How to Measure Safety Risks for Cyclists at Intersections?

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1 Introduction

Many municipalities in Europe and the rest of the world realized that the promotion of cycling is an attractive and cost efficient solution for traffic and environmental problems (European Commission, 2020). To confirm more people to cycle more often an attractive bicycle infrastructure is a key factor. That means that the quality of bicycle paths (e.g. surfaces, connections), the degree of traffic safety (e.g. risks at intersections) or travel times (e.g. waiting times at traffic lights) has to be improved. It is a big problem at this point that there is no or only too little suitable data on bicycle traffic available that could be used by traffic or city planners for the further expansion and the adjustment of the infrastructure to the concrete needs of cyclists (Monheim et al., 2016). Therefore, more and more cities or regions and research institutions started data driven initiatives to learn more about cyclists' behaviours and demands to actively find solutions to that problem (Fahrradportal, 2017). This leads to bicycle data which is collected by diverse sensor systems—so-called *Intelligent Transport Systems* (ITS). Bicycle counting, intelligent bicycle parking, bike2work campaigns based on bicycle apps, smart camera systems to detect (near) accidents, sensor systems to measure air quality or other solutions are

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already used in cities all around Europe and the rest of the world. The challenge here is that most of these applications are not aligned to each other in neither the national nor the European context. This makes an evaluation of the potentials of existing (and forthcoming) ITS solutions in the field of cycling very difficult or nearly impossible. Countries and even cities are not comparable in their efforts of cycling promotion (e.g. traffic safety, amount of cyclists). The effect and the potential of these local based solutions on mobility transition in cities remain unclear as there are diverse approaches how to count or detect cyclists not only in one country but in nearly every city working on data driven solutions for cyclists (European Commission, 2020). As a result, standards on open bicycle data for a common understanding do not exist so far.

The EU funded project *BITS (Bicycles and Intelligent Transport Systems)*[1] is working on solutions to the challenges mentioned above. One of the central goals of the project is to make cycling data from different European countries available in a comparable format and structure. This target will be delivered by an open data platform, the so-called *CyclingDataHub* (CDH)[2] which is hosted by the Province of Antwerp (Belgium). The platform gives all interested stakeholders open access to external data sets with focus on ITS applications in the cycling domain. Facing more and more digitalized societies, the idea is to increase the amount of available cycling data by external stakeholders as municipalities, businesses and researchers working on data driven cycling solutions. Interested external partners as the Province of Utrecht or the Region of Hannover are also contributing to the CDH by supplying their specific data sets. The digital platform as result of the BITS project will be a step forward to a common understanding of cycling data and makes *SmartCycling* more visible in the European and the transcultural context.

Initial cycling data sets will be delivered by the pilot regions of the BITS project through the implementation of already existing and totally new ITS as camera detection of near interactions (e.g. Province of Antwerp), bicycle counting (e.g. East Riding of Yorkshire), digital bicycle parking (e.g. City of Bruges) or air quality sensor systems (e.g. City of Zwolle) in the whole North Sea region (Netherlands, Belgium, Denmark, Germany, United Kingdom). The implementations will be evaluated in terms of its potential to attract more people for bike usage and to make cycling more safe and smart. One of the key ideas of the Interreg funded project is that regions which promote cycling for a very long time (Netherlands, Belgium, Denmark) exchange ideas with less experienced regions (Germany, UK) to identify the best solutions and new approaches. Therefore, the smartest solutions will be transferred, tested and evaluated to other partner regions as part of the project.

[1] https://northsearegion.eu/bits/

[2] www.cyclingdatahub.eu

1.1 Cycling Safety and Relevance of near Interactions

The promotion of cycling becomes more and more attractive for cities and regions. As mentioned above, an improvement of traffic safety for cyclists contributes to a more frequent bicycle use. A bicycle infrastructure with a high level of safety feeling is an important factor whether people decide to cycle more often or not (Fahrradportal, 2019). One important indicator regarding the safety level is the number of bicycle accidents in the whole city area (or at certain problem points as intersections or streets without bike lanes). If the number of accidents is decreasing parallel to an increasing degree of bicycle use, it can be assumed that a) cycling is more recognized by other traffic participants and / or b) that infrastructure improvements successfully led to more traffic safety (Keller, 1988). While sales quantities and the availability of pedelecs (*pedal electric cycle*) are increasing (Zweirad-Industrie-Verband, 2020), the number of bicycle accidents is growing. Although the number of people died in traffic accidents in Germany using all means of transport decreased, the number of killed cyclists as consequence of bicycle accidents is increasing year by year (Süddeutsche Zeitung, 2019). In total, the amount of cyclists involved in an accident in Germany increased up to 30 percent between 2000 and 2018 while the number of other traffic participants involved in an accident has decreased for more than 30 percent at the same time (Ortlepp, 2019). Because of the strongly growing during the Corona pandemic when many switched from public transport to more individual means of transport as the bicycle or the car to keep distance, experts assume that the number of killed and severely injured cyclists will grow even further (RP Online, 2020).

