Establishment and Analysis on Typical Road Traffic Near-Crash Scenarios Related to Pedestrian in China

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ABSTRACT

Naturalistic driving recorders were installed on 11 passenger cars, running in 5 Chinese cities ranging from first tier to third tier cities to obtain naturalistic driving data. And 65 near-crash cases related to pedestrians are extracted from the database and researched. Based on vehicle's speed obtained from OBD (On-Board Diagnostic), image process method and kinematic formulas, information of the pedestrian, road environment and vehicle is collected. Firstly, based on the 65 samples, qualitative analysis on the key elements such as pedestrian's walking direction and road congestion status is conducted to obtain characteristics of near-crash cases related to pedestrians in China. Secondly, typical scenarios at the time of risk start (TRS) are obtained from 39 samples through cluster analysis. Thirdly, the differences between the current study and previous studies are analyzed and discussed further.

INTRODUCTION

Of all traffic participants, pedestrians are the most vulnerable kind. In an accident, the pedestrian usually suffered much severer casualty than the occupants. In 2014, there were 58,523 casualties from road traffic accidents in China, including 15,110 pedestrians, accounting for about 26%[1]. Autonomous Emergency Braking System is assumed to be an effective counter measure for this situation. AEB could help to avoid collisions or reduce crash severity through automatic braking. However, in Chinese market, complete evaluation system which is accustomed to Chinese traffic characteristics has not been established to support the development of Pedestrian AEB. Typical scenarios related to pedestrians obtained from Chinese near-crash cases are the essential information for the AEB effectiveness evaluation system in China, and they are the foundation for the R&D of Pedestrian AEB.

CURRENT RESEARCH STATUS

EU project APROSYS (Advanced Protection Systems) obtained three typical scenarios from accidents related to pedestrians based on GIDAS (German In-Depth Accident Study) [2]. Another EU project VFSS (Advanced Forward-Looking Safety Systems) designed four testing scenarios for Pedestrian AEB based on four databases[3]. In China, Liu Ying obtained four typical scenarios with the corporation of Geely Automobile Research Institute[4].

All the testing scenarios mentioned above include the following factors: vehicle's speed, pedestrian's walking direction and driver's view obstruction. It can be seen that these factors are essential to establish testing scenarios and evaluate function of Pedestrian AEB. Most researches obtain typical scenarios based on accidents instead of near-crash cases. It may result in difference in concrete variables. Besides, all the research mentioned above do not consider about pedestrian's walking speed or just design testing scenarios utilizing average pedestrian speed, which could not reflect difference on pedestrian's walking characteristics.

ANALYSIS ON CHARACTERISTICS OF NEAR-CRASH CASES RELATED TO PEDESTRIAN

Near-crash cases refer to events in which drivers take efficient steps under urgent road traffic situations and avoid potential accidents successfully.

Naturalistic driving recorders were installed on 11 passenger cars in 5 Chinese cities to obtain naturalistic driving data. Once the longitudinal or lateral acceleration is higher than 0.3g, or vertical direction is higher than 0.5g, the device is triggered. Videos in that period are then written into memory card. After that, all the video samples during the period in which sudden speed change occurs are judged and sifted manually to get near-crash cases. 65 near-crash cases related to pedestrians from September 2015 to May 2016 are extracted from the database eventually. Based on the 65 samples, qualitative analysis on information such as pedestrian's walking direction and road congestion status is conducted to obtain characteristics of near-crash cases related to pedestrians in China.

Each near-crash sample can be extracted to the combination of several variables. Through video observation and recording, statistical distribution of each variable, as shown in Table 1, is obtained.

Table 1.
Statistical distribution of variables

Variable name	Variable value	Sample size	Proportion
Driver's view	Obstructed	13	20.00%
	Not obstructed	52	80.00%
Time period	Daytime	55	84.62%
	Night	10	15.38%

Light conditions	Good	60	92.31%
	Not good	5	7.69%
Weather condition	Sunny	60	92.31%
	Rainy	5	7.69%
Road congestion status	Congested	2	3.08%
	Not congested	63	96.92%
Intersection or not	Intersection	33	50.77%
	Non-intersection	32	49.23%
Pedestrian crossing from	Along the road	12	18.46%
	Left	28	43.08%
	Right	25	38.46%
Pedestrian comply traffic rules	Yes	29	44.62%
	No	36	55.38%
Pedestrian age	Children	6	9.23%
	Adults	50	76.92%
	Old people	9	13.85%
Pedestrian's Wearing	Dark	57	87.69%
	Light	8	12.31%

Following conclusions can be drawn from Table 1

1) The condition that the driver is driving under daylight and sunny weather is respectively 5 times and 11 times more than driving under darkness and rainy weather. Presumably, people drive more carefully under darkness and rainy weather. Therefore, accidents are less likely to happen in latter conditions.

