Analyzing the impacts of built environment factors on vehicle-bicycle crashes in Dutch cities

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1 ABSTRACT[1]

Cycling safety policy and research have mostly focused on cycling infrastructure, cyclists' behavior, and safety equipment in the past decades. However, the role of built environment characteristics (BECs) in the safety of cyclists has not yet been fully examined. For the Netherlands, this is rather surprising given the significant modal share of bicycles in daily trips, the importance attributed to urban spatial planning, and it being one of the most planned countries in the world. Despite the considerable improvements that have taken place in traffic safety over the decades, the (actual) number of cyclist deaths between 2011 and 2020 increased by on average 2% per year; the cyclists had a major portion of traffic death (followed by passenger cars); also, almost one-third of traffic death happened in built-up areas (about 25% of fatalities occurred on 50km/h roads in urban areas) in this period [1]. Considering the aim of construction of on average 75,000 new homes per year until 2025 [2], as well as promoting bicycle use in as a healthy and sustainable mode of transport in the Netherlands [3], understanding the relationships between the BECs and cycling safety is invaluable for improving the safety of cyclists.

BECs are usually represented by indicators called "5Ds", namely (population) density, (land-use) diversity, (land-use) design, distance to transit, and accessibility to destinations [4]. Different BECs lead to an increase or decrease in the number and probability of crashes as they contribute to variations in exposure, speeds, and conflicts between different mode users [5-7]. Previous research has shown correlations between population and employment density [8, 9], as well as density of residential [7, 9, 10], commercial, and educational land use classes [9, 11] on the occurrence of vehicle-bicycle (V&B) crashes in the areas, even after controlling for exposure. Moreover, land-use diversity [10, 12] and proximity to facilities such as transit stops and commercial and service locations were shown to increase the risk of V&B crashes [9, 13-16].

Disregarding the collective effects of the abovementioned BECs can potentially lead to an under/overestimation of their importance due to the unobserved effects of missing variables. Moreover, BECs change over time and space as a result of different land use and transport policies. These changes naturally affect travel behavior and, in turn, traffic safety. For example, the Netherlands underwent major developments during the 1970s and 1990s, with policies such as "Dutch New Towns" (1960-1985) and urban expansion "VINEX Areas" (1993). Safer road network designs, accessible public transport, and short distances to services (e.g., supermarkets) were some of the goals for the development of these newer areas. These spatial policies and developments together with transport planning have played a role in the declining numbers of fatal crashes [10, 14, 17] and also safer roads for cyclists. Nonetheless, these changes add to the complexity of the problem of understanding the effect of the BECs on safety because the homogeneity across different areas is lost.

[1] Based on the results of our latest accepted paper in the journal of Accident Analysis and Prevention [18].

This study developed and utilized a wide-ranging set of land-use, road network, traffic, and socioeconomic variables that affect V&B crashes in two types of property damage only (PDO) and fatality/severe injury (KSI) [18]. The spatial contiguity effects of the BECs were particularly considered in the analysis to address the spatial heterogeneities and dependencies. We compiled a rich dataset on a case study area in a selected number of municipalities in the "Randstad Area" in the Netherlands. This area is the most urbanized part of the country. The data were analyzed at 100x100 m grid cell units. We utilized Hurdle Negative Binomial (HNB) models which can handle count datasets involving an excessive number of zero outcomes (a common issue in crash count data) [19]. We also accounted for the spillover effects of some observed BECs in the neighbouring cells on V&B crashes in the target units.

Therefore, spatial HNB models were conducted to analyze traffic crashes. Figure 1 shows the "standardized coefficients" for significant variables (95% CI) of the models. Regarding the impacts of the BECs, the results show that fewer V&B crashes are likely in areas with a higher proportion of households with children. This result was expected as the speed limit of the access roads in residential areas with housing for families is set at 30km/h. Moreover, relatively many families with children live in the VINEX areas that are designed (and also found) to be safer locations for cyclists. Increased urbanization level raises the probability and frequency of V&B crashes that can be due to the higher population and the conflicts caused by an increased rate of trip attractions/generations in the areas. In contrast, a reduced crash probability was found for areas with higher land-use diversity where the locations are closer to each other. This encourages the residents to walk or cycle more. We also studied the impact of the "ages of the built-up areas" on road safety. These characteristics are used as proxy variables for various land-use policies and related land-use designs. The results suggest that areas built after 1990 are safer for cyclists in terms of occurrence of PDO crashes. These findings verify that the development of VINEX areas (in the 1990s) has had a positive impact on reducing bike involved crashes. However, our results reveal an increase in frequency of sever V&B crashes in these areas.

