BITS: A Key Performance Indicators (KPIs) supported approach to assess traffic safety for cyclists at intersections in the Netherlands

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Abstract: Traffic safety is an important factor in the decision process whether people decide to use the bicycle or not. Critical situations that do not lead to an accident are often not reported to the police. To fill this knowledge gap, several regions as the city of Zwolle and the Province of Friesland (Netherlands) have started to detect near accidents at intersections among vehicles and bicycles by 3D camera data to evaluate traffic safety. Four intersections in Friesland and Zwolle were monitored. Different types of intersections (e.g. shared space concept) were considered. Near accidents can be divided into different conflict categories depending on vehicle speed and time to collision (Post-Encroachment Time PET). The preprocessed data including Key Performance Indicators (KPIs) to make cycling safety at the intersections measurable and comparable are provided. Based on the numbers and visualizations, it will be discussed which of the discussed intersections show critical profiles regarding numbers of near accidents, distribution and amount of very critical situations. With the results the intersections can be adjusted to increase traffic safety.

Keywords: Traffic Safety, Near Accident, Post-Encroachment Time, KPIs, Bicycle Data, Cycling

Addresses Sustainable Development Goal 11: Sustainable cities and communities

1. Introduction

Traffic safety is an important factor in the decision process to use the bike or not. The police has a rough overview about situations that lead to severe injured or killed cyclists. As an example, according to official statistics 481 bicycle accidents were registered in the bicycle city of Oldenburg (Germany) in 2020 which is a decrease of 139 accidents compared to 2019 [Po21]. Many accidents especially in the case of not or only slightly injured traffic participants are not registered (e.g. alone accidents [GHS21]). That leads to the problem that the number and the spatial distribution of critical situations that are relevant for the (perceived) safety situation but may not lead to an accident is quite unclear. New knowledge about near accidents could be used to make the traffic situation more safe, especially for vulnerable road users (cyclists, pedestrians).

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Around 50-60 percent of all inner city bicycle accidents are happening at intersections [SBL80]. These numbers are confirmed by more recently published sources [UV20, Ba13]. Around 25 percent of all killed traffic participants in inner city accidents are cyclists [KLP13]. Accidents and conflicts are often happening when car drivers disregard the priority of a straight moving forward cyclist at a junction, turning to the left or the right (often with severe consequences because of high speeds), traffic participants disregarding red traffic lights or cyclists who suddenly turning to the left [Al88].

As part of this study, the Dutch mobility advisor Mobycon assigned MicroTraffic to make a camera based detection of near accidents at four different intersections. The goal is to improve the infrastructure to avoid severely injured or even killed traffic participants. The MicroTraffic software detects the vehicle speed and number and severity level of near accidents. A risk profile for all types of traffic participants is generated. The aim of this study is to make the four intersections comparable regarding to traffic safety based on vehicle speed and time to collision (Post-Encroachment Time PET). According to the results municipalities may improve the safety situation. That does not mean a rebuilding of the intersection or the roundabout. Traffic safety could also be improved by smaller measures as new markings or adjustments of signals (e.g. green times at traffic lights). As part of a study that was conducted in 2021 on behalf of the Institute for Road Safety Research SWOV (Netherlands), infrastructure measures based on a camera detection campaign of near accidents has contributed to increase traffic safety at two intersections in the city of The Hague. It can be proven by a before-after analysis that several improvements contributed to a decrease of critical situations because more cyclists may pass the intersection in the designated way. Passing behaviour becomes less complex when green spaces prevent crossing the road for vehicles and bicycles at certain spots. The study confirmed that the separation of green phases for (not) motorized traffic is an important factor for traffic safety [WND21].

Chapter two (methodology) gives an overview about the data collection and the near accident definition. In chapter three we will present the four intersections in the Netherlands and its specific circumstances. The most important Key Performance Indicators (KPIs) will be displayed to make the intersections comparable in terms of traffic safety. These numbers are the foundation for the discussion which intersections have the most critical profile regarding the total number and distribution of (high risk) near accidents. In the conclusion and outlook chapter the results are summarized.