Especially the traffic safety situation at intersections needs to be improved. Earlier statistics from the late 1980s revealed that during that time already more than 50 percent of the bicycle accidents in inner cities were happening at intersections with an increased risk at night and in the early morning because of reduced lightning conditions (Heuser, 1987). More recently published statistics (e.g. German Bicycle Club ADFC, City of Muenster, Germany) show that nowadays more than 60 percent of the inner city bicycle accidents are happening at intersections (Ortlepp, 2019; Korn & Thiemann Linden, 2012). The danger potential arises if cyclists do not follow traffic regulations when turning especially to the left, running red lights, cycling on the wrong (and prohibited) side of the road or cycling directly on the automobile road instead on the separated bicycle path. To increase the safety level of cyclists at intersections, the bicycle traffic guidance needs to be clearly visible for all traffic participants, priority rules need to be precise, cyclists have to be separated by motorized traffic in a sufficient degree and the sight view of the cyclists should not be restricted (Ortlepp, 2019; Stock, 1980). Other factors of the intersection as the average daily volume of motorized traffic and bicycles, the width of the side walk and the existence of traffic islands may have an influence on the frequency of critical situations (Kim et al., 2012).

A big problem that is not solved so far is that many dangerous situations at intersections are not registered. At least a high number of accidents with severe injured or killed cyclists are reported to the police. Nonetheless, many accidents are not documented. About 42 percent of the accidents with severe injured and 25 percent of the accidents with light injured will not be part of the statistics (Keller, 1988). According to a research of Hautzinger the estimated number of unreported cases is very high. Nearly 99 percent of all single-bicycle accidents, about 97 percent of all accidents between cyclists and pedestrians and about 82 percent of all accidents between cyclists and cars are not part of official accident statistics (Hautzinger et al., 1993). When it comes to near accidents or interactions the reporting rate becomes more and more uncertain. According to the results of a survey among cyclists in Freiburg, Germany, about one-third of the respondents stated to be involved in a cycling accident in the past few years. More than three out of four people indicated that they were involved in at least one near accident (Fuchs & Pfeiffer, 2009). That many cyclists are experienced with near interactions is validated by another study from Brazil. Over a duration of 17 months 1.133 bicycle commuters were screened (e.g. by telephone interviews). According to this study 9 percent of the respondents were involved in a bicycle accident, while 88 percent stated to be involved in at least one near accident (Bacchieri et al., 2010). A survey by the German Traffic Safety Council (Deutscher Verkehrssicherheitsrat DVR) among 1.000 adult cyclists revealed that nearly 50 percent of the responding cyclists were involved in at least one near accident with a suddenly opening car door ("dooring" situation) (Deutscher Verkehrssicherheitsrat, 2019). Factors which are part of registered bicycle accidents are quite well known. Especially seniors and children are endangered. Male cyclists are much more often killed in traffic accidents (Auto Club Europe, 2011). However, safety statistics do only cover situations which were reported to the police. As mentioned above, in the field of cycling these are mainly accidents with severe consequences (killed or seriously injured cyclists) (Statistisches Bundesamt, 2019). As most of the near accidents are not reported to the police, the frequency of near accidents or near interactions between cyclists and other traffic participants was observed mainly by surveys (e.g. Freiburg, Brazil) but not by camera measurements. That means that the available data on near interactions is mainly based on the subjective perspective of the cyclists. As it is not clearly defined what near interaction or near accident does mean, the existing results are not or at least only hardly comparable. The objective perspective (e.g. by sensor systems) of near interactions was not detected so far.

