Analysis of the causation mechanism of vehicle-to-electrical two-wheeler accidents based on video footage of real-world collisions

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I. INTRODUCTION

Nowadays in China, people prefer to choose efficient and low-cost transportation. However, the lack of effective protection for ETW riders leads ETW riders are prone to involve in severe crash and suffer from high risk for severe injury [1-3]. According to the official traffic statistics in China, E2W fatalities increased more than 11 times from 589 to 6539, and nonfatal injuries increased 5 times from 5295 to 30,532 during the period of 2004–2015 [4].

With the advent of vehicle active safety technologies, various advanced systems have been employed[5], particularly AEB and AES systems [6-8].In order to test and promote these systems, a comprehensive understanding of the characteristics of ETW accidents is required. Driving Reliability and Error Analysis Method (DREAM) can be used to identify accident causations, which has applied to several previous studies [9-10]. As far as we know, DREAM was rarely used to analyse the causation patterns of vehicle-to-ETW accidents. More recently, road monitoring and driving camera were utilised in DREAM to build a comprehensive understanding of the accident process [9] [11].

The main focus of this study is to analyse the contributing factors and causation patterns between vehicles and ETW riders. This will allow for the proposal of countermeasures to avoid or mitigate ETW accidents.

II. METHODS

Incident database and characteristics

The study was conducted according to the finding by Han et al [11]. In which, the ETW accident scenarios were defined as 54 kinds of scenarios, a total of 9 categories, 6 types of scenarios in each category. A total of 282 vehicle-to-ETW cases were selected from the VRU Traffic Accident database with Video (VRU-TRAVi), most of the accidents occurred in China [12], all of which included videos of collisions between ETWs and sedans, SUVs and trucks. The accidents selected were not caused deliberately, and the video records were clear enough to observe the basic road scenarios, surrounding environment, and the movement of the ETWs and other vehicles, in which, 40 cases contained traffic police reports and the important information for causation mechanism analysis is listed in Table 1.

The DREAM analysis method

DREAM is an adaptation of Hollnagel's Cognitive Reliability and Error Analysis Method (CREAM), applied to the field of vehicle safety with the aim of identifying and categorising the causation relationship among different factors in crash accidents [13-14]. More specifically, DREAM contains two basic elements: critical factors (phenotypes); and contributing factors (genotypes). Links are used to connect the critical factors and the contributing factors. In each case, one critical factor and various contributing factors, i.e. the genotypes, capture the circumstances that bring about the phenotypes [9]. In this study, the DREAM method was used to analyse one of the most common accident scenarios: Scenario 102 (Fig. 2b in Han et al., 2017), where the vehicle was going straight and the ETW approached from the left side. The analysis sequence followed three steps:

1. The most common scenarios were analyzed firstly using the 282 accident cases. 2. Based on the references[9][10], If the difference in the frequency of each influencing factor exceeds 10 times, it is considered that there is sufficient discrimination to judge the phenotypes and the genotypes factors, respectively. Therefore, a total of 30 cases as a minimum sample in scenario 102 were extracted randomly (all identified factors related to the descriptive data). 3. These chosen factors were discussed and countermeasures were suggest to tackle the

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contributing factors shown in the current vehicle-to-ETW causation patterns.

TABLE I

INTRODUCTION OF THE DETAILED DATA COLLECTION FROM (VRU-TRAVI)

	Data		
Type of characteristic	Characteristic description	Detailed description	Picture
			description
Road traffic environment	Several on-site pictures, including surrounding environment	Intersection/straight road Daytime/Dark Dry/wet road surface	
ETW information	Deformation pictures and outline of the ETW	Type and brand of ETW Speed of ETW Height/weight/age of ETW rider	STA.
Vehicle information	Deformation pictures, inside and outline of the vehicle picture.	Type and brand of vehicle Speed of vehicle Height/weight/age of driver	
Other information	Descriptive information	Accident scenario diagram, note-taking from both parties involved and accident videos, etc.	

III. INITIAL FINDINGS

A statistic of ETW accident scenarios

As far as we know there is still no understanding of the comprehensive scenarios that describe complexity and diversity vehicle-to-ETW accidents, even when considering CIDAS (China In-Depth Accident Study). Therefore, this study was based on the existing two-wheeler-vehicle accident scenario studied by Han *et al.* [11][15]. Scenario 102, where the vehicle was driving straight and the ETW approached from the left side, contained the largest number of accidents, accounting for 40% of all cases (see Fig. 1). For this study, only Scenario 102 was analysed through DREAM.