2. Methodology

The detection of a near accident in this study is based on the Post Encroachment Time (PET) which is the time between one traffic participant is leaving a conflict area and another conflicting participant arriving at it. Risk levels are based on the relation between PET and the speed level of the traffic participant. The majority of the conflict points belonging to a low risk level. A smaller number of situations can be perceived in the medium risk area. High risk situations with vehicle speed levels between 35 and 50 km/h

are very rare. Critical risk situations were not monitored at the four intersections.

The vehicle speed levels are classified according to the Wramborg biomechanical survivability thresholds for collisions between vehicles and vulnerable road users (cyclists and pedestrians). Ten percent of the cyclists die in a collision with a vehicle with a speed level of 30 km/h. About 80 percent mortality is reached at 50 km/h [Wr05]. The Vulnerable Road Users Safe Systems indicator (VRUss) is a risk indicator for the categorization of the risk level that is based on vehicle speed and the position to a pedestrian or a cyclist. Vehicle speed is used to calculate the time that a vehicle needs to reach a conflict point. The minimum time to a conflict point is extracted from that and connected with the speed level of the vehicle to determine the risk level of a situation according to Wramborg's risk class definition [Wr05]. Tab. 1 shows the classification.

Risk Level	Critical Risk (C)	High Risk (H)	Medium Risk (M)	Low Risk (L)
VRU Conflicts	Gap < 2 seconds Speed > 50 km/h	Gap < 2 seconds Speed > 35 km/h	Gap < 3 seconds Speed > 15 km/h	Gap < 5 seconds Speed < 15 km/h

Tab. 1: VRUss Indicator Risk Thresholds. Source: MicroTraffic.

3. Intersections

3.1 Haadwei and Thiedamawei (Province of Friesland)

The first intersection is located in Damwâld (5.540 inhabitants in 2020 [CBS21]). The administration decided to rebuild two roundabouts at the Haadwei mainroad as intersections with shared space concept. A camera detection was conducted at the rebuilt Haadwei-Thiedamawei intersection at four days in June 2019 between 7 am and 11 pm.

Many critical situations between cyclists and vehicles are happening when cars driving through and leaving the intersection on the north-south axis. The coloured arrows in Fig. 1 indicate the driving direction of the vehicles. A lot of situations are happening when the vehicles are approaching from western direction. At the northern and the southern axis more than 300 critical situations at each side were detected. At the eastern approach more than 200 near accidents were registered during the measurement.

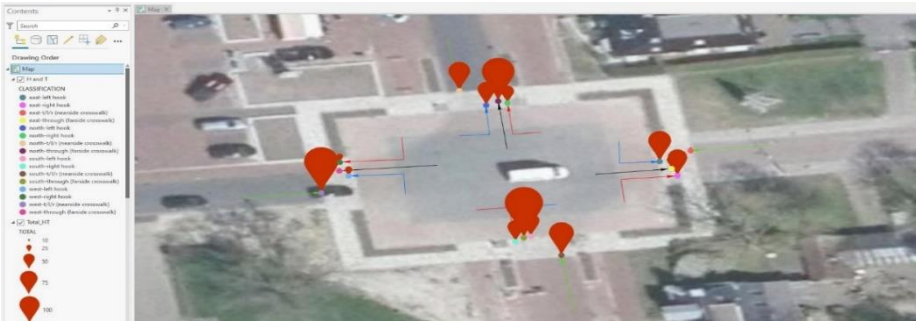

Fig.1: Near Accidents at Haadwei and Thiedamawei. Source: ArcGIS, copyright by Esri.

Vehicle speed levels were divided by the time to collision. The most conflicting situations are happening when vehicles approaching from the northern, southern or western direction. Turning to the left or to the right side is less critical. The risks are quite equal spatially divided to all four corners of the intersection.

According to a report by *BonoTraffic by* driving behaviour at this location is often unpredictable. Because of the barrier in the center, many people interpret the traffic situation still as roundabout what would mean that vehicles in the intersection are prioritized (and not the vehicles approaching from the right side). Citizens complained about high speed levels and dangerous overtaking situations. When traffic volume is low, some left turning vehicles crossing the barrier from the left side. In peak hours cyclists are preferring to use the pedestrian path, especially in the afternoon [LW19].

