A preliminary analysis of vehicle-to-powered two-wheeler accident scenarios based on the VRU-TRAVi database

Di Pan, Yong Han, Qianqian Jin, Hongwu Huang

I. INTRODUCTION

Road traffic accidents involving two-wheeler vehicles (referred to as TWs) have long been a worldwide concern because of their high rates of injury and fatality. According to a World Health Organization (WHO) report, 54% of traffic deaths worldwide occurred among motorcyclists (28%), pedestrians (23%) and cyclists (3%) [1]. In China, The People's Republic of China Traffic Accident Statistical Yearbook (2017) shows that 87,216 two-wheeler riders were injured and 23,521 were killed in 2017[2].

Many studies have been performed on two-wheelers, such as accident investigations [3-4], injury mechanism analyses [5-6] and proposed countermeasures [7]. As one of the Advanced Driving Assistance Systems (ADAS), the AEB system has been proven to be effective in reducing accidents [8]. Currently, Euro-NCAP has released the testing and assessment protocols for pedestrian and bicyclist safety performance evaluation for 2016 and 2018, respectively [9]. In China, C-NCAP has also conducted AEB safety performance assessment tests for pedestrians since 2018 [10]. However, there are still no AEB test procedures for assessing the safety performance of electric two-wheelers (ETWs) and motorcycles (i.e. powered two-wheelers, which are here referred to as PTWs).

The purpose of this study was to analyse the vehicle-to-PTW accidents in China through the use of the accident video data in VRU-TRAVi and to determine the typical accident scenarios. The results will be helpful to develop PTW AEB test protocols.

II. METHODS

Data Sources

In this study, all accident videos were selected from the VRU TRaffic Accident database with Video (VRU-TRAVi), which was established in 2015 by collecting accident videos from the internet and in-depth accident investigation teams [3][7]. Each video was analysed by recording accident information related to the environment, vehicles and human, such as "date of accident", "type of vehicle" and "participant number". The selection criteria for the accidents were: (1) the accidents should include only one vehicle and one PTW; (2) the accidents should occur on the roadway in China; and (3) the videos should be clear and complete enough to observe the accident scenarios. In total, 538 accident cases met the criteria and were analysed.

Vehicle velocity estimation

The impact velocity of the vehicle and of the PTW were calculated by estimating the travel time of the vehicle as they passed through a vehicle length according to reference [3]. In which, the traveling time was short time about 0.2 s before collision. The vehicle length was identified by the average length of each vehicle type (minicar (3.5 m), small family sedan (4.0 m), medium sedan (4.5 m), large sedan and SUV (5.0 m); electric bike (1.4 or 1.8 m), motorcycle (2.0 m)).

Definition of PTW accident scenarios

In order to describe the PTW accident in more detail, the study utilised the classification method of accident scenarios available in CIDAS [4], which defines seven categories of scenarios: 2 – Turning; 3 – Crossing; 4 - PTW Crossing; 5 - Resting Traffic; 6 - Longitudinal Traffic; 7 - Other Accident; and 8 – PTW Reversing. The analysis of the accident videos showed instances of reversing action by a PTW, thus it was necessary to establish the category "8 - PTW Reversing". Four numbers were used to encode each scenario, e.g. "3201". The first number is always "3", indicating a PTW accident. The second number indicates the category of scenario, such as "2 -

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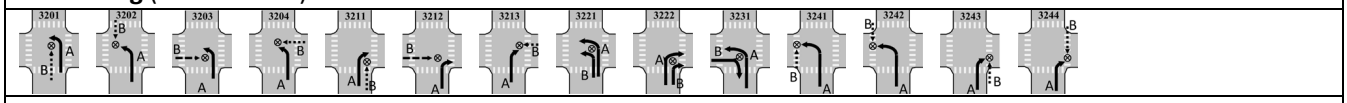
Turning". The last two digits indicate the number of the different scenarios in each category. In total, 77 scenario types were defined (Table I).

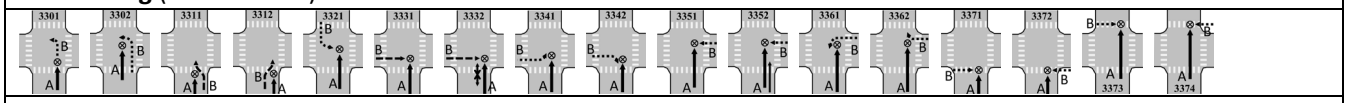
TABLE I

PTW ACCIDENT SCENARIOS DEFINED ACCORDING TO ACTUAL ACCIDENTS (A: VEHICLE, B: PTW)

