The effects of hourly variation in exposure to cyclists and motorized vehicles on cyclist safety in a Dutch cycling capital

Teun Uijtdewilligen[*#], Mehmet Baran Ulak[#], Gert Jan Wijlhuizen[*], Frits Bijleveld[*], Atze Dijkstra[*], Karst T. Geurs[#]

[*]SWOV Institute for Road Safety Research
PO Box 93113, 2509 AC The Hague, the Netherlands
email: teun.uijtdewilligen@swov.nl;
gert.jan.wijlhuizen@swov.nl; frits.bijleveld@swov.nl;
atze.dijkstra@swov.nl

[#]Faculty of Engineering Technology,
Department of Civil Engineering
University of Twente
PO Box 217, 7500 AE Enschede, the Netherlands
email: m.b.ulak@utwente.nl; k.t.geurs@utwente.nl

Keywords: Cyclist safety, Network-wide exposure, Hourly variation in volumes, Cycling infrastructure.

1 INTRODUCTION

While cycling is promoted as a sustainable and healthy mode of transport in many cities in the Global North [1, 2], there are increasing concerns about the safety of cyclists. The increasing bicycle use in urban areas leads to a more intensely used cycling network, resulting in safety risks for cyclists [3]. Since 2010, the number of bicycle fatalities stagnated and the number of severely injured cyclists increased by 28% until 2018 in the European Union [4]. It is therefore necessary to examine how bicycle use and motorized vehicle use in cities affects the number of bicycle crashes.

To investigate this, the effect of the network-wide hourly exposure to cyclists and motorized vehicles on bicycle crash frequency is examined. That is, the total number of cyclists and motorized vehicles in the whole road network for each hour of the week were estimated and used as the network-wide hourly exposure. This approach allowed us to capture safety impacts of temporal variation in the numbers of cyclists and motorized vehicles in the same network more accurately. It is a different approach compared to most bicycle safety studies, which often only use the daily average of bicycle and motorized vehicle volumes. The work presented here is based on our publication in Safety Science [5].

2 CASE STUDY AREA

The city of Utrecht, the Netherlands is chosen as the case study area considering that Utrecht has the highest bicycle usage levels in the Netherlands and is internationally known for being very bicycle friendly with a well-designed cycling network. For example, in 2015, over 40% of the short trips (1-7 km) were made bicycle, while for cars this was 22% [6]. Altogether, this makes Utrecht a good representation of the Dutch “cycling culture”, which positively affects the level of safety. However, as Dutch crash statistics show, the number of cyclists involved in fatal and severe crashes increased in the past ten years and the share of cyclists in these crashes is the largest compared to other road users [7]. This makes Utrecht an interesting case to examine the impacts of the exposure to cyclists and motorized vehicles on bicycle safety.

3 NETWORK-WIDE HOURLY APPROACH

To estimate network-wide hourly bicycle volumes, two data sets are used. First, a GPS-based data set from the Dutch Bicycle Counting Week in 2016 (*Fietstelweek*) is used. This data set is used to represent the temporal variation (hours of the day) in bicycle volumes for the Utrecht cycling network. Second, the Municipality of Utrecht provided an extensive data set containing hourly volumes from sixteen permanent count stations for the years 2015 until 2019. A Support Vector Regression (SVR) model is fitted to estimate the hourly volumes on road sections without a count station, with the hourly GPS-based volumes as predictor of the hourly volumes from the count stations.

To derive hourly motorized vehicle volumes, two data sets are used. First, hourly motorized vehicle count data are used, which were collected at intersections and other locations with cameras or induction loops. Second, the transport model from the Municipality of Utrecht is used to estimate hourly volumes of missing sections in the first data set. These were estimated by multiplying the average relative hourly volumes of the sections that were available by the weekly motorized vehicle volumes from the transport model.

As the interest of this study is hourly variation in bicycle crashes, and modelling this variation, the total network exposure for each hour of the week is estimated. To obtain these aggregated volumes, the hourly bicycle volumes and motorized vehicle volumes from each road section are aggregated. Crashes are also aggregated at each hour of the week, based on their occurrence time, resulting in an hourly bicycle crash frequency. To illustrate, Figure 1 shows the hourly variation in bicycle volume, motorized vehicle volume and bicycle crash frequency.

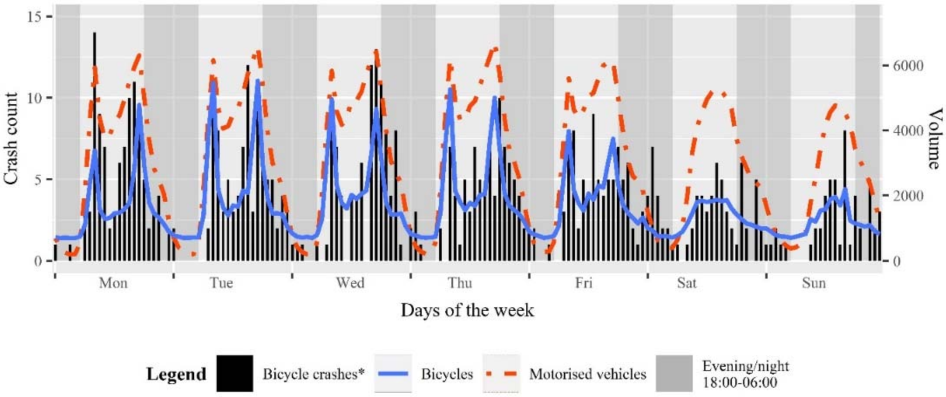

Figure 1:Hourly variation in bicycle volumes, motorized vehicle volumes, and bicycle crashes (*black bars) in the network of Utrecht, the Netherlands.

