Analysis of stopping behaviour of cyclists at a traffic light-controlled intersection using trajectory data

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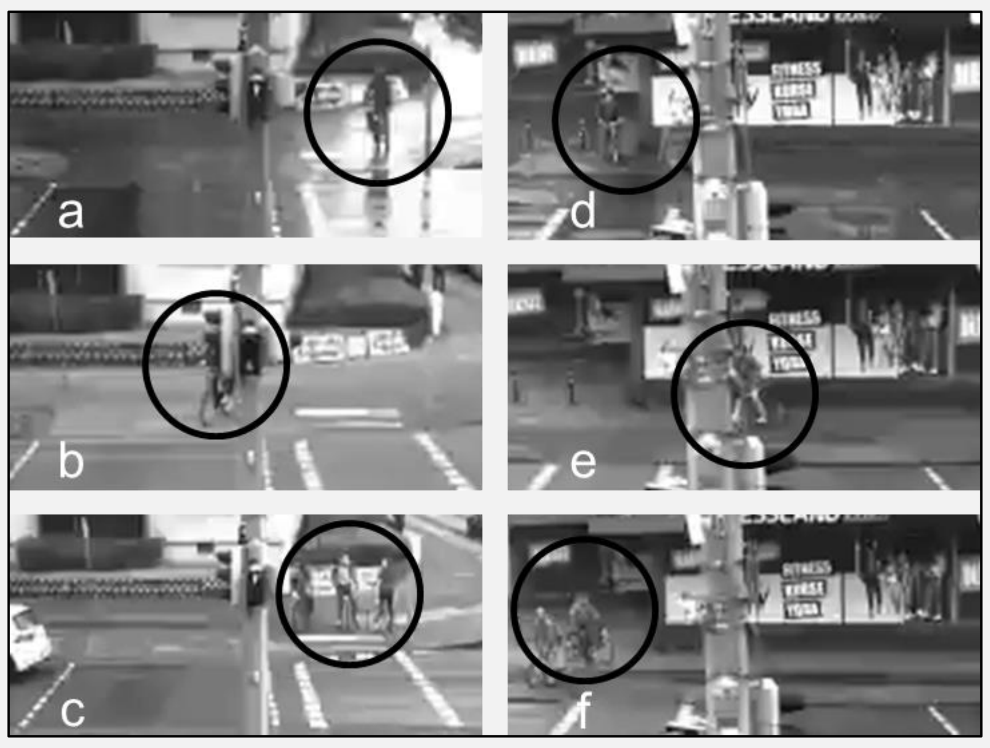

Figure 1. Examples of different stopping behaviours. First column shows the correct direction of travel and second column shows the wrong-way cyclists.

Introduction

Infrastructure elements like stop lines, footpaths, and bicycle paths provide vulnerable road users (*VRU*) where to stop, but actual stopping behaviour differs from the guidance. In addition to poor infrastructure, such as potholes or high curbs, the presence of other road users and the further route choice can also affect the stopping point of *VRUs* at intersections. An analysis of the stopping behaviour can help to improve simulation models because this is currently hardly considered and cyclists stop at an imaginary line. Parameter distributions can be used for implementation for example in the microscopic simulation SUMO (Lopez et al., 2018). Additionally, the analysis can point out further risks for autonomous driving.

Method

The traffic observation took place between March 11th and March 17th 2019 at the AIM Research Intersection in Brunswick, Germany. This large-scale research facility is part of the Application Platform for Intelligent Mobility (AIM) and records trajectory data with stereo-camera systems.