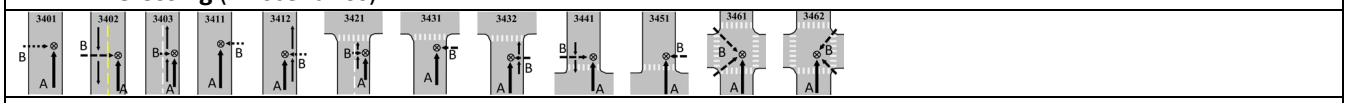
2 - Turning (14 scenarios)



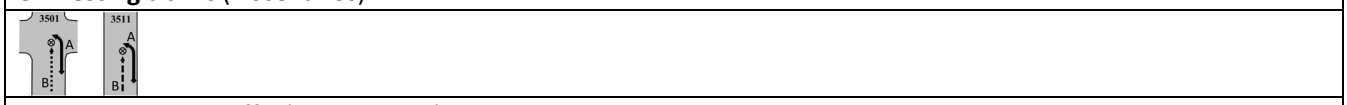
3 - Crossing (17 scenarios)



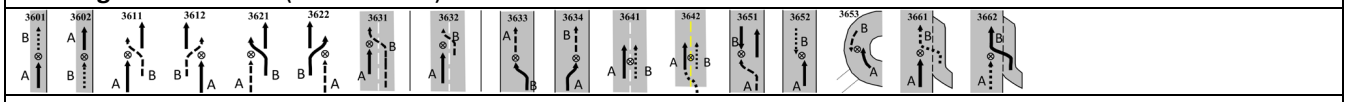
4 - PTW Crossing (12 scenarios)



5 - Resting traffic (2 scenarios)

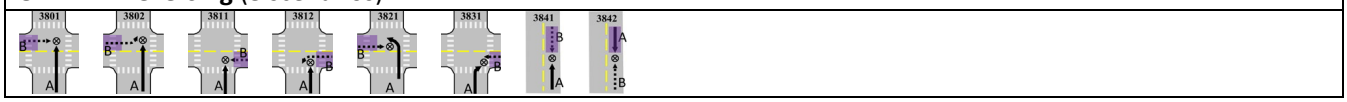


6 - Longitudinal Traffic (17 scenarios)



7 - Other Accident (7 scenarios, including the accidents involving vehicle reversing and U-turns)

8 – PTW Reversing (8 scenarios)



III. INITIAL FINDINGS

Environment Information

Of the total 538 vehicle-to-PTW accidents analysed, only 256 (47.6%) cases had date information, which showed they occurred in 2007–2019. There were 157 accidents with location information (29.2%), which showed they occurred mainly in eastern and central China. Most accidents happened in the daytime (85.1%) rather than nighttime (14.9%). In terms of precipitation, 89.4% of accidents occurred when there was no precipitation (dry), while in 10.6% of accidents it was raining. In terms of road types, the majority of accidents occurred at intersections (64.3%), followed by straight roads (17.5%) and junctions (15.8%).

Impact Velocity

Figure 1 shows the impact velocity distribution in PTW accidents. Due to frame dropping or skipping issues, it was not possible to estimate the distance travelled by the vehicles from the videos. As a result, the velocities of the vehicle and the PTW were estimated in 496 accidents. The velocities of the vehicles and PTWs were mostly in the range of 20–50 km/h and 10–40 km/h, respectively.

Distribution of PTW accident scenarios

Figure 2 shows the distribution of PTW accident scenarios. Of the 538 vehicle-to-PTW accidents, 94.61% (509) could be clearly classified in 68 scenarios, while the remaining 29 special accidents were classified as "Others". Most accidents occurred in category "3 - Crossing" (54.5%), followed by categories "2 - Turning" (15.4%), "4 - PTW Crossing" (7.2%), "8 - PTW Reversing" (7.2%) and "6 - Longitudinal Traffic" (7.1%). However, only 2.6% of total accidents could be attributed to category "7 - Other Accidents" and only 0.56% could be attributed to category "5 - Resting Traffic'. This indicated that categories "3 - Crossing" and "2 - Turning" were significant and should be analysed in more detail.

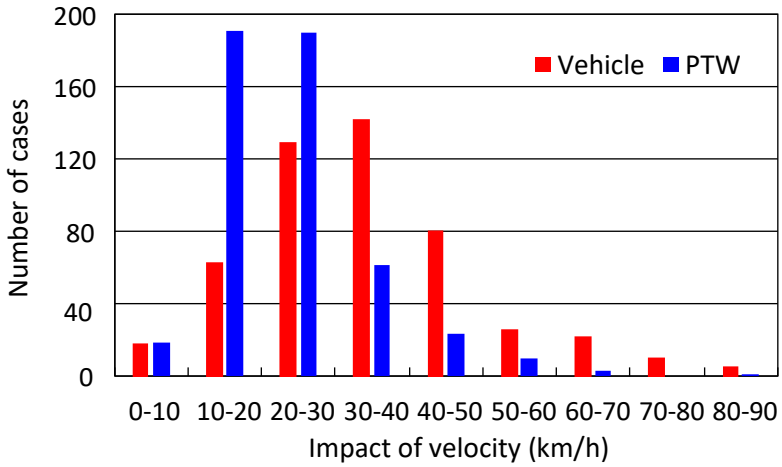


Fig. 1. Impact Velocity Distribution in PTW accidents (Estimate).