2) The location, whether is at intersection or not, does not have effect on occurrence of near-crash. 97% near-crash cases happen on roads which are not congested. By reviewing videos, we find that people drive faster in spacious road and conflicts are more likely to happen.

3) At the time of risk start (TRS), the number of the cases in which pedestrian is crossing the road is about 3 times more than that of the cases in which the pedestrian is walking along the road. The reason why people walking along the road are less likely to have conflicts with vehicle is that they are more likely to be perceived by drivers. Therefore, drivers can take measures in advance to avoid conflicts.

4) Approximately 55% near-crash cases are due to pedestrian's failure to comply with traffic rules. Therefore, uncertainty of pedestrian's movement should be fully taken into account when establishing testing scenarios of Pedestrian AEB.

5) People in each life stages may have conflicts with vehicle. People of different ages have different characteristics on factors such as height and walking speed. These differences should be considered about carefully in establishment of testing scenarios of Pedestrian AEB.

6) In near-crash cases, most pedestrians wear dark clothes which are more difficult to detect in poor light condition compared to light-color clothes.

7) Some cases happen between vehicle and several people. Identification of multiple pedestrians is more challenging for AEB system. And research on this situation is very essential.

OBTAINMENT OF TYPICAL SCENARIOS AT TRS

Time of risk start (TRS) means the moment when drivers realize emergency and potential risk of crashing with pedestrian. Through vehicle speed obtained from OBD , image process method and kinematic formulas, information of vehicle speed, distance between pedestrian and vehicle and pedestrian's walking speed at TRS is obtained and quantitative analysis is conducted then. Typical scenarios at TRS can be obtained from the data mentioned above through multivariate statistical method of cluster analysis.

Analysis of Quantitative Information

Due to the limitation of image processing algorithm, quantitative information of two kinds of cases cannot

be obtained. In the first kind, distance between vehicle and pedestrian cannot be calculated accurately since the road is uneven. In the second kind, location of pedestrian's feet cannot be selected if pedestrian's feet are masked in the image. Therefore, the distance cannot be calculated. Quantitative information of 39 samples is obtained except two kinds of cases mentioned above eventually.

Vehicle Speed Distribution at TRS Vehicle speed distribution at TRS is shown in Figure 1. Samples which vehicle speed is in 10-40km/h account for 92.3% of the total; Frequency of vehicle's traveling at high speed is small among near-crash cases.

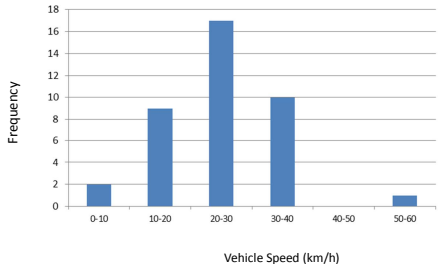

Figure 1.Distribution of Vehicle Speed

TTC (Time to Collision) Distribution at TRS TTC distribution at TRS is shown in Figure 2. Cases which TTC is among 1.4s and 4.8s account for 94.9%.

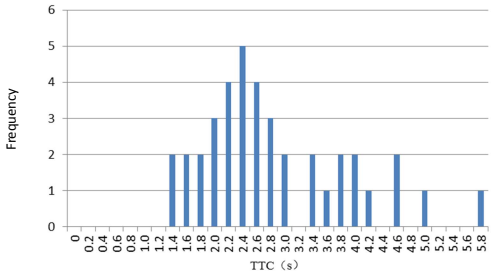

Figure 2.Distribution of TTC

Relationship between TTC and Vehicle Speed Relationship between TTC and vehicle speed is shown in Figure 3. We can draw conclusion that TTC is basically independent of vehicle speed from Figure3

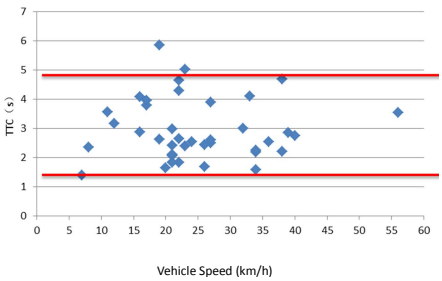

Figure 3.Relationship between TTC and Vehicle Speed

Relationship between Vehicle Speed and Pedestrian's Walking Speed Relationship between vehicle speed and pedestrian's walking speed is shown in Figure 4. Vehicle speed is roughly linear with pedestrian speed.

Figure 4.Relationship between Vehicle and Pedestrian's Walking Speed

Introduction of Cluster Analysis

Cluster analysis classifies individuals or objects so that the similarity between objects in the same group is stronger than the similarity between objects of other groups. The whole process of obtaining typical scenarios includes two steps. First, all samples are classified into several groups. Second, eigenvalues are extracted from these groups as parameters of testing scenarios.