The numbers mentioned above make clear that there is a huge demand on data about conflict situations which do not result in an accident. Therefore, the first main research question of this paper is how to detect near interactions between cyclists at intersections by ITS (in this case camera systems). The detection of near interactions at intersections could contribute to a higher degree of safety and comfort for cyclists on the mid and long term as new conflict points in the bicycle infrastructure could be identified. The prerequisite for more safety is that the knowledge collected is integrated in forthcoming infrastructure improvements. As the newly generated data should not only contribute to the improvement of the traffic situation at one certain intersection the data need to be opened to a broader audience. That leads to the second research question of this contribution. In the following it will be answered based on the specific example from Antwerp what steps are necessary to take to make the resulting data publishable in a high quality for interested stakeholders on open data portals as the CyclingDataHub. Finally, it will be discussed how to evaluate the regarding traffic safety. One existing approach to measure a collision risk of specific traffic situations is the Surrogate Safety Measure (SSM) that is based on traffic parameters as speed, acceleration, time and space headway. The term *surrogate* stands for identifying safety critical events (or near accidents) in traffic, which can be used as an alternative to accident records (Johnsson, 2020). The Time-to-Collision (TTC) estimates the expected time when two traffic participants collide and is often used to judge the degree of danger of a certain conflict situation. Based on that different driving assistance systems with focus on motorized traffic and different types of driver behaviours (e.g. sensor, V2V communication based) have been developed (Tak et al., 2018).

2 Measurement of near Interactions with 3D Camera Technology

The first discussion point of this publication is how to detect near interactions between cyclists at intersections by ITS. As part of the European project *BITS (Bicycles and Intelligent Transport Systems)* which is funded by the North Sea Region (NSR) programme and is aiming at the improvement of the availability of open bicycle data regarding road safety, convenience and comfort for cyclists, the Province of Antwerp tested a 3D camera technology by Viscando from Sweden to detect near interactions between cyclists, vehicles and pedestrians at a dangerous intersection in late September 2019. Facing the challenges mentioned above, the topic of near accidents seems to be quite relevant as local police reports reveal that the number of bicycle accidents in Antwerp has increased between 2014 and 2018 year by year (Wang et al., 2019). The observed intersection is located in the municipality of Bornem which has about 20.000 inhabitants and belongs to the arrondissement Mechelen in the southwestern part of the Province of Antwerp. At the Puursesteenweg a cycle highway is interrupted by a traffic lane and railway tracks.

The images of the 3D camera are automatically processed what means that no images or video files are recorded. The traffic participants are divided into different categories as cyclists, pedestrians and vehicles (cars and trucks). The trajectory of every road user is registered with a time stamp. A conflict situation is detected when two traffic participants are crossing one another's trajectory and do pass this crossing point in a time interval below 1 s (dT, time difference between the arrival of the two objects at the conflict point CrossPtX, CrossPtY). This time difference is often referred as Post Encroachment Time (PET) in literature (Paul, 2019). For the localization the intersection was divided into a coordinate system (Fig. 1). The conflicts are detected with an accuracy of about 15 centimetres. To enable

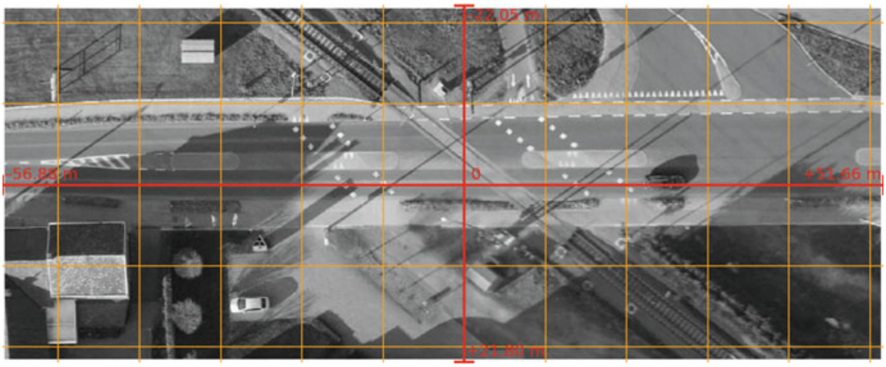

Fig. 1 Coordinate system at the intersection in Bornem / Antwerp. Source: Viscando, Province of Antwerp

a localization each conflict situation contains an x and y coordinate (CrossPtX, CrossPtY on the ground plane of the point of intersection between the trajectories of the tracks that participate in a conflict). In total, 114 near interactions between cyclists were detected during 5 days of measurement (Monday, the 23rd until Friday, the 27th of September 2019). It has to be mentioned that the near interactions between cyclists and vehicles or pedestrians will not be further discussed in detail in this publication.