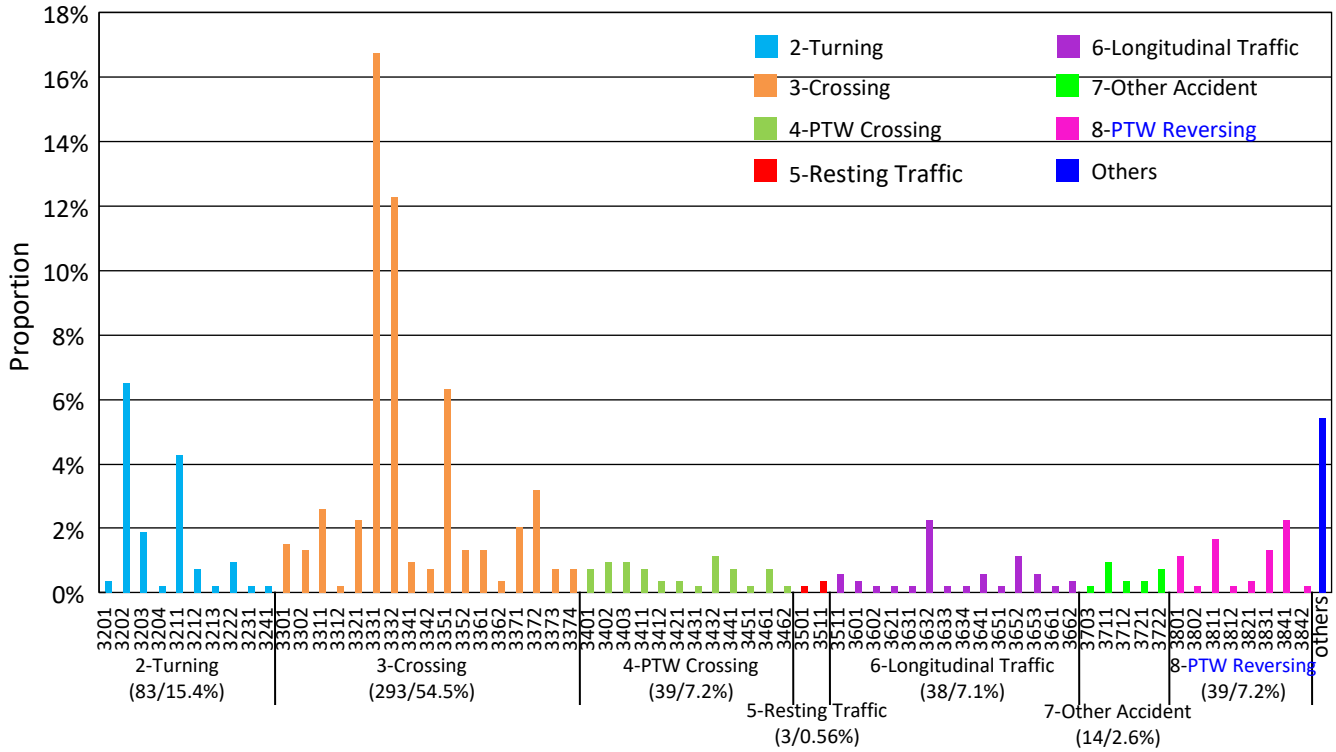


Fig. 2. Distribution of PTW accident scenarios.

Typical PTW accident scenarios

Based on the frequency of accidents in different scenarios, 13 typical scenarios were identified (see Fig. 3). It is clear that the number of accidents at intersections is significantly higher, especially the two most common scenarios, 3331 and 3332, and also scenarios 3202 and 3351. Possibly this is because the traffic environment at an intersection is very complex and the vehicle could be travelling faster because it is going straight. Accordingly, there are more typical scenarios at intersections, including accidents that occurred in the same direction (3211, 3311), in the opposite direction (3321), or when the PTW was approaching the vehicle from the left (3203). In addition, PTW accidents which occurred while driving on the sidewalk from the right (3372) and from the left (3371) are also noteworthy and accounted for 5.2% of the total accidents. The only two typical situations on straight roads are 3632 and 3841, which indicate that a vehicle moving straight and forward (1) collided with a left-turning PTW or (2) collided with a PTW moving straight in a reverse area. Another scenario of PTW driving in the reverse area was 3811. Though only nine accidents occurred in this scenario, as the behaviour involved is not in line with the rules of the road this may lead to more serious accidents.