Hierarchical clustering method is used in this research. Firstly, n samples are regarded as n groups, and each group contains a sample. Secondly, two groups with the most familiar property are combined into a new group. The same process is repeated until all the samples are classified into one group. Thirdly, clustering tree diagram is drawn to describe the whole process and the number of groups and sample size in each group are determined[5].

Hierarchical clustering method greatly reduces subjective consciousness's influence on classification compared to classifying manually. Moreover, the classification process is a kind of mathematical calculation, which can be repeated easily.

Steps of Cluster Analysis

39 samples including both qualitative and quantitative information are utilized to do cluster analysis.

Variable Selection Some variables in qualitative analysis are not applicable in cluster analysis, such as light conditions and pedestrian's age. In these variables, the proportion of some variable value is less than 15%. The proportion disparity of difference variable values may lead to ignorance of some value. Therefore, this kind of variables is ignored when clustering.

Five variables of three types, as shown in Table 3, are selected to do cluster analysis.

Table 2.
Selected variables of cluster analysis

Type	Variable value	Variable name
Environment information	Time period	Daytime
		Night
	Intersection or not	Intersection
		Non-intersection
Vehicle information	Vehicle speed	km/h
Pedestrian information	Pedestrian crossing from	Along the road
		Left
		Right
	Pedestrian's walking speed	km/h

Cluster Process As described in literature [6], inconsistent coefficient is used to determine final number of groups. In the process of clustering, inconsistent coefficient of certain combination's higher than that of last combination represents that effect of last combination performs well. Larger increase in inconsistent coefficient means better effect of last combination. The last eight combinations are shown in Figure 6. The increase between 34th and 35th combination's inconsistent coefficient is the largest of all, indicating that effect of the 34th combination is the best. Therefore, all the 39 samples are divided to 5 groups.

Clustering tree diagram of the whole process is shown in Figure 7.

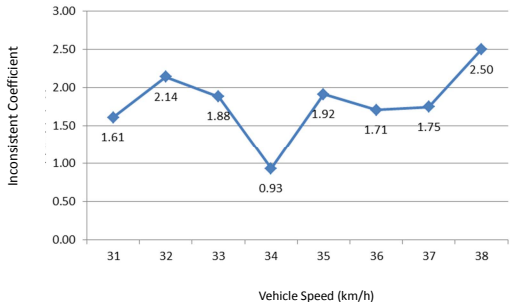

Figure 6. Inconsistent Coefficient

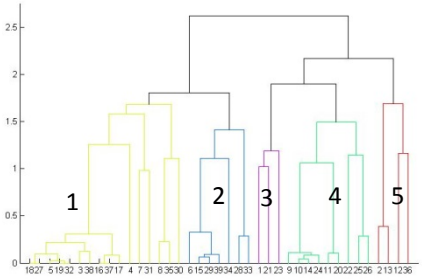

Figure 6. Clustering Tree Diagram

Analysis on Clustering Result Removing the third group with only three samples, we focus on left four groups and rename them. Clustering result, as shown in Table 4, has obvious characteristics in each group. Variable values of the first group are set to be the main condition. Other groups have some changes in variable.

Table 3.
Clustering Result

			Cluster				Total
Variable name		Variable value	1	2	3	4	
Pedestrian's speed higher than 4km/h	Number	Yes	13	5	9	3	30
		No	3	2	0	1	6
	Proportion (%)	Yes	**81.25**	71.43	100.00	75.00	76.92
		No	18.75	28.57	0.00	25.00	15.38
Time period	Number	Daytime	15	6	8	0	29
		Night	1	1	1	4	7
	Proportion (%)	Daytime	**93.75**	85.71	88.89	0.00	74.36
		Night	6.25	14.29	11.11	100.00	17.95
Intersection or not	Number	Intersection	16	7	0	0	23
		Non-intersection	0	0	9	4	13
	Proportion (%)	Intersection	**100.00**	100.00	0.00	0.00	58.97
		Non-intersection	0.00	0.00	100.00	100.00	33.33
Pedestrian crossing from	Number	Along the road	3	0	4	2	9
		Left	13	0	3	0	16
		Right	0	7	2	2	11
	Proportion (%)	Along the road	18.75	0.00	44.44	50.00	23.08
		Left	**81.25**	0.00	33.33	0.00	41.03
		Right	0.00	100.00	22.22	50.00	28.21
Number and proportion	Number		16	7	9	4	36
	Proportion		41.03	17.95	23.08	10.26	92.31

Box plots of vehicle speed, pedestrian's walking speed, distance between vehicle and pedestrian at TRS of four groups are shown respectively in Figure 8, Figure 9, Figure 10 and Figure 11.

