International Co-operation on Theories and Concepts in Traffic Safety

Examining the nonlinear effects of traffic and built environment factors on the traffic safety of cyclist across different age groups

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Introduction: Traffic crashes are a major concern for public health causing tremendous social and economic burdens. The safety problem has been growing particularly for cyclists over the last decades with more and more people shifting to cycling as a healthy and sustainable mode of transport. Literature shows that age is an important factor in crash involvement and consequences. Therefore, it is very important to identify when, where, and how a cyclist from across different age groups involve in cycling crashes to help cyclists navigate safely in the traffic system. However, there are few studies identifying the risk factors for cyclists from across different age groups. This study addresses this gap by identifying and understanding the effects of traffic, infrastructure, and land use factors on vehicle-to-bike injury and fatal crashes of cyclists from different age cohorts.

Methodology: The study was conducted in the Randstad Area encompassing the Netherlands' four major cities: Amsterdam, Rotterdam, The Hague, and Utrecht. The area also includes new urban centres and housing developments that have expanded from the city centre toward the city boundaries and new towns such as Almere and Houten. For the analysis of abovementioned factors, we used 100x100m^2 grid cells [1] (a total of 42,272 100-cells) which consist of comprehensive land-use, socioeconomic, and demographic information [2]. To analyse the safety of cyclists in these 100-cells, we used severe injury and fatality bicycle-to-vehicle crashes (F&I B-V) occurred between 2015 and 2019. However, there are very few 100-cells with severe injury and fatality crashes, leading to the imbalanced data problem. To address this problem which is also brought about by examining different age groups, we employed resampling techniques based on k-means clustering and adaptive synthetic over-sampling (ADASYN) [3]. Finally, we applied the XGBoost-Tweedie approach to identify nonlinear effects of investigated factors on crashes of various age groups.

Results: The results of the study are intriguing, but also more complex compared to outcomes of a generalized linear model due to the non-linear nature of the modelling setting (XGBoost-Tweedie). Nonetheless, one interesting outcome is the difference between the “Total” which is the results when all crashes combined and the results of the individual age groups. We observe a large difference which can make a substantial difference in the interpretation of the effects of the variables. For instance, the Total result for the “Effect of log(BKT)” implies a kind of Safety-in-Numbers effect as the crash rates stabilizes and even reduces after a certain threshold namely 90 Bicycle-kilometres travelled; however, this result is not apparent at all in the age group results except for the minor cyclists (0-14). Similarly, we see a more stable effect of weighted traffic speed in the Total; however, the age groups differ considerably.

Regarding the infrastructure, increase in the ratio of separated cycling paths in the 100-cell seems to decrease crash rates in general. Ratio of the mixed traffic, on the other hand, has a more complex effect on crash rates, where young adult (25-44) crash rates continuously increases with larger share of mixed traffic, minor (0-14) and elderly (65+) crash rates decrease after reaching to a threshold of 20%. It is striking that we cannot observe these varying patterns clearly neither for separated, nor for mixed traffic conditions in Total result. Previous literature also found that effects of cycling infrastructure on the safety of cyclists are subtle rather than profound. The land use variables such as average house value seem to have more consistent influence on all age groups. We see a sharp increase in crash rates of all age groups from 100,000 to 250,000 Euros. For average house values more than 250,000, we can see that crash rates remain the same or in the case of senior adults (45-64) and elderly (65+) crash rates are reducing. Considering the housing prices and cycling behaviours in the Netherlands, this probably shows that the low-to-middle income neighbourhoods with relatively high cycling shares have the highest injury and fatality bike-to-vehicle crash rates, whereas higher income neighbourhoods are slightly safer.

Discussion and conclusions: This study shows that analysis of crash rates of different age groups shows that the influences of investigated variables widely vary and the analysis of total crash rates may not disclose the nature of cyclist crashes of different age groups. That being said, it is worth noting that the crash rates of age groups were calculated based on the vehicle-kilometres travelled, which is not divided into different groups. Therefore, the exposure to motor vehicles which defines that crash rate are not based on age groups, but only the number of crashes. Furthermore, we must admit that the results provided by this non-linear effects analysis are not always easy to interpret and can be complicated to use for practical purposes directly. Nonetheless, it is clear that the problem of safety and the effects of variables that might have an influence on cycling safety is far more complicated than what can be captured by generalized linear models. If the researchers and practitioners desire is to profoundly understand the nature of the cyclist crashes and the complex relationships, the methodology adopted by this study is a promising direction.

1. CBS, *Statistische gegevens per 100 vierkant 2017*. 2017.
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3. Morris, C. and J.J. Yang, *Effectiveness of resampling methods in coping with imbalanced crash data: Crash type analysis and predictive modeling.* Accid Anal Prev, 2021. **159**: p. 106240.