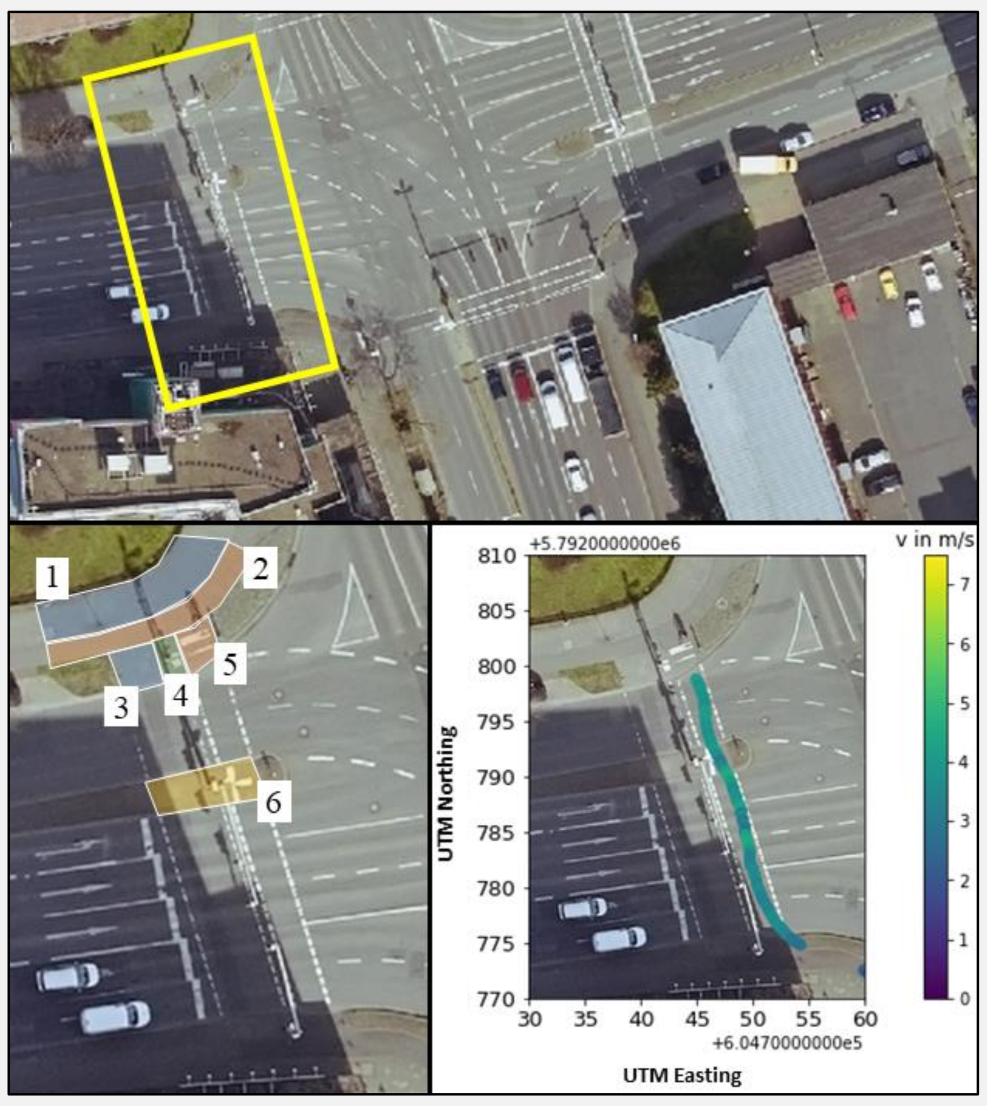

Figure 2. AIM Research Intersection in Brunswick, Germany; orientated North. Top: Satellite image of AIM Research Intersection (yellow: area of interest for this analysis). Bottom, left: Detailed view of the area of interest with polygons (1: footpath, 2: bicycle path, 3: waiting area and stop line for pedestrians, 4: space between pedestrian and bicycle waiting areas and stop lines, 5: waiting area and stop line for cyclists, 6: crossing aid). Bottom, right: An example trajectory of a cyclist on the bicycle path in map projection system UTM 32U. Orthophoto source: DLR e. V.

The period of daytime from 6:30 a.m. to 6:30 p.m. was analysed. The intersection has separate footpaths and bicycle paths, separate stop lines for both, and also separate crossing lanes for pedestrians and cyclists (Figure 2, top). The area of interest for this analysis was divided into areas with the help of polygons (Figure 2, bottom left).

