Infrastructure and spatial effects on the frequency of cyclist-motorist collisions in the Copenhagen region

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Cycling is increasingly recognized as the answer to the need for healthy and sustainable alternative transport in a world of depleted resources (e.g., Jacobsen, 2003; Elvik, 2009; Pucher and Buehler, 2008; Vandelbulcke et al., 2009). However, promoting cycling generates a vivid debate between the risks and the benefits (e.g., Int Panis et al., 2010; Bos et al., 2013), especially when considering that the risks are the determinants of cycling avoidance strategies that make the diffusion of cycling nearly impossible in several countries (e.g., Parkin et al., 2007; Winters et al., 2011).

Investing in cycling infrastructure aims at mitigating possible conflicts. Previous studies analyzing the frequency of cycling crashes have associated a higher number of crashes with a higher number of intersections (e.g., Wang and Nihan, 2004; Quddus, 2008; Møller and Hels, 2008), congested traffic conditions (e.g., Li et al., 2007; Møller and Hels, 2008; Wang et al., 2009), but also a higher diffusion of cycling facilities (e.g., Rodgers, 1997; Aultman-Hall and Hall, 1998; Pucher et al., 1999). However, existing studies analyzed countries with marginal cycling market shares and even more marginal presence of dedicated cycling infrastructure. Hence, this study addresses the gap of the missing comprehensive analysis of cyclist-motorist crash frequency in a cycling nation with extensive infrastructure, and the missing consideration of spatial correlation in existing cycling crash frequency models.

Crash data were extracted from the crash database maintained by the Danish Road Directorate and created on the basis of police records. The focus was on 5,349 cyclist-motorist collisions occurred in the Copenhagen region between 2009 and 2013, where the type of crashes was selected to avoid the well-known under-reporting problem more typical of single-bicycle crashes, the area was chosen to exploit the very detailed bicycle network developed for implementation in the LTM, and the period was decided to limit the analysis to plausibly similar conditions in terms of network and traffic.

Network and exposure data were extracted from the bicycle network constructed for the Copenhagen region and from the traffic derived from the OTM and LTM. The network consists of more than 363,000 links across the Copenhagen region and details the type of bicycle paths (i.e., road without cycling infrastructure, road with painted bicycle lane, road with segregated bicycle path, road with Copenhagen-style bicycle path, footpaths), the number of intersections, and the zone characteristics (i.e., LTM zone system). Cycling traffic was calculated from the OTM and the TU data, while other traffic (i.e., car, van, truck) was obtained from the LTM, and was aggregated at the zone level in terms of cycle-km, car-km, van-km, and truck-km.

The crashes were assumed to have a Poisson distribution, where the expected number of crashes was a function of observed zone characteristics, a first error term expressing the heterogeneity across zones, and a second error term accounting for the spatial proximity of the zones. Tests were performed where the first error term was either Gamma or Lognormal distributed, and the second error term was a Conditional AutoRegressive spatial correlation effect with neighboring structure based on either distance or physical contiguity. Estimates for the parameters of the observed zone characteristics, the distribution of the heterogeneity and the distribution of the spatial correlation were obtained via Bayesian estimation with the MCMC method using two chains simulated with 25,000 iterations as burn-ins and 75,000 iterations as posterior mean and standard deviation calculation.

Estimation results highlighted that: (i) there is proportionality between number of crashes and cycle-km, although the parameter is significantly lower than 1 and indicates that the number of crashes increases less than proportionally with the exposure and thus the safety in numbers phenomenon is observed; (ii) estimates for the exposure to traffic show the expected increase in the number of crashes with the increase in the motorized traffic, with the detail that only the car-km are significantly related to the increase in the number of serious and fatal injury crashes; (iii) infrastructure effects show a reduction in the number of crashes with segregated bicycle paths and an increase with cycling in mixed traffic, in contrast with 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; (iv) infrastructure effects show differences between urban and suburban areas, and an increasing possibility of conflicts evidently related to intersections and mixed traffic, although a decrease is observed for severe and fatal injury crashes on suburban roads; (v) a correlation exists between a higher number of crashes and a lower average income in the zone, possibly as a proxy for the level of care of the infrastructure in the zone; (vi) a correlation exists between an increased number of crashes and a higher number of employed and a lower number of students in the zone, possibly as a proxy for crashes when there is congestion that has been proved increasing tension and the perception of risk among cyclists; (vii) 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%, and even 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.

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