3 Evaluation

One of the main deliverables of the BITS project is the realization of a European open data portal with focus on bicycle data. The approach of the so-called *Cycling-DataHub* is to make cycling data from all over Europe available and accessible for external stakeholders. Municipalities, research projects and other interest groups can publish their cycling data in categories as Cycle Use, Cycle Infrastructure, Safety, Environment and Emissions and Bicycle Business Performance. Therefore, the second research question which needs to be discussed in the following is what problems need to be solved to make the resulting data publishable in a high quality for interested stakeholders on open data portals.

As part of the pre-processing phase third parties and stakeholders which are interested to work with this kind of open data need to be enabled to localize the intersection and the conflict points. Therefore, the x and y coordinates given need to be converted into geocoordinates (longitude and latitude format, see 3.1). In addition to the missing localization, it was not clear which of the near interactions measured are more conflictful or even dangerous than others. Although the degree of severity and of relevance regarding the risk estimation was not calculated in detail for each near interaction point so far, first ideas on how to evaluate the near interactions on safety issues were collected. This leads to the third research question of this research paper how to evaluate the resulting data regarding to safety issues. As we may learn by Surrogate Safety Measure, a study of speed levels, the time-to-collision and cycling directions could contribute to assess specific risks at intersections. Regarding the time dimension the conflict situations were filtered into different times of the day (morning, noon, afternoon) to understand the distribution of the near interactions over the whole day (see 3.2). Based on the vx and vy coordinates of cyclists and other traffic participants (e.g. vehicles) the average speed levels were calculated. These were not only divided into different times of the day but also geographically to the different parts of the intersection. In the last step cycling directions were determined (see 3.3). Contrasting directions could mean a higher potential risk at a certain point and could be more relevant for a later risk assessment (see conclusions and future work 4.).

3.1 Geocoordinates

The conflict points in the raw data set were only provided with x and y coordinates on the intersection in the coordinate system by Viscando (see Fig. 1). To enable external people who are interested to work with the data set to locate the intersection and the conflict points, the University converted the x and y coordinates into geoinformation in the longitude and latitude format. The geocoordinates of the zero point (Fig. 1, point of intersection of the red lines) are 51.085709, 4.263511.

$$\text{Conversion formula longitude} : \text{dx}/\ (111300 * \text{COS}(51.085703)) + 4.263511),$$

$$\text{Conversion formula latitude} : (-\ (\text{dy}/111300) + 51.085703)$$

$$\text{dx in metres} = \text{Distance x coordinate from the zero point}$$

$$\text{dy in metres} = \text{Distance y coordinate from the zero point}$$

$$111,300 \text{ in metres} = \text{Distance of latitude (constant)}$$

$$\text{COS}(51.085709) = \text{Correction factor of longitude}$$

3.2 Filtering into Different Times of the Day

The 114 conflict situations at the intersection all contain a number dT between 0 and 1 which indicates the time to conflict point in seconds (time difference between the arrival of the two objects at the conflict point). These were filtered into conflict situations of above 0.2 (39 situations), between 0.1 and 0.2 (17 situations) and below 0.1 (56 situations). In a next step the conflict situations were filtered into different times of the day (morning, noon, afternoon). The average mean time of a near interaction over the day is 32 minutes. The peak time can be identified in the morning hours (7 h–9 h) with one near interaction each 17 minutes. The mean time at the afternoon (16 h–18 h, 24 minutes) is also higher compared to the average level but lower compared to the morning. Monday is the day with the shortest mean time of near interactions over the day (25 minutes).

The calculated mean times can be validated by the numbers of bicycles counted during the 5 days of the 3D camera measurement. As mentioned above, the daily traffic volume (e.g. motorized traffic, bicycles) may have an influence on the frequency of critical situations. This can be proven by other statistical values of the Province of Antwerp. Besides the measurement of near interactions at intersections, the Province is counting bicycles at different locations on a regular basis. Two counting stations are located at the municipality of Bornem (FMN GV 04 A Bornem and FMN GV 04 B Bornem) close to the intersection. The hourly values of these two stations during the last working week in September 2019 reveal that there were two peaks in the amount of counted bicycles between 7 h and 9 h in the morning and 16 h and 18 h in the afternoon (Fig. 2). That confirms the assumption that the frequency of near interactions increases when the amount of counted cyclists is growing. Taking the bicycle counting data into account, this effect seems to be stronger in the morning as the total number of counted bicycles in the afternoon is slightly higher compared to the morning hours.

