Analysis of the Factors that affect the Avoidance rate for Car and Two-wheeler Accidents Based on Logistic Regression

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I. INTRODUCTION

Car and two-wheeler accidents can be effectively avoided by Autonomous emergency braking systems (AEB). This study examines the technical parameters for optimization of the AEB system. In order to identify the factors that may affect the avoidance rate, 188 car and two-wheeler accidents were sampled and analyzed. The trajectory of each vehicle under each combination of influencing factors was simulated by PC-CRASH. The correlation between avoidance rate and car speed, two-wheeler speed, two-wheeler type, AEB detection angle, detection distance, TTC and brake deceleration was studied by using the binary logistic regression method. The results showed that the car speed was positively related to the avoidance rate, and that when the two-wheeler speed was under 60 km/h, it was negatively related to the avoidance rate. A higher avoidance rate was found in bicycle than for other types of two-wheeler. Except for the detection distance above 50 m, AEB system parameters such as detection angle, TTC and braking deceleration were all positively related to avoidance rate.

II. METHODS

Sample Data

The research sample comprised 188 cases of car and two-wheeler accidents that occurred on urban roads in the CIDAS database. The inclusion criteria required the two-wheeler rider to be injured and the car to be travelling straight. We divided Two-wheeler into four types: fuel motorcycle; electric motorcycle without pedals; electric bicycle with pedals; and bicycle. They accounted for 38%, 21%, 33% and 8% of accidents, respectively.

Analytical Method

Use PC-CRASH [1] to reconstruct the trajectory, speed and dynamic parameters of the car and two-wheeler 2 s before collision. Load the AEB system module in the virtual environment for the target accident case, set different parameter combinations, record whether the accident can be avoided, and analyze the avoidance rate under various influencing factors. Previous studies [2] and [3] have verified the effectiveness of this method.

The paper selected four key parameters of the AEB system to evaluate the correlation between any two sets of parameters and the avoidance rate. for example, Fig.4 shows the influence of car speed and detection angle. When the values of the two parameters are 20km/h and 30°, then the detection distance takes the values 50 m, 80 m, 100 m and 150 m, the trigger time TTC takes the values 0.5 s, 1.0 s, 1.5 s and 2.0 s, and the braking deceleration takes the values 6 m/s2, 7 m/s2, 8 m/s2 and 9 m/s2, which can have 64 combinations. The number of avoidable accidents under 64 combinations is calculated. The ratio of the number of avoidable accidents to the total number of accidents is defined as the avoidance rate.

Data Statistics

Figure 1 shows that the car collision speed is mainly distributed in three intervals of less than 20 km/h, 20–40 km/h and 40–60 km/h, accounting for 29%, 44% and 18%, respectively. An interval of greater than 80 km/h accounted for only 2%. Figure 2 shows that about 76% of the fuel motorcycles and 82% of the electric motorcycles in the accident scenarios have a speed higher than 20 km/h, while about 45% of the electric bicycles and 87% of the bicycles have a speed lower than 20 km/h. Figure 3 shows the cars and two-wheelers relative position distribution 2s before collision: about 98% of accidents occur within 50 m in the longitudinal distance, and about 96% are within 20 m in the lateral distance.

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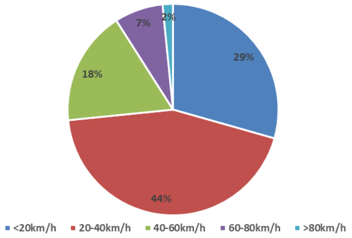

Fig. 1. Car collision speed distribution

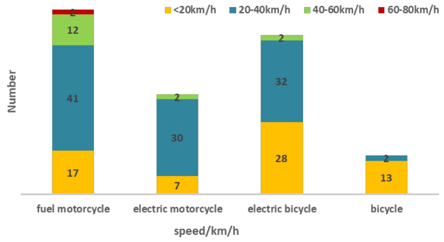

Fig. 2. Two-wheelers collision speed distribution

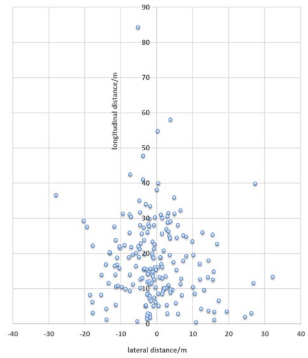

Fig. 3. Position distribution 2s before collision

Avoidance Rate Analysis

The key parameters of the AEB system module are set as follows: the detection angle is 30°, 40°, 50° and 60°, the detection distance is 50 m, 80 m, 100 m and 150 m, the trigger time TTC is respectively 0.5 s, 1.0 s, 1.5 s and 2.0 s, the braking deceleration is 6 m