The Key Performance Indicators (KPIs) are the key to make traffic safety at the intersections comparable. The speed levels are mainly constant on a comparatively higher level with an increase above 20 km/h in the peak hours in the early morning and in the late afternoon/evening. It is the intersection with the highest number of conflicts (1137) what is also reflected by a very high frequency 00:05:03 of near accidents (there is one near accident in about five minutes, see Tab. 2). Although speed levels are high, two third of all near accidents (757) belonging to low risk situations.

Risk Level	Average vehicle speed per period	
Average speed total	19.2 km	
Average count per day	284.25	
Average count per hour	11.84	
	Count & Average speed (according to risk class)	Frequency (according to risk class)
Low	757 (17.79 km/h)	00:07:36
Medium	380 (22.03 km/h)	00:15:09
Total	1137	00:05:03

Tab. 2: KPIs Haadwei & Thiedamawei (Friesland). Source: https://bicycle-data.de/city-analysis/

3.2 Haadwei and Foarwei (Province of Friesland)

Haadwei-Foarwei which is nearby was also rebuilt as a shared space concept. If there are approaching vehicles from more than two sides this can lead to confusion what is especially the case in the afternoon hours. As Fig. 5 confirms, there are more conflict situations in the eastern compared to the western approach. One reason could be that many cyclists who are cycling from north to south are using the eastern side of the intersection. As car drivers do not expect cyclists moving on this side, some near accidents may be registered here [LW19]. There are still traffic safety problems at Haadwei-Foarwei as priorities are not clear to the traffic participants what can also be confirmed by local media reports about a car accident in August 2020 [RTV20].

The detection of near accidents took place at four days in June 2019 from 7 am until 11 pm. There is a conflict hotspot at the southern axis with more than 300 situations especially when cars driving through or turning to the left side (Fig. 2). Vehicles that driving through and leaving to the northern axis are also highly relevant. More than 250 situations were detected in the northern part what is a little bit less compared to the first intersection. Many situations (>250) are happening at the eastern approach.

Fig. 2: Near Accidents at Haadwei and Foarwei. Source: ArcGIS, copyright by Esri.

Conflict levels tend to be lower compared to Haadwei-Thiedamwei. Especially the western and eastern axis show very low risk levels. The northern axis seems to be the most conflicting spot. The southern axis tends to be more conflicting compared to the west and the east. According to speed and PET the whole traffic safety situation seems to be more critical at Haadwei-Thiedamawei compared to Haadwei-Foarwei.

Speed levels are very similar at both intersections. At Haadwei-Foarwei we perceive quite constant speeds on a higher level with average above 20 km/h in the peak hours (morning, late afternoon and also at noon 1-2 pm). The total number of situations (1050) and the frequency (00:05:29) are slightly lower (Tab. 3). However, three high risk situations were detected at the second intersection with an average speed level of more than 38 km/h. Two of these happened at the northern, another one at the eastern axis. Both Friesland

intersections show similar results.

Risk Level	Average vehicle speed per period	
Average speed total	19.79 km	
Average count per day	262.5	
Average count per hour	10.94	
	Count & Average speed (according to risk class)	Frequency (according to risk class)
Low	728 (18.33 km/h)	00:07:54
Medium	319 (22.96 km/h)	00:18:03
High	3 (38.13 km/h)	31:59:40
Total	1050	00:05:29

Tab. 2: KPIs Haadwei & Foarwei (Friesland). Source: https://bicycle-data.de/city-analysis/

3.3 Assendorperstraat and Luttenbergstraat (City of Zwolle)

Zwolle is a medium sized city (128.840 inhabitants in 2020 [CBS21]). According to a 2021 ranking of the American interest group PeopleForBikes, Zwolle is the best place for cycling in the world [TK21]. Assendorperstraat-Luttenbergstraat is an inner city intersection with a typical Dutch road design with partially separated (protection islands) and coloured bike paths at both sides. Space is limited and cannot be broadened.