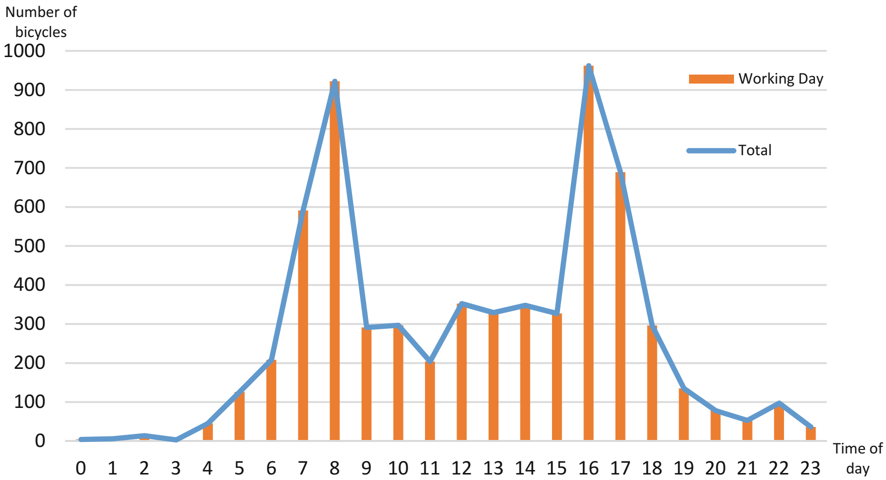

Fig. 2 Number of counted bicycles per hour in Bornem, 23rd to 27th of September 2019 (University of Oldenburg)

After all it can be summarized that according to the calculated mean times the probability to be involved in a near interaction with another cyclist is much higher in the morning compared to other times of the day. The frequency of conflict situations in the afternoon is lower than in the but higher as the rest of the day. These results are confirmed by the statistics of bicycle accidents in European cycling cities. According to statistics of the City of Erlangen / Germany, most cycling accidents are registered between Monday and Friday in the morning time (7–9 h). In addition, there are also many cycling accidents registered between Monday and Thursday in the afternoon (16–18 h) (City of Erlangen, 2017).

3.3 Speed Levels and Directions

Beside the mean times the speed levels, the average speed and the speed distribution in kilometres per hour (km/h) of all conflict situations were calculated as other potential relevant key performance indicators (KPIs). The speed levels can be calculated by the vx and vy coordinates given by each vehicle or traffic participant (x and y components in metres per second of the velocity vector for the tracks participating in the conflict at the point CrossPtX, CrossPtY).

Speed level in km/h:

$$\Delta \mathrm{V} = \sqrt{\left(\Delta \mathrm{vx\hat{}2} + \Delta \mathrm{vy\hat{}2}\right)} * 3.6$$

The average speed of all near interactions is 11.270 km/h, the top average speed of one interaction is 22.296 km/h. As another step of the data preprocessing outliers had to be removed as motorcycles, scooters, mopeds, bicycles and speed pedelecs were not divided. One alleged bicycle crossed the intersection with a speed level of 80 km/h, another one with 45 km/h, two other ones with more than 30 km/h.

Not only the mean times but also the speed levels reflect that the risk to be involved in a near interaction could be higher in the morning compared to other times of the day. Between 7 h and 9 h when many commuters cycling to work or school what is confirmed by the bicycle countings (Fig. 2) the near interactions with the highest average speed levels can be identified (12.962 km/h). The speed levels in the afternoon (16–18 h) are close to the average speed levels (11.086 km/h) (Table 1).

When discussing about potential risks and speed levels it also has to be mentioned that quite a lot of near interactions with very low speed levels were measured. More than one-third of all situations (39) with an average speed level below 10 km/h were detected (see distribution of average speed levels in Fig. 3). A very low risk of these near interactions as part of a later risk assessment process (see 4. conclusions and future work) can be assumed.