Results

Cyclists without the presence of other cyclists (cyclist alone = *CA*) as well as cyclists with at least one other cyclist (cyclist in group = *CG*) in the crossing area were analysed.

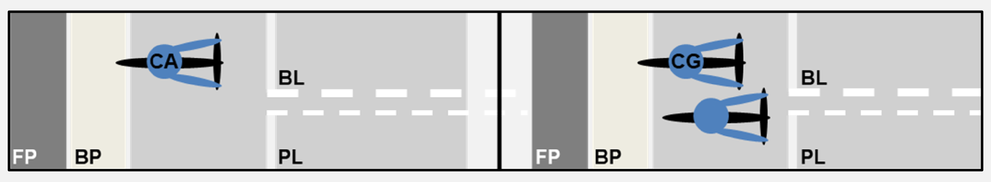

Figure 3. Overview and explanation of abbreviations: Cyclist alone (*CA*, left) and Cyclist in group (*CG*, right). Both variants can use the pedestrian lane (*PL*) or bicycle lane (*BL*) and can start in front of *PL*, *BL* or on footpath (*FP*) or bicycle path (*BP*).

The stopping behaviour of cyclists differs depending on whether the permitted direction of travel was used or not. The permitted direction of travel for cyclists is counter-clockwise at an intersection in Germany. Figure 3 shows the introduced abbreviations. There is a stop line in front of the *BL* and the *PL*. Behind the small waiting area for cyclists at the stop line in front of *BL* is the bicycle path (*BP*) and behind this the footpath (*FP*). As already shown in Figure 2, all possible areas were examined as potential stopping areas. There were no stops in the *BL* and *PL* areas (see Figure 2), which are on the roadway for motorized traffic.

During the observation period, 1,886 cyclists (incl. wrong-way cyclists (*WWC*)) were tracked and used for an analysis. There were 1,411 Cyclist alone (*CA*) and 475 Cyclist in group (*CG*) at the intersection.

Table 1. Comparison of *CA* and *CG* distinguishing whether the cyclist stopped or rode through (without stop) and if so, where the cyclist stopped or which lane the cyclist used (*PL* or *BL*).

CA (n = 1,411)	stop and ride	*PL*	n = 61
		BL	n = 371
	ride without stop	*PL*	n = 125
		BL	n = 854
CG (n = 475)	stop and ride	*PL*	n = 2
		BL	n = 188
	ride without stop	*PL*	n = 2
		BL	n = 283

Table 1 shows the different classes of both groups according to stopping or not stopping and where they stopped or rode. Both *CA* (69.38%) and *CG* (60.00%), crossed the intersection more frequently without stopping within the observation period. In all cases, cyclists stopped more often at the *BL* or used the *BL*, thereby complying with the law. Only 13.18% of the *CA* and 0.84% of the *CG* stopped at the *PL* or drove on the *PL* without stopping. *WWC* on the *BL* were analysed and in the case of *CA* without stopping, there were around 7% *WWC* (n = 41), in the case for *CA* with stopping, there were around 10% *WWC* (n = 27).

A distinction was made between cyclists who stopped before crossing the intersection and cyclists who crossed through without stopping.