The detection of the near accidents was conducted at six days in March 2020 from 6 am to 10 pm. The overwhelming majority of the near accidents is happening when vehicles turning to the left from Assendorperstraat to Luttenbergstraat (see Fig. 3). More than 900 (>85 percent) of the 1050 detected situations are happening when cyclists crossing the bike path. Only a very small number of situations occurring at other spots.

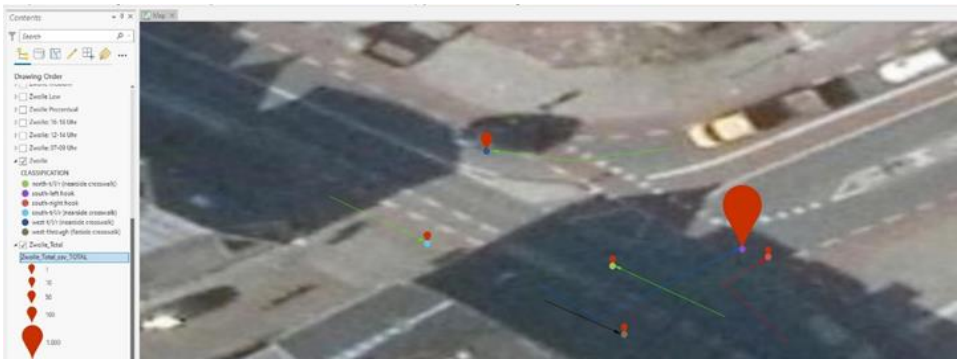

Fig. 3: Near Accidents at Assendorperstraat/Luttenbergstraat. Source: ArcGIS, copyright by Esri.

A look to the relation of the speed levels and the time to collision shows a slightly different image. The most critical situation that may occur is still a vehicle that turns from the Assendorperstraat to the left into the Luttenbergstraat. Although the total number of

situations is not high at this location, an increased share of medium risk situations occured when cyclists crossing the Assendorperstraat straight to the Southwest into the Bartjenstraat. Many vehicles are crossing the Assendorperstraat with high speed.

The KPIs in Tab. 4 show that average speed levels are lower (15 km/h) compared to the Friesland cases. Before 2 pm the speed level is below 15 km/h. Later it is slightly increasing up 16.5 km/h. The total number of near accidents (1090, around 181 per day) and the frequency (seven minutes and 55 seconds for one situation) is also lower. The share of medium risk near accidents is higher: Nearly 50 percent of all near accidents (525) are belonging to the medium risk class. The relating frequency of 16 minutes and 27 seconds is close to Haadwei-Thiedamawei (15 minutes and nine seconds, see Tab. 2) and higher compared to Haadwei-Foarwei (18 minutes and three seconds, see Tab. 3). Three high risk situations were registered in the measurement in Zwolle.

Risk Level	Average vehicle speed per period	
Average speed total	15 km	
Average count per day	181.67	
Average count per hour	7.57	
	Count & Average speed (according to risk class)	Frequency (according to risk class)
Low	562 (11.25 km/h)	00:15:22
Medium	525 (18.9 km/h)	00:16:27
High	3 (36.55 km/h)	47:59:40
Total	1090	00:07:55

Tab. 4: KPIs Assendorperstraat & Luttenbergstraat (Zwolle). Source: https://bicycle-data.de/city-analysis/

3.4 Oldeneelallee (City of Zwolle)

The fourth use case of this study is the Oldeneelallee in Zwolle. The location in the Southern part of the city is a multilane road which is interrupted by railway tracks on the eastern side. In the Northern (connection to the Burgermeester de Vos van Steenwijklaan), the Western and the Southern part (connection to the Gouverneurlaan) the intersection can be crossed by cyclists. Many media and police reports about traffic accidents can be found [Al20, vdZ20, RTV18]. The camera detection took place for seven days in late October / early November 2020 from 7 am to 5.30 pm. At the 30st of October the system was only active from 7 am to 2 pm.