Table 1 Average speed levels of all near interventions (University of Oldenburg)

	Average in km/h	7 h–9 h	12 h–14 h	16 h–18 h
All days	11.270	**12.962**	9.530	11.086

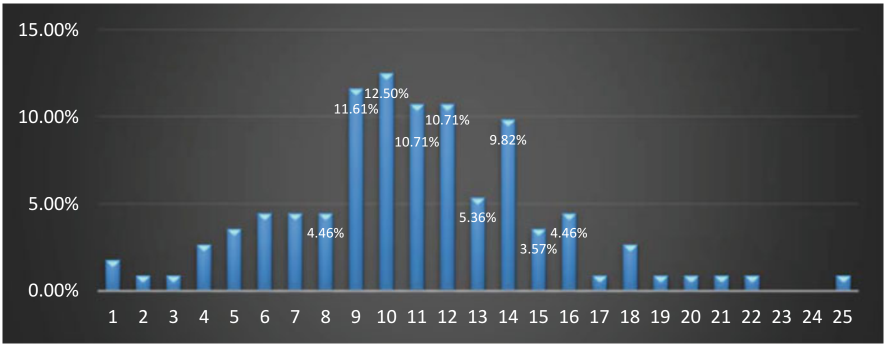

Fig. 3 Distribution of average speed levels (University of Oldenburg)

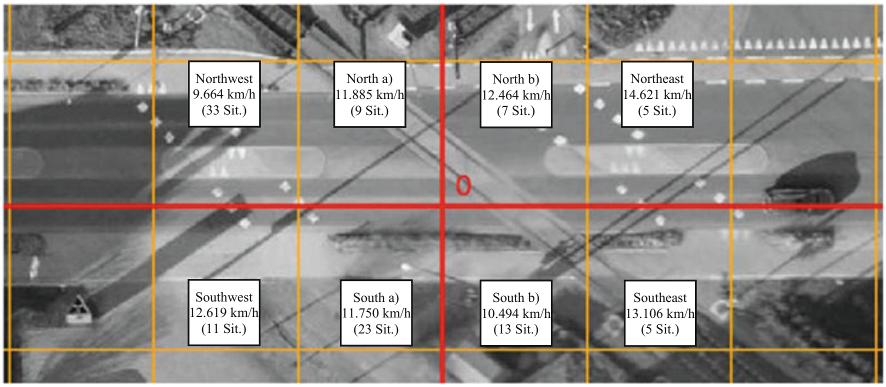

Fig. 4 Geographical distribution of all speed levels (grid by Viscando, values by University of Oldenburg)

It can be assumed that a supposed bicycle that passes the intersection with a speed level faster than 35 km/h is not a bicycle but could be a motorcycle. Therefore, this small number of high speed bicycles was filtered out of the data set to make the results more accurate.

As a next step, the speed levels were not only investigated in the time but also in the geographical dimension to learn more about risks at different parts of the intersection (Fig. 4.). A higher degree of risk in the southern part over the whole day could be assumed as the average speed levels in the southern part of the intersection are higher than the general average speed level. In the field south a) where the cycling path is interrupted, 23 near interactions were detected. It is remarkable that in the northwestern part of the intersection many interactions (33) with a quite low

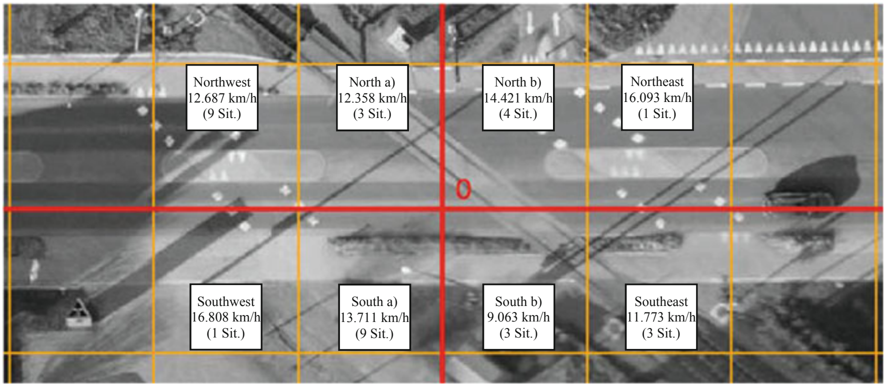

Fig. 5 Geographical distribution of speed levels in the morning time 7–9 h (grid by Viscando, values by University of Oldenburg)

average of speed levels were detected (9.664 km/h). The highest speed levels were detected in the northeast (14.621 km/h) and in the southeast part (13.106 km/h). The number of near interactions detected in the north (54 situations) and the south (52 situations) is nearly equal.