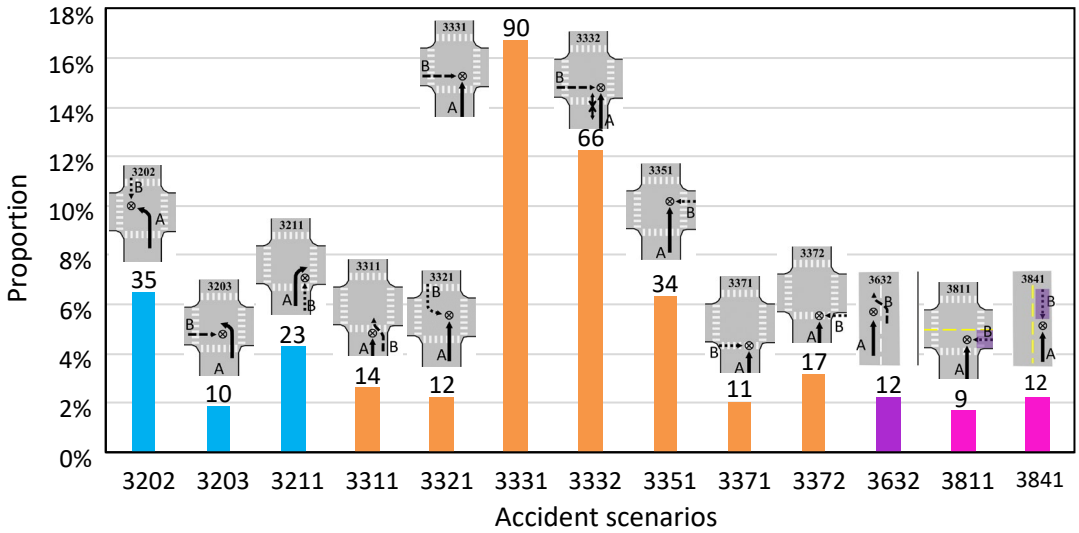


Fig. 3. Typical PTW accident scenarios.

IV. DISCUSSION

The PTW accidents in the VRU-TRAVi database were characterized by in daytime and without precipitation. The results were comparable with Sui et al. [4] based on CIDAS data. However, 80.1% of PTW accidents occurred at road junctions (crossroads, T and Y junctions). The proportion was higher than the results of Sui et al. [4] and NAIS data (both about 60% of all TW accidents analysed) [11]. The reason might be that most videos came from intersection monitors that are common in China. The other was that CIDAS and NAIS mainly collect traffic accidents involving casualties. Therefore, accidents in VRU-TRAVi could supply another vision on PTW accidents in China. Moreover, accidents at intersections should be prioritized and introduced to the AEB assessment.

The range of impact velocities of vehicles was consistent with the findings of Cao *et al*. [11]. However, Han *et al*. found that the range of velocities was 30–50 km/h in the vehicle-to-two-wheelers accidents [3], which is less than the range observed in this study. This may be due to the velocities of the PTWs being faster than those of bicycles, i.e. when the PTW impacts the vehicle, the collision occurs before the vehicle has accelerated fully. When considering the PTW AEB test, a higher vehicle velocity should therefore be considered. Accordingly, it was recommended that the velocity range of the vehicle is 20-60 km/h for the AEB assessment, while the PTW is 10-40 km/h.

The two largest accident scenarios 3331 and 3332 indicate that a vehicle moving straight hit a PTW driving straight from the left in a perpendicular direction without and with visual obstruction, which is consistent with Sui et al. [4]. However, through analysis based on GIDAS data, Liers et al. found the two most common PTW accident scenarios: a car turning left hit a PTW moving straight in the opposite direction and a car turning left hit a PTW moving straight in a perpendicular direction [12]. Painter et al. found a common scenario in India where a car moving straight hit a head-on an oncoming PTW [13]. Due to the differences in road environment, traffic characteristics and driver behavior, scenarios vary in countries.

The main limitation of this study is that as the accident videos were downloaded from the Internet, it may not be possible to cover all PTW accidents. Adding more PTW accidents will enrich the analyses of the scenarios.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

[1] WHO, 2018. [2] MPSTMB, 2018. [3] Han, Y., *et al*., IRCOBI, 2017. [4] Sui, B., *et al*., ESV, 2017. [5] Mizuno, K., *et al*., TIP, 2016. [6] Huang, Y., *et al*., AAP, 2019. [7] Han, Y., *et al*., *Int J Crashworthiness*, 2019. [8] Zhao, Y., *et al*., TIP, 2019. [9] Euro-NCAP, 2018. [10] C-NCAP, 2018. [11] Cao, Y., *et al*., ESV, 2019. [12] Liers, H., *et al.*, ESAR, 2013. [13] Painter, M., *et al*, IRCOBI Asia, 2018.