Fig. 1. Available information on the scenarios involved in the 282 accident cases.

DREAM applied in Scenario 102

Figure 2 is an aggregated chart of 30 cases in which were in the standpoint of ETW involvement, all of which took place at intersections where the vehicle was going straight and the ETW approached from the left side. This chart should be read from right to left, reversing the causal chain. Of the 30 incidents in this group, the most common critical factor (N=28) was 'Timing: too early action'. This category was attributed to the 28 ETW riders who acted too early, i.e. acted before the traffic situation was established – for example, taking off before the traffic lights

turned to green.

As Fig. 2 shows, 'Misjudgment of situation' was the most frequent contributing factor preceding the critical factor. This was attributed to 13 ETW riders who interpreted the traffic situation incorrectly, leading to a belief that the traffic environment was safe (e.g. that there was no other vehicle in the intersection at the time). The 'Misjudgment of time gaps' (N=10) occurred where an ETW rider erroneously estimated the velocity or distance from other vehicles. The code of 'Incomplete judgment of situation' was used for unexpected events or events which developed too fast for the rider to respond.



Fig. 2. Causation patterns at intersections where the vehicle drives straight and the ETW approaches from the left (N=30).

A host of factors and combinations thereof contributed to the 'Misjudgment of situation', 'Misjudgment of time gaps' and 'Incomplete judgment of situation' codes. In these cases, the majority of the contributing factors were that: the riders (18 of 30) habitually stretched the rules because they had not previously experienced any negative consequences; the ETW rider did not notice an upcoming vehicle until it was too late to respond; or that the ETW rider never saw the upcoming vehicle. Where the ETW rider failed to see the upcoming vehicle, this was often due to the presence of a temporary obstruction that prevented the ETW rider from detecting the vehicle. In the videos, these temporary obstructions included fixed stone pillars, moving vehicles, stationary vehicles, fixed bridge piers, etc.

IV. DISCUSSION

Through using the coding process available through DREAM and applying it to Scenario 102, three major issues were identified regarding ETW's safety: habitually stretching rules and recommendations, late observation and missed observations. Effective countermeasures were recommended to address these issues.

The most notable problem was that the ETW rider lacked road safety awareness, particularly in habitually stretching the rules, which is still a universal problem for VRUs in China based on the resource of the videos [10] [16-17]. This problem was noted by Xie *et al.* [10], whose study focused mainly on vehicle- and motorcycle-to-pedestrian accidents in Chinese rural areas; that study proposed detailed and practical countermeasures. Therefore, the priority of the countermeasures is the VRU's safety awareness should be established and following the traffic rules. Another common contributing factor was a temporary obstruction to an ETW rider, where the

accident vehicle was driving but the ETW appeared perpendicularly in the intersection, creating an extremely dangerous scenario, due to the fixed obstacles or other moving/waiting vehicles. Also, this scenario points to a weakness in active safety system AEB with a small time (TTC), leading to a collision even vehicles fitted with idealised sensors [18]. Azra *et al.* [9] proposed utilising the vehicle-to-vehicle (V2V) and ADAS based on vehicle-to-infrastructure (V2I) to address the obstruction problem.

Given that advanced safety technologies have developed rapidly over the last few years, detailed practical frameworks and specific systems could be proposed to mitigate this scenario. For example, at an urban intersection, the detector systems in V2I systems, such as cameras and radars, could be located at different orientations to allow them to detect an ETW prior to entering the intersection, even when view is obstructed, and then sending the ETW's position and velocity and future possible trajectories to nearby driving vehicles. Based on this information, these approaching vehicles could use collision avoidance algorithms, along with driver decision-making, to trigger the Intelligent Speed Adaptation (ISA) and warning systems to slow down and thereby avoid or mitigate the injury outcome.

The major limitation of this study was that some of the selected set of 30 videos did not provide detailed descriptive materials (such as note-taking describing each party's actions) that could be used to analyse the detailed causation patterns of ETW accidents. Therefore, the possible causation patters were coded through the cases with only video evidence, leading to subjective findings and tendencies. It is likely that the ETW riders' awareness or mental state, which was assumed, may not represent reality. If there were a large number of cases available, the determination could be regarded as a strong assumption. As it is, these 30 cases do not represent a detailed sample of all the results in Scenario 102.

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