Traffic conflict analysis of intersections with designated bicycle paths

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Abstract— **This paper aims to analyze traffic conflicts and interactions between cyclists and drivers in order to understand Vehicle to Bicycle (V2B) communication as well as to develop a safer road environment for cyclists. Bicycle infrastructure has developed rapidly in the last twenty years in Hungary, nevertheless, the risk of cycling has not changed significantly in built up areas. According to one of our former results the biggest share of accidents belongs to movements, when turning vehicles do not yield to cyclists moving straight ahead on their designated bicycle path. In the recent research, we have continued to analyze accident data specifically in the above presented traffic situation. The cities of Gyor, Szombathely, Zalaegerszeg, Tatabanya, Szekesfehervar and Komarom were chosen as new study areas. In line with the former study the accident data showed similar results: 17% of all bicycle accidents occurred at intersections with separated bicycle paths. For better understanding the cause of accidents field surveys were conducted at the 15 risky intersections in Western Hungary. The average hourly conflict rate was calculated for each intersection. The results show that the average hourly conflict rate ranges between 11 and 21%. The most common conflicts occurred with vehicles turning right from a major road not giving priority to cyclists crossing the minor road as well as with vehicles turning left from a minor road.**

Keywords— road safety, cycling infrastructure, urban intersections, conflict rate, bicycle path

I. INTRODUCTION

The paper contributes to the scientific field of Cognitive Infocommunications, which “investigates the link between the research areas of infocommunications and cognitive sciences, as well as the various engineering applications which have emerged as a synergic combination of these sciences”. The mode of recent communication between cyclists and drivers relate “to the intra-cognitive communication: information transfer occurs between between two humans”. In the future, when Vehicle to Bicycle communication advances, the mode of communication is going to be converted to “inter-cognitive communication: information transfer occurs between a human and an artificially cognitive system” [1].

Bicycle ridership and infrastructure have developed rapidly in the last decades in Hungary. After the Netherlands and Denmark, Hungary has the third most daily bike users in the European Union. Consequently, the exposure to risk has increased significantly, especially in built up areas. To reduce risk, bicycle infrastructure, such as designated paths have increased in popularity across Hungary.

Several research findings conclude that designated bicycle paths can increase safety [2, 3, 4, 5] as they cut down the number of the interactions between drivers and cyclists. Nevertheless, traffic conflicts and accidents have been prevalent at intersections that follow road segments with designated bicycle paths or protected bike lanes [6, 7].

A large proportion of cyclists involved in accidents between right-turning vehicles and cyclists going straight ahead die from their injuries [8, 9, 10, 11].

Designated bicycle paths provide a physical separation between motor vehicles and bicycles. Unfortunately, this separation cannot always be maintained at intersections, and bicyclists need to interact with motorists. Bicycle crossings are a serious safety issue since drivers might not anticipate interacting with cyclists prior to turning movements [12].

According to our earlier results, the largest share of accidents belongs to movements when turning vehicles do not yield to cyclists moving straight ahead on their separated bicycle facility [13, 14]. In our recent research, we have continued to evaluate accident data specifically for this traffic situation using the Hungarian accidents database [15]. Corresponding to the former studies the statistics of the recent study showed similar results: 17% of all bicycle related accidents occurred at intersections with designated bicycle facilities in Hungary.

A recent analysis of vehicle-bicycle interactions show that the conflict risk is influenced differently, depending on who arrives at the interaction zone first. The yielding probability also depends mostly on the speed of the motorized vehicle and the closeness of the bicyclist [16].

Cyclist interactions with motorized vehicles at intersections are a significant accident probability factor. Development of Vehicle to Bicycle (V2B) communication systems can reduce collisions and increase driver awareness of potential conflicts with cyclists.

This paper analyzes traffic conflicts and interactions between cyclists and drivers in order to better understand Vehicle to Bicycle (V2B) communication.

II. SITE SURVEYS

Particular types of traffic conflicts are good substitute for accidents in that they produce estimates of average accident rates nearly as precisely, as those from recorded accident data.

Therefore, if there are inadequate accident data to create an estimate, a conflicts study can be helpful [17].

