + 2p_d = \overline{D} + p_d$$

RESULTS

- Estimates of the Poisson-lognormal CAR model

	mean	st.dev.	val2.5pc	val5.0pc	val95.0pc	val97.5pc
log(cycle-km)	0.6690	0.0361	0.5969	0.6066	0.7206	0.7276
log(car-km)	0.3490	0.0877	0.1945	0.2147	0.4856	0.5026
log(van-km)	0.3150	0.1097	0.0929	0.1211	0.4922	0.5130
log(truck-km)	0.1746	0.0812	0.0242	0.0434	0.2932	0.3263
Copenhagen-Frederiksberg	-0.0492	0.0447	-0.1334	-0.1213	0.0099	0.0262
suburban areas	-0.6141	0.2039	-1.0271	-0.9541	-0.2881	-0.2231

RESULTS

	Mean	st.dev.	val2.5pc	val5.0pc	val95.0pc	val97.5pc
log(km roads without bicycle facilities)	0.2755	0.0540	0.1831	0.1905	0.3559	0.3795
log(km roads with painted bicycle lanes)	0.0565	0.0247	0.0124	0.0163	0.0865	0.0969
log(km roads with segregated bicycle paths)	-0.2928	0.0642	-0.4062	-0.3957	-0.2026	-0.1706
log(km roads without bicycle facilities) in suburban areas	-0.1230	0.1309	-0.3805	-0.3380	0.0839	0.1286
log(km roads with painted bicycle lanes) in suburban areas	0.1555	0.0644	0.0328	0.0513	0.2546	0.2632
log(km roads with segregated bicycle paths) in suburban areas	0.1442	0.1052	-0.0602	-0.0270	0.3039	0.3490
number of intersections	0.0414	0.0188	0.0240	0.0252	0.0686	0.0748
number of intersections in suburban areas	-0.0246	0.0116	-0.0478	-0.0440	-0.0244	-0.0060

RESULTS

	Mean	st.dev.	val2.5pc	val5.0pc	val95.0pc	val97.5pc
log(average income)	-0.1499	0.0989	-0.3521	-0.3190	0.0030	0.0638
full-time employed (1000’s)	1.1385	0.3903	0.3876	0.5100	1.7752	1.8928
part-time employed (1000’s)	0.0549	0.0306	-0.0212	-0.0046	0.0937	0.1232
students and pupils (1000’s)	-0.4595	0.0902	-0.6205	-0.5965	-0.3195	-0.2948
retired (1000’s)	0.1788	0.0604	0.0504	0.0710	0.2662	0.2935
on welfare (1000’s)	0.8984	0.3201	0.2762	0.3864	1.4157	1.5248
constant	-2.5614	1.1020	-4.7364	-4.3964	-0.7594	-0.4204
st.dev. (u)	0.3160	0.0554	0.2070	0.2250	0.3950	0.4180
st.dev. (v)	0.2622	0.0596	0.1451	0.1610	0.3639	0.3823

CONCLUSIONS

- Estimates for the exposure variable illustrate the proportionality between number of crashes and cycle-km

  The parameter is significantly lower than 1, thus the number of crashes increases less than expected and indicates that the safety in numbers phenomenon is observed

- Estimates for the exposure to traffic show the expected increase in the number of crashes with the increase in the motorized traffic

  The increasing possibility of conflicts is responsible for this increase, although only the car-km are significantly related to the increase in the number of serious and fatal injury crashes

CONCLUSIONS

- Infrastructure effects show a reduction in the number of crashes with segregated bicycle paths, and an increase with cycling in mixed traffic

  Findings opposite to the literature, most likely because this is the first analysis in a cycling nation where infrastructure is extensive and several studies were based on self reports

- Infrastructure effects show differences between urban and suburban areas, also in terms of intersections

  The increasing possibility of conflicts is evidently related to intersections and mixed traffic, although a decrease is observed for severe and fatal injury crashes on suburban roads

CONCLUSIONS

- A correlation exists between a higher number of crashes and a lower average income in the zone

Cycling per se may be associated with lower income groups, and the number of crashes is associated with more cycling, but could also relate to the richness of the zone

- A correlation exists between an increased number of crashes and a higher number of employed and a lower number of students in the zone

Commuting could be a proxy for crashes when there is congestion, which has been proved increasing tension and the perception of risk among cyclists

CONCLUSIONS

- Spatial effects are very relevant, with an increase in the explanatory power in the model and a posterior proportion of variation equal to 54.7%

  The ratio between st.dev.(u) and the sum of st.dev.(u) and st.dev.(v) is higher for serious and fatal injury crashes (62.9%)

- Further research will focus on link-based models and on spatial analysis of frequency and severity of cyclist-motorist crashes

THANK YOU FOR YOUR ATTENTION!

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