Examining the crash risk factors associated with cycling: findings from four Dutch cities

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1 INTRODUCTION

Due to investments in cycling infrastructure and promotion of cycling as a green and healthy mode of transport, cycling gains popularity in many cities around the globe. These growing cycling levels lead to an increasing number of severe and fatal bicycle crashes, particularly in urban areas where more than half of the fatal crashes in the European Union occurred [1]. Therefore, understanding the factors affecting bicycle safety in urban areas is crucial to improve the wellbeing of cyclists and further promote cycling as a sustainable and healthy mode of transport. This paper aims to contribute to safer urban cycling by examining bicycle crash risk factors in Dutch cities.

Bicycle crashes have a strong spatial and temporal character as these crashes tend to cluster at specific locations which is influenced by temporal variation in these crashes [2]. It is therefore important to consider this heterogeneity of crashes in space and time when investigating bicycle safety. To address this nature of bicycle crashes, the current study uses a high-resolution spatiotemporal dataset with hourly variation in bicycle crashes and exposure metrics on each road section of the cycling network. Other examined risk factors are network structure, cycling infrastructure, speed limits, and proximity of popular destinations for cyclists. Moreover, to provide transferability of the results, the cycling networks of the four largest Dutch cities are analyzed simultaneously.

2 DATA AND METHODS

2.1 Study area

The study area covers the four largest Dutch cities: Amsterdam, Utrecht, Rotterdam, and The Hague. The infrastructure of Amsterdam and Utrecht is characterized by being more cycling-friendly, while in Rotterdam and The Hague the infrastructure is more car-oriented. This is also illustrated by the difference in cycling levels. These are the highest in Amsterdam and Utrecht, with around 40% of the short trips (1-7 km) made by bicycle and 25% by car. In Rotterdam and The Hague this is 30% for both the bicycle and the car [3].

2.2 Data

The crash data includes all police-reported injury (light or severe) and fatal crashes involving at least one cyclist and that occurred on road sections and intersections in the analysed networks between 2015 and 2019. The data for the predictors comes from a large variety of data sources, which is a consequence of analysing four cities in one study. For example, the data for the exposure metrics comes from GPS tracks, local hourly bicycle count data, local transport models, and local hourly motorised vehicle count data.

2.3 Methods

The network-wide hourly exposure to cyclists is estimated by calibrating the hourly bicycle GPS data with the local bicycle count data. For motorised vehicles, the average relative hourly volumes from the local count stations are multiplied by the estimated weekly average volumes obtained from the local transport models. To investigate the effect of network structure on bicycle safety, intersection density and betweenness centrality are retrieved. The latter shows the degree of a network being reliant on a number of road sections [4]. Lastly, due to the hourly disaggregation of bicycle crashes, the number of zeros increased and the crashes are distributed over all hours of the week (168 hours). As a result, nearly all hours where at least one bicycle crash occurred only have one crash. This makes the bicycle crashes virtually a binary variable as there is either a crash or no crash. Therefore, logistic regression is used to estimate the probability of a bicycle crash occurring, defined as bicycle crash risk.

3 RESULTS

The focus of the results is on the main findings adopted from a general model that combines the data from all four cities. City-specific results are also presented as there are some significant differences between the studied cities. However, it is noteworthy that, despite the large variety of data sources (that may cause these differences to some extent), most results are quite robust across the cities. Figure 1 presents the standardized coefficient estimates for the significant variables of the general model and the four city-specific models.