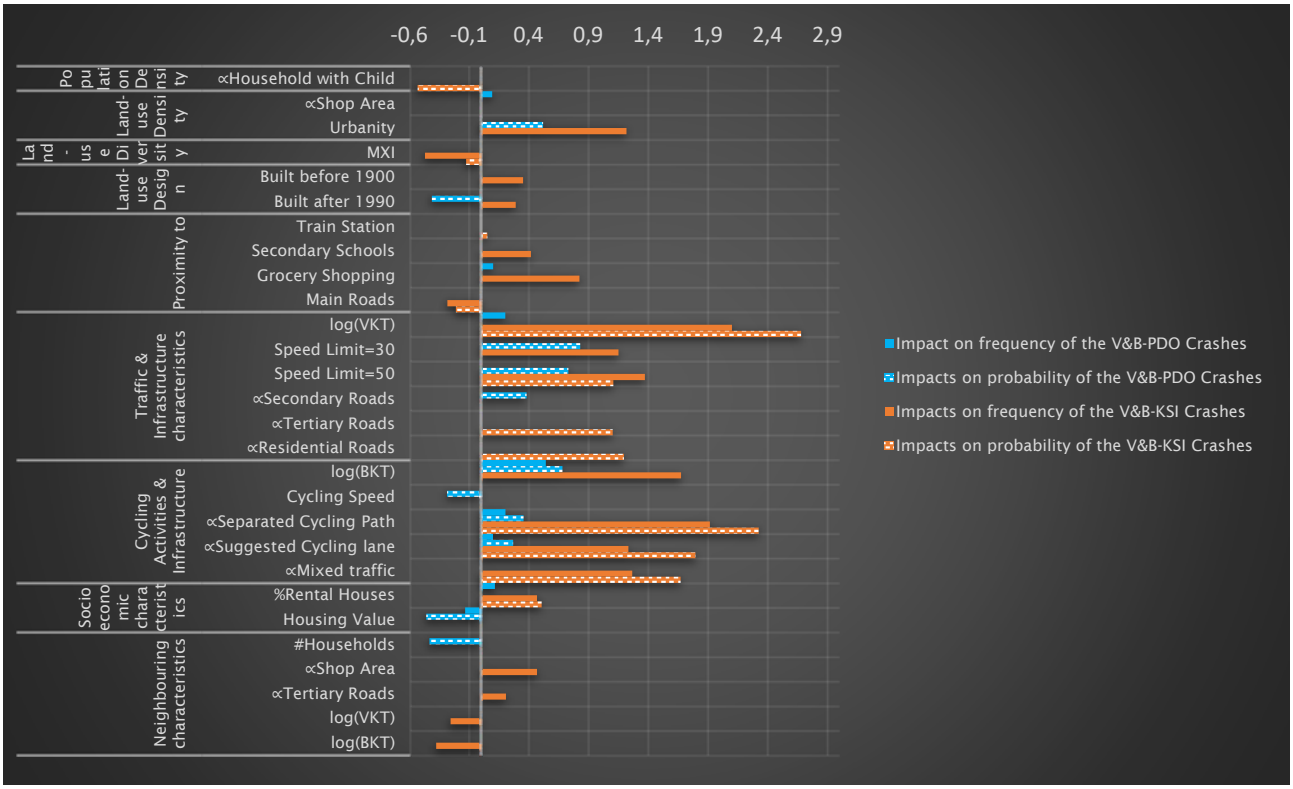

Figure 1 Comparison between the standardized Count/Zero (binary)-Model coefficients of the V&B crashes

Figure 1 also illustrates that high proximity to schools increases the frequency of severe V&B crashes. One reason for this might be the tendency of secondary school students to cycle in groups (i.e., bunch cycling). Such behavior has been found to increase the risk of sports cycling crashes in the Netherlands [20]. Also,

shorter distances to schools are common in areas with older buildings which were found to be riskier areas for cyclists. Also, higher proximity to grocery stores increases the frequency and/or probability of KSI crashes in the area. Regarding the effects of the cycling facilities, the results confirm that V&B crashes are concentrated on the arterial roads that are adjacent to the high volume and high-speed roads. Moreover, separated cycle paths negatively affect the V&B crashes compared to the suggested cycle lanes and mixed traffic roads. Although the separated cycle paths prevent conflicts with motor vehicles, the presence of busy side roads, parked vehicles along the cycle paths, as well as large intersections that need to be crossed can increase the probability and frequency of V&B crashes. Finally, as for the spillover effects of neighboring variables which reflect spatial spillover effects, the results suggest that high vehicle/bicycle volumes in neighboring cells were associated with a reduction in the frequency of severe V&B crashes. Moreover, the results indicate that traffic and land-use characteristics in surrounding areas (e.g., vehicle/bicycle volumes, proportion of shopping areas) are associated with traffic safety in the targeted analysis unit.

One of the major contributions of this study is analyzing the collective impacts of a comprehensive set of BECs along with the traffic and infrastructure-related factors. This comprehensive variable set became the cornerstone to examining a cumbersome topic in cycling safety: identifying the relationship between cycling safety and the built environment. For example, this study showed that

- the magnitude of built environment impacts on safety varies based on crash severity;
- land-use density and diversity contrary affect V&B crashes in cities;
- safety of cyclists should be enhanced in areas around grocery shopping and schools;
- vehicular traffic volume is the major problem in cycling safety;
- safety of cyclists needs to be improved on territory and residential roads.

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