More than 40 percent (187) of all critical situations are happening at the northern axis. Here are some problems on the bike path when vehicles turning to the left into the Burgermeester de Vos van Steenwijklaan. The southern axis also shows a lot of conflicts (160). Here is also a problem with vehicles turning to the left leaving the Oldeneelallee into the Gouverneurlaan direction (70). In addition, many situations also occur when the vehicles driving straight from the northern axis and leaving the intersection at the Southern axis (79). At the western side of Oldeneelallee quite a lot of near accidents can be perceived when vehicles approaching from the northern axis and turning to the right (71).

Three high risk situations at the western axis were registered what what makes it to a conflicting spot. The site view seems to be not optimal at this part of the intersection when cyclists want to cross the Oldeneelallee to the Southern direction.

Average vehicle speed levels at Oldeneelallee (17 km/h) are slightly higher compared to Assendorperstraat-Luttenbergstraat but lower compared to the Friesland use case (Tab. 5). The speed level remains constant over the whole day around 16 and 17 km/h. As an outlier, in the late afternoon the speed level is increasing exorbitantly. Compared to the other intersections that were discussed before, the total number (447), the average count per day/hour (63/2-3) and the frequency (22 minutes and 32 seconds) of the near accidents are relatively low. The number (169) and share of low risk situations (37 percent) are the lowest of all four intersections. The distribution of high risk situations is remarkable: More than 60 percent of all near accidents are belonging to medium or high risk situations. Although the total number of conflicts is low, Oldeneelallee is the only intersection that counts five high risk situations including a hotspot. The average speed level (39.45 km/h) is higher compared to the Haadwei-Foarwei case. Oldeneelallee is the only intersection with a share of high risk situations (>one percent). The probability for a critical situation is much higher although near accidents are happening less frequently. It can be concluded that this intersection may have some severe traffic safety issues.

Risk Level	Average vehicle speed per period	
Average speed total	17.09 km	
Average count per day	63.86	
Average count per hour	2.66	
	Count & Average speed (according to risk class)	Frequency (according to risk class)
Low	169 (12.09 km/h)	00:59:38
Medium	273 (19.77 km/h)	00:36:55
High	5 (39.45 km/h)	33:35:48
Total	447	00:22:32

Tab. 5: KPIs Oldeneelalle (Zwolle). Source: https://bicycle-data.de/city-analysis/

4. Conclusion

As part of this study we tried to compare the cycling safety situations at four different intersections in the Netherlands based on a 3D camera data collection based on vehicle speeds and PET. We learned that two intersections in the Province of Friesland with a shared space concept show a high number of situations and high frequencies what means that more near accidents are occurring in the same time. An increased average speed of the vehicles can be perceived. The number of situations is slightly higher at Haadwei-Thiedamawei compared to Haadwei-Foarwei, but the speed level is slightly higher at the second one. The measurement at Haadwei-Foarwei also include some high risk situations what is surprisingly not the case at the first intersection although this is the place with the highest total number of situations. Both data sets show increased average speed levels in

the peak hours in the morning and in the afternoon.

Inner city intersections may show other characteristics regarding traffic safety compared to rural areas. The near accidents at the Assendorperstraat-Luttenbergstraat intersection that was designed in a typical Dutch style are happening with a comparatively low average vehicle speed of 15 km/h. A trend to increasing speed levels in the afternoon peak hours can be perceived. The high majority of the situations is detected when the cars turning to left. Another relevant risk potential was identified when the moving straight forward vehicles approaching the intersection with increased speed levels although these situations do not happen very often.

At the Oldeneelallee by far the lowest number of situations was detected. Only one near accident occurs in 22 minutes. Compared to Haadwei-Thiedamawei it is the other way around: The measurement at the intersection with the lowest number of detected situations include the highest number of high risk situations. The probability for a medium or high risk situation is highly increased at this location. Especially the crossing in the northwestern part of Oldeneelallee where several high risk situations were detected seems to have problems with the road design what is confirmed by local media reports. Similar as at Assendorperstraat-Luttenbergstraat, vehicles are speeding up when going straight through. The site view for cyclists seems to be limited and may be improved to increase traffic safety. After improvements has made, a before and after analysis on the effects of the measures can be realized as the The Hague study by the Institute for Road Safety Research SWOV has tried.

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