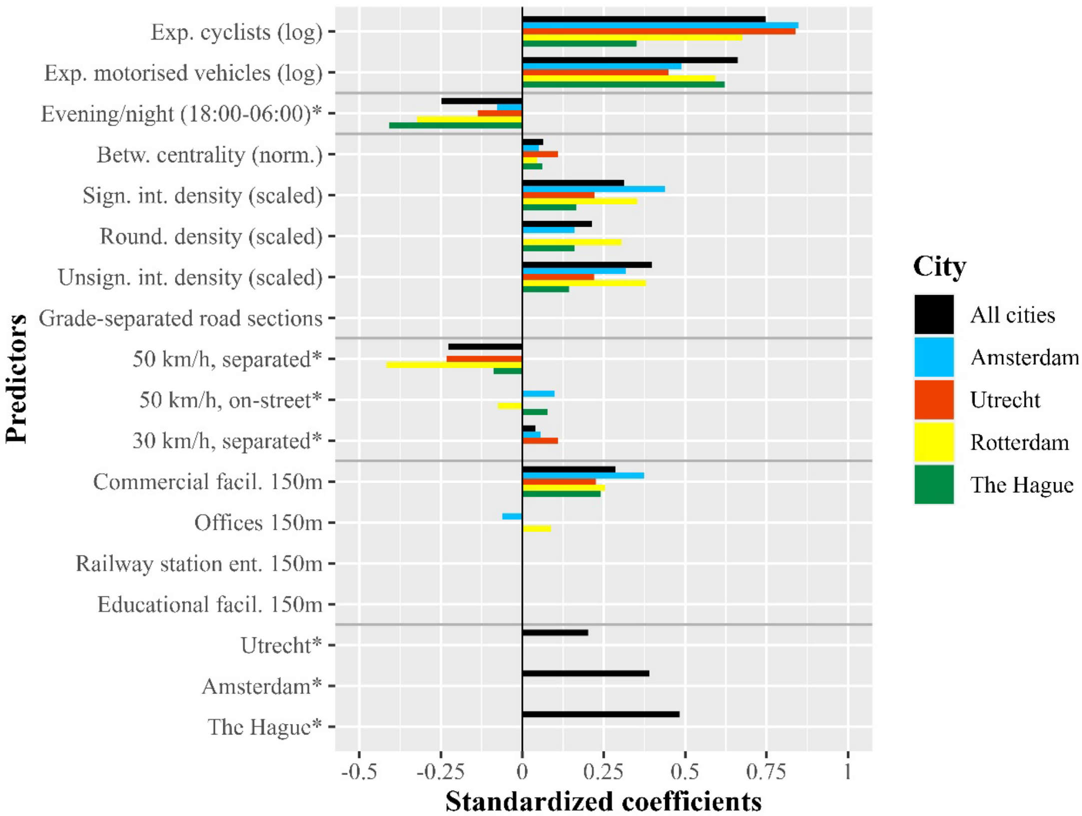

Figure 1: Results of the five logistic regression models. **Reference: for evening/night (18:00-06:00) is morning/day (06:00-18:00); for cycling infrastructure is 30 km/h with on-street cycling facilities; for municipality is Rotterdam.*

Both the exposure to cyclists and the exposure to motorized vehicles show a strong impact on bicycle safety in all cities. The results indicate that hours with larger exposure levels lead to a higher bicycle crash risk. Furthermore, it can be noticed that a relative increase in the exposure to cyclists has a slightly larger impact than the same relative increase in exposure to motorized vehicles. Moreover, bicycle crash risk is lower during the evening/night hours (18:00-06:00) than during the morning/day hours (06:00-18:00).

The betweenness centrality indicator has a relatively low impact on bicycle safety and results imply that the more central the road section is, the slight higher the bicycle crash risk. One reason might be that at road sections with high centrality, many routes come together, leading to increased interactions and conflicts between road users. The intersection density variables have an average impact on bicycle safety. The results indicate that bicycle crash risk is higher where there are more intersections per kilometer.

For the cycling infrastructure variables, the results indicate that bicycle crash risk on 50 km/h roads with separated bicycle tracks is lower than the reference (30 km/h roads with on-street cycling facilities). This might be caused by the fact that for three out of the four cities only the higher volume 30 km/h roads are included and that such roads may have negative implications for bicycle safety. Secondly, no significant relationship between 50 km/h roads with on-street cycling facilities and bicycle crash risk is found in the general model. This result may be caused by the contradictory city-specific findings, as bicycle crash risk on this road type is higher than the reference in Amsterdam and The Hague, it is lower in Rotterdam, and in Utrecht no significant relationship is found. Lastly, the results show a counter-intuitive higher crash risk at 30 km/h with separated bicycle tracks compared to the reference, but the impact on bicycle safety is low. Presumably, these roads are designed as 50 km/h roads with separated bicycle tracks, which may cause speeding as the design does not fit the intended speed limit.

It is shown that cycling within 150 meters network distance of commercial facilities has a relatively strong impact on bicycle safety. The findings imply that in shopping areas bicycle crash risk is higher, presumably due to increased numbers of pedestrians or other road users. For the other destination types, this study found no significant relationship with bicycle safety in the general model.

4 COCNLUSIONS

The main conclusions of the study are as follows:

1. The exposure variables (cyclist and motorized vehicles) have the largest effect on bicycle crash risk.
2. Bicycle crash risk is lower during the evening and night hours than during the daytime hours.
3. The most central road sections (i.e., betweenness centrality) in the cycling network have a higher bicycle crash risk, but the overall impact of centrality is limited.
4. The higher the intersection density, the higher the bicycle crash risk.
5. Compared to 30 km/h roads with on-street cycling facilities, bicycle crash risk on 50 km/h roads with separated bicycle tracks is lower.
6. 30 km/h roads with separated bicycle tracks have a higher bicycle crash risk than 30 km/h roads with on-street cycling facilities, but the impact on bicycle safety is limited.
7. Roads close to commercial facilities have a higher bicycle crash risk than roads further away. The impact of commercial facilities on bicycle safety is relatively high.

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