Swedish traffic conflict observer's manual [18] says: "If the form of the relation between the severity and frequency of the events is known, it is theoretically possible to calculate the frequency of the very severe but infrequent events (accidents) based on known frequency of the less severe, but more easily observable events (conflicts)".

Fig. 1. Selected sites in the city of Zalaegerszeg, Petofi-Kossuth intersection on the top and Platansor-Dozsa intersection on the bottom

In order to recognize the cause of accidents, field surveys were conducted. Fifteen risky intersections from middle-sized cities of Western Hungary (Gyor, Szombathely, Zalaegerszeg, Tatabanya, Szekesfehervar and Komarom) were chosen as study areas (figure 1). The average hourly conflict rate was calculated for each intersection.

Fourteen bicycle crossings at T-junctions and four-leg intersections were selected for video observations. The selection was based on accident data [15] retrieved from the Hungarian database, named Web-bal. Peak-hour traffic at the selected locations was videotaped.

Along the traffic volume of motorized vehicles and bicycles, conflict situations were registered as well. The four most common types of traffic conflicts were identified at all sites, as follows. Other types of vehicle-bicycle conflicts occurred in very low numbers.

1. Vehicle turning right from the minor road and a risk of collision with a cyclist appear
2. Vehicle turning left from the minor road and a risk of collision with a cyclist appear
3. Vehicle turning left from the major road and a risk of collision with a cyclist appear
4. Vehicle turning right from the major road and a risk of collision with a cyclist appear

Figure 2 illustrates the four most frequent types of traffic conflicts observed at the site surveys.

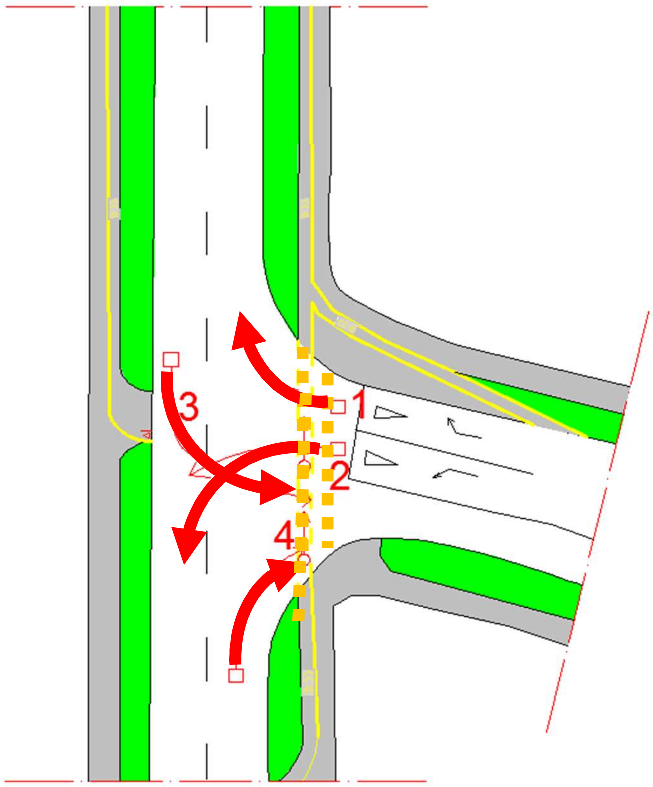

Fig. 2. The four main types of registered traffic conflicts

Using these four conflict types, conflict rates are determined based on review of the video record.

The conflict rate is calculated as:

$$CR = \frac{CVB}{IVB} \tag{1}$$

where *CR* is the conflict rate (%); *CVB* is the number of vehicle-bicycle conflicts; and *IVB* is the number of vehicle-bicycle interactions.

III. Results

The summary of the resulting conflict rates as well as the share of the four most frequent conflict cases are presented in table 1.

The results show that the average hourly conflict rate ranges between 8 and 21%. Typical causes of the conflicts were drivers not giving priority to cyclists and negligence of drivers when bicyclists were in the dead angle. Two equally frequent conflict situations occurred when vehicles turned left from the minor road (case 2) and vehicles turned right from the major road (case 4) not yielding to cyclists crossing the minor road.