That the morning time is the most conflictful time of the day is also proven by the geographical distribution of the speed levels between 7 h and 9 h (Fig. 5.). In the northern part of the intersection a remarkable increase of the average speed levels could be perceived (13.237 km/h). Especially in the northwestern part the increase is obvious (12.687 km/h). The increase of the average speed levels in the southern part is less remarkable (12.670 km/h) and lower compared to the northern part. Therefore, taking into account the speed levels a higher risk in the northern part during the morning hours could be assumed.

3.4 Preferred Routes and Directions of the Cyclists

The analysis regarding preferred routes and cycling directions by Viscando has shown the following results. When crossing the railway line, as well as when crossing the Puursesteenweg, the cyclists tend to show different preferences of the route they choose depending on the directions they are cycling to. When crossing the railway from the western side, the bicyclists are almost equally likely to choose the northern pavement, the southern pavement or the automobile road, with a slight preference for the latter. When crossing the railway from the east, the cyclists use the northern pavement more often than the southern one. In both cases, between 37 and 39 percent of the cyclists tend to cross the railway at the level crossing for vehicle traffic. When crossing the Puursesteenweg from the north, the cyclists do prefer the eastern crossing slightly more often. When crossing the Puursesteenweg

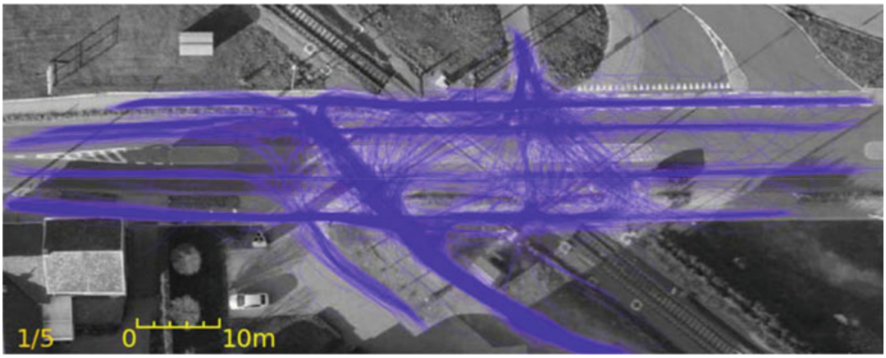

Fig. 6 Heatmap of Bicycle trips. Source: Viscando, Province of Antwerp

from the south, the cyclists show a strong preference for the western crossing. In both cases, there is a significant share of cyclists who tend to shorten their way and cross both the railway line and the Puursesteenweg at the level crossing for vehicle traffic. This tendency is more significant for the bicyclists coming from the cycling path in the northern part of the intersection (see Heatmap Fig. 6).

In addition to the speed levels, the cycling directions could also be a relevant factor to determine the degree of risk of a critical situation. Contrasting cycling directions (combined with differing speed levels of the two cyclists involved) could lead to an increased risk of collision. The cycling directions can be abbreviated by the vx and vy coordinates given of every traffic participant. As an example, cyclist 1 has the coordinates −1.89 (x) and − 3.15 (y). A negative x coordinate means that the cyclist is approaching the intersection from east cycling to the western direction. It has to be mentioned here that the algebraic sign of the y axis (+ and -) is reversed. That means that a negative y coordinate indicates that the cyclist is moving from the southern to the northern direction. At all, cyclist 1 is approaching the intersection from the south and is cycling to the northwestern direction with a speed level of 13.22 km/h. Cyclist 2 with the coordinates 6.91 and 1.37 is cycling to the southeastern direction with 25.35 km/h. It can be deduced that this conflict situation which happened in the central southern part of the intersection had a very high risk of collision because the cyclists moved (a) with a high average speed level of 19.29 km/h, (b) with differing speed levels (13.22 km/h vs. 25.35 km/h) and (c) to conflicting directions (northwestern vs. southeastern direction). Fig. 7 shows some of the most conflictful situations because of high speed cyclists, significant speed level differences and contrasting directions.