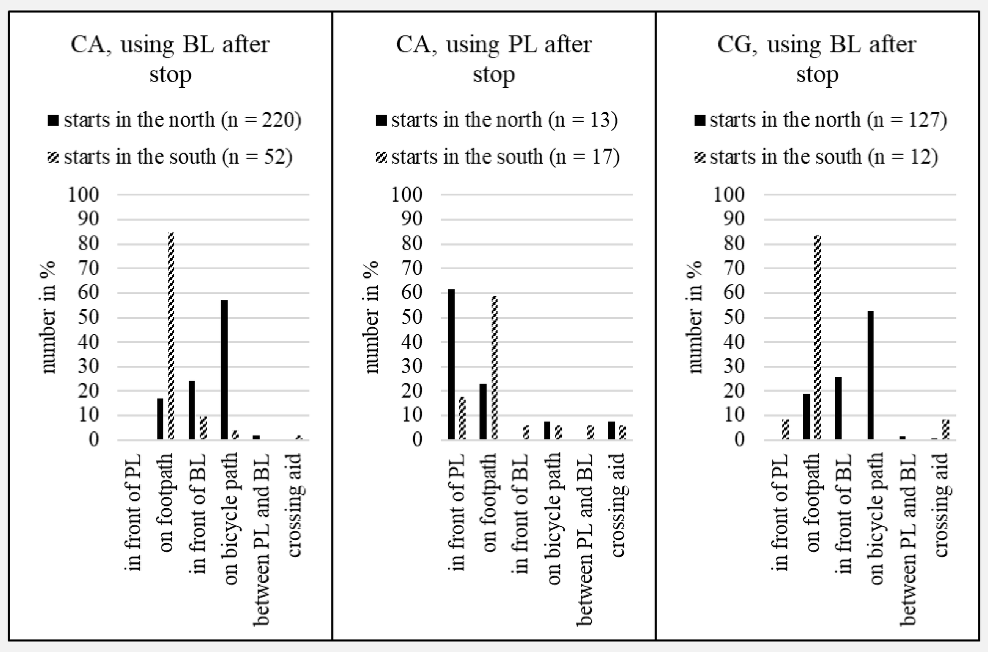

Figure 4. Comparison of stopping locations. Left: *CA* and using the *BL* after stopping. Middle: *CA* and using the *PL* after stopping. Right: *CG* and using *BL* after stopping. *CG* using *PL* after stopping is not shown. "Starts in the south" are *WWC*.

CAs using *BL* after the stop, stopped most often on the bicycle path (57.27%) but *WWC* with 84.62% on the footpath (Figure 4, left and Figure 1a + d). Possible reasons for this can be that the stop line is too close to the road and it feels unsafe for the cyclist or that puddles have formed on the roadway due to the precipitation and the cyclists have taken more distance to the intersection. If cyclists used the *PL* after stopping, their previous stopping position were concentrated in front of the *PL* (61.54%), while the previous stopping position of *WWC* were mostly on the footpath (58.82%) (Figure 4, middle and Figure 1b + e). The distribution of stopping position for *CG* using *BL* after the stop is similar to *CA* using *BL* after the stop. The most frequent stop is on the bicycle path and for *WWC* on the footpath (Figure 4, right and Figure 1c + f). Overall, *WWC* always stopped on the footpath, possibly to provide space for oncoming cyclists.

Conclusion

The majority of cyclists use the *BL* and ride in the right direction (69.38% for *CA* riding without stop, 60.00% for *CG* riding without stop). The speeds between *CA* and *CG* differ slightly, and the stopping behaviour is very similar if the *BL* is used after the stop. The stopping behaviour changes when driving on the *PL* after the stop, but too few cases are known for *CG*. More people stopped on the bicycle path than directly at the stop line. This requires further investigation as to whether the stop line is too close to the traffic and therefore conveys a lower sense of safety. It can be assumed that weather can have an impact on stopping behaviour and driving behaviour (puddles on the road). This should be considered in further studies. It was observed, especially in the case for *WWC*, that cyclists stopped on the footpath because there was a small canopy to protect them from the rain. The infrastructure also plays a major role in stopping behaviour, as the stopping behaviour of *WWC* showed in this study. Furthermore, it was not examined whether the number of other cyclists also had an influence on stopping behaviour. In overall, it can be stated that stopping behaviour of cyclists could be modelled descriptively based on the conducted traffic observation. Parameter distributions are derived and in a next step ready for implementation for example in the microscopic simulation SUMO.

Lopez, P. A., Behrisch, M., Bieker-Walz, L., Erdmann, J., Flötteröd, Y. P., Hilbrich, R., Lücken, L., Rummel, J., Wagner, P. & Wießner, E. (2018, November). Microscopic traffic simulation using sumo. In 2018 21st international conference on intelligent transportation systems (ITSC) (pp. 2575-2582). IEEE.

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