Numerous references highlight the prevention of right-turn accidents similarly to our results. However, left-turn movements from the minor road received less attention. The average conflict rate of case 2 is 9%, which is almost equal to case 4 with 8%. One of the reasons behind the case 2 is that at all locations, two-way bicycle paths were implemented, and drivers turning out from the minor road may pay less attention to cyclists arriving from the right side. One way designated bicycle paths on both sides of the road as well as bike lanes offer a safer solution for cyclists.

Table 1. Conflict rates and the share of the four most frequent conflict situations (in %)

Location	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**CR**
Gyor, Tihanyi-Sport		10%		10%	19%
Gyor, Vasvari - Liezen Mayer	4%	11%			15%
Gyor, Jerevani -Vorossipkas			7%	4%	11%
Gyor, Szauter -Plaza	4%	7%	4%		15%
Szombathely, Paragvari - Vaci		7%		13%	20%
Szombathely, Dolgozok - Kassak	5%		2%	5%	12%
Szombathely, Brenner - Narai		7%		13%	20%
Zalaegerszeg, Petofi-Kossuth			4%	7%	10%
Zalaegerszeg, Platansor- Dozsa	2%	8%	2%	5%	17%
Tatabanya, Ipari park	3%	14%			17%
Tatabanya, Koztarsasag St.	3%	8%			11%
Szekesfehervar, Horvath-Kaszap		11%		6%	17%
Komarom, Martirok- Bem	3%	4%	1%	13%	21%
Komarom, Martirok- Asztalos	2%	7%	2%	6%	17%
Average of all sites	**3%**	**9%**	**3%**	**8%**	**15%**

Further observations of the study:

- The majority of the bicycle related accidents are caused by motor vehicles if there is a two-way bike path available on one side of the road..
- Off-set bicycle crossing with a distance of 5 meters from the major road may also contribute to a positive safety effect.
- In case of low traffic volume, bike lanes can be safe solutions with a much better visibility of cyclists. However bike lanes are notably less frequently applied than bicycle paths in Hungary.
- Protected two way bicycle paths along main roads represent higher accident probability than those one way bicycle paths or lanes along both sides of the road.
- At 4-leg junctions cyclists riding on the protected bike path parallel to the main road are especially endangered arriving in the crossing.
- At many locations, the pavement markings are not adequately visible because of lack of maintenance. Poor visibility of pavement markings is demonstrated in figure 3.
- 3-leg crossings with two-way bike paths on one side are not as safe as T junctions without any segregated bicycle facilities.
- Installing a separated bicycle facility does not automatically come together with higher level of traffic safety.

Fig. 3. Poor visiblity of pavement markings at bicycle crossings [8]

Finally, several countermeasures to mitigate the safety issues have been presented as follows:

- Proper maintenance of road markings at bicycle crossings is crucial.
- Colored pavement within the intersection crossing marking increasing the visibility of the bicycle facility.
- Raised bicycle crossing vertically separated from motor vehicle traffic supporting the crossing bicycle traffic.
- Enhanced traffic signs in the minor road to bring diver's attention for crossing cyclist.
- Flashing yellow lights in the main road to warn motorists about bicycle crossing to slow down.
- Clear sight distance at which visibility of both cyclists and motor vehicles is ensured.

- Installing one way bicycle facilities on both sides of the road in dense urban areas instead of two way bicycle tracks or paths on one side of the road.
- Applying bike lanes more often and eliminating 2-way bike paths in densely populated residential areas.

IV. Conclusion

Bicyclist interactions with motor vehicles at intersections in urban road environments are a significant accident probability factor. The findings of this study contribute to develop countermeasures to improve cyclist's safety at intersections equipped with designated bicycle paths. Furthermore, the detailed study of the research demonstrates examples of low cost safety measures for each selected intersection such as raised bicycle crossing or enhancing pavement marking visibility.

Vehicle to Bicycle (V2B) communication is an arising technology that is expected to reduce the number of accidents caused by motor vehicles and improve bicycle safety standards.

In this paper traffic conflicts and interactions between cyclists and drivers have been investigated in order to contribute to a better understanding of Vehicle to Bicycle communication as well as to develop safer road environment for cyclists.

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