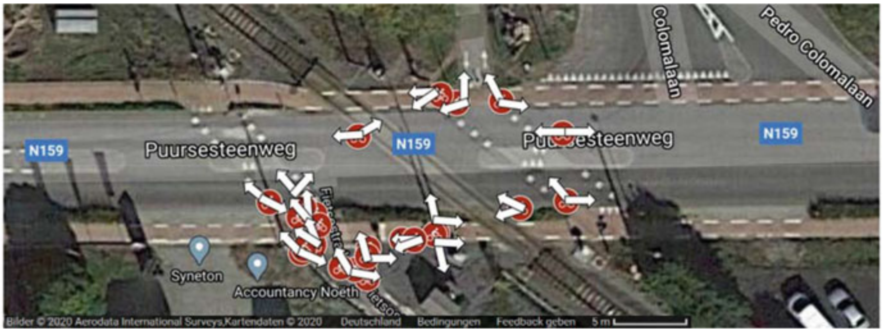

Fig. 7 Some of the most conflictful near interactions regarding speed level differences and contrasting cycling directions. Source: GoogleMyMaps (University of Oldenburg)

4 Conclusions and Future Work

Several research questions were discussed and answered in this research paper. The first question was how to detect near interactions between cyclists at intersections by ITS. The solution which was discussed is the 3D camera system of Viscando that detected 114 near interactions among cyclists during five days in late September 2019. The measurement shows where are problem points at the intersection with an increased number of conflict points. The second research question of this paper was which steps are necessary to make the resulting data publishable in a high quality for interested stakeholders on open data portals. The x and y coordinates of the traffic participants (vx, vy) and the near interactions were transformed into geoinformation to enable the localization of the intersection and the conflict points. It seems to be that not each conflict point has the same relevance in terms of traffic safety what leads to the third research question how to evaluate the resulting data regarding to safety issues. To further understand the degree of risk of a near interaction the speed levels and the directions of the cyclists were further investigated. Especially in the morning hours (7–9 h) many near interactions with increased speed levels were detected. Taking the number of counted bicycles in Bornem into account, it can be assumed that there is a connection between the number of near accidents and the number of cyclists passing the intersection. The average speed levels in general tend to be higher in the southern part of the intersection but are higher in the northern part in the morning hours. The cycling directions reveal further conflict potential as contrasting directions of two cyclists could be more dangerous than equal directions.

The preprocessed and refined data set of the near interactions including geoinformation and speed levels will be provided and make public accessible in the *CyclingDataHub* and other open data portals in a suitable raw data format. The quality standards defining the quality of open data according to the 5-star open data model by Berners Lee will be considered. That includes an open license, a structured data set in a machine readable format (e.g. CSV or JSON but no PDF file), open standard formats, usage of Uniform Resource Identifiers and linkage to other similar data sets in a common structure and format (Oyama et al., 2016). Based on the results of the detection of the near interactions the Province of Antwerp is actually planning construction measures to improve the traffic safety situation at the intersection in the municipality of Bornem. The idea is to repeat the detection of near interactions by the 3D camera system after realizing the measures to evaluate whether the level of safety has increased.

Generally applicable factors on the safety assessment of cyclists' safety at intersections could be deduced by the results of the study of the near interactions in Antwerp which were discussed in this paper. Based on the results of the University, the Province of Antwerp and Viscando are now working together on a methodology to measure risk levels for cyclists at intersections. As can be understood from the results above and existing methodologies as the Surrogate Safety Measure, differences and distributions of speed levels and cycling directions seem to be important indicators to measure the degree of risk of a certain near interaction.

To learn more about cycling safety at intersections the Antwerp case need to be compared to measurements at more intersections. A remaining question which will be part of future research is how intersections in different countries and cities could be compared regarding traffic safety. As part of the BITS project near interactions between cyclists and vehicles at two intersections in the Province of Friesland and another two in the City Zwolle were detected in the Netherlands. The camera system which was tested in these implementations is different compared to the Viscando technology. The speed levels of the vehicles and the time difference to collision (value between zero and 5 s) were measured. The four Dutch cases will be compared to the Antwerp case where 32 near interactions between cyclists and vehicles were detected. Although the conflicts between cyclists and car drivers or trucks were not discussed in detail in this publication, it can be mentioned that the average speed levels of the vehicles in Antwerp tend to be higher (23 km/h) compared to the other intersections. Therefore, a higher risk compared to the Dutch cases could be assumed. Nonetheless, further research which will be part of future publications is necessary at this point.

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