4 RESULTS

To estimate bicycle crash frequency, seven Negative Binomial (NB) regression models are fitted; one model for every analyzed road category: the full network, 50 km/h roads, 30 km/h roads, 50 km/h roads with separated cycling facilities, 30 km/h road with separated cycling facilities, 50 km/h roads with on-street cycling facilities, and 30 km/h roads with on-street cycling facilities. Both the log of the hourly exposure to cyclists and exposure to motorized vehicles are used as predictors for the models, including a dummy variable morning/day (06:00-18:00) with evening/night (18:00-06:00) as reference category.

The results show that for the full network, for 50 km/h roads, and for 50 km/h roads with separated cycling facilities the exposure to cyclists is a significant positive predictor. This means that during hours with increased exposure to cyclists, the number of bicycle crashes increases as well. Furthermore, the coefficients of the exposure to cyclists are lower compared to the exposure to motorized vehicles. This suggests that during hours where the total network exposure increases, motorized vehicles are a stronger factor for the increase in bicycle crashes than cyclists are. Lastly, the coefficients of the exposure to cyclists show a non-linear relationship with bicycle crashes, meaning that an increase in the exposure to cyclists leads to a less than proportional increase in bicycle crashes.

For the exposure to motorized vehicles, the results show significant positive coefficients for all but one road category, meaning that during hours with increased exposure to motorized vehicles bicycle crash frequency increases as well. Moreover, the size of the coefficients is larger for both 50 km/h roads and 30 km/h roads with on-street cycling facilities compared to other road categories. Thus, bicycle crashes increase more on these roads when exposure to motorized vehicles increases than on the other road categories. Furthermore, the models show that the exposure to motorized vehicles is more linearly related to bicycle crashes compared to the exposure to cyclists. For comparison, Figure 2 illustrates the difference between the coefficients of the exposure to cyclists and motorized vehicles per road category.

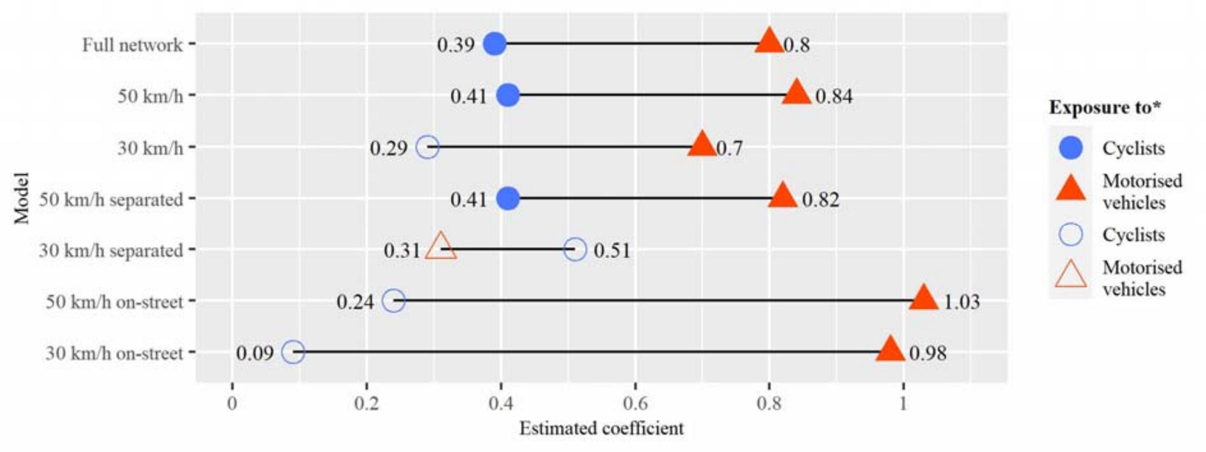

Figure 2: Difference between exposure to cyclists and motorized vehicles. *Hollow shapes are not significant

Finally, morning/day (06:00-18:00) is an important negative predictor for most of the road categories. Negative in this sense means that, after correcting for exposure, fewer bicycle crashes occur during the morning and day compared to the reference category evening/night (18:00-06:00).

5 CONCLUSIONS

The following conclusions can be drawn from the results:

1. Bicycle crash frequency increases less than proportional with an increase in the exposure to cyclists and more linearly with an increase in the exposure to motorized vehicles.
2. Peak hours have the highest levels of the total network exposure, which consequently leads to higher numbers of bicycle crashes.
3. In absolute numbers, cyclists are more involved in crashes during the day than during the evening and night. However, after correcting for exposure, the evening and night are less safe than the daytime hours.
4. Bicycle crashes on 50 km/h roads are more sensitive to an increased exposure to motorized vehicles than bicycle crashes on 30 km/h roads.
5. Separated facilities are found to be safer than on-street cycling facilities given the motorized vehicle volumes.

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