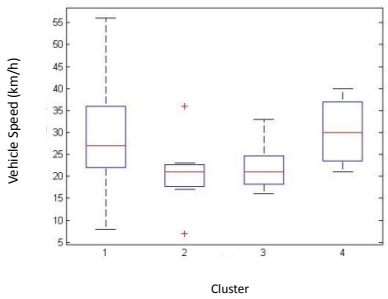

Figure 8. Box Plots of Vehicle Speed

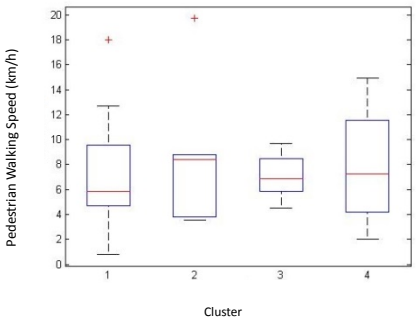

Figure 9. Box Plots of Pedestrian's Walking Speed

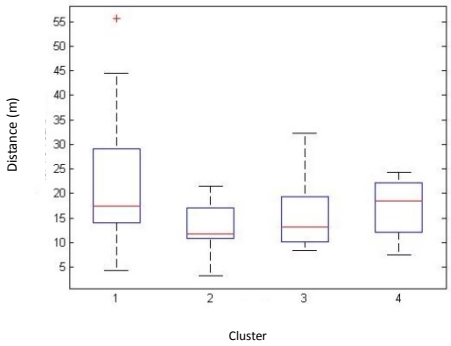

Figure 9. Box Plots of Distance between Vehicle and Pedestrian

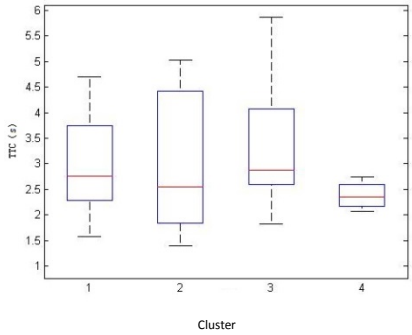

Figure 10. Box Plots of TTC

Obtainment and Analysis on Typical Scenarios

According to the result of clustering, 4 typical near-crash scenarios related to pedestrians at TRS are obtained, which cover 92.3% of the total samples. The 4 scenarios are shown in Table 4

Table 4.

Typical Near-Crash Scenarios

Cluster	Time period	Cross or not	Pedestrian crossing from	Vehicle speed（25 to 75 percentile）km/h	Pedestrian walking speed（25 to 75 percentile）km/h	Distance between pedestrian and vehicle（25 to 75 percentile）m
1	Daytime	Yes	Left	22-36	5-10	14-29
2	Daytime	Yes	Right	18-23	4-9	11-17
3	Daytime	No	Along the road	18-25	6-9	10-19
4	Night	No	Along the road/Right	24-37	4-12	12-22

In the first and second scenarios, the location is at intersection in daytime. The difference between these two kinds is that pedestrians cross roads from different directions. The proportion of crossing road from left side is higher than that of right side. Presumably, Left A pillar hinders driver's view to perceive pedestrians crossing from left side in advance.

In the third scenario, the location is at normal road in daytime, and the pedestrian is walking along the road. By reviewing videos, we find that roads are usually narrow or sidewalks are occupied in these scenarios, and pedestrians have to walk on motorway and conflicts happen naturally.

In the fourth scenarios, the location is at normal road at night. Pedestrian is walking along the road or crossing the road from right side. Similar with scenario 3, the situation of pedestrian's walking along the road happens on narrow road.

CONCLUSIONS AND DISCUSSIONS

Conclusions

1) Through qualitative analysis, the following conclusions could be drawn: at TRS, the number of the cases in which the pedestrian is crossing the road is about 3 times more than that of the cases in which the pedestrian is walking along the road. The condition that the driver is driving under daylight, good lighting and uncongested road is respectively 5 times, 11 times, and 31 times more than driving under darkness, bad lighting and congested road.

2) Aiming at TRS, 4 typical scenarios are obtained including 5 variables: time (day & night), road character (congested & uncongested), pedestrian walking direction (along the road & across the road), car speed and pedestrian's travel speed. Most vehicle speeds are among 18-37km/h and most pedestrian's

travel speeds are among 4-12km/h. 4 scenarios cover 92.3% of the total samples.

Discussions

1) Obstruction is not included in the cluster analysis as a factor in this study, since drivers have seen the pedestrian at TRS. Meanwhile, it is included in the cluster analysis as a factor in similar studies, which obtain test scenarios based on crash cases since the happening of crash is related to obstruction. This difference can reveal the characteristics of near-crash and crash.

2) Unlike the previous studies, which only bring the average pedestrians' travel speed into test scenarios, the pedestrians' travel speed was included in the cluster analysis as a factor in this study, thus allowing more detailed information of pedestrians' travel speed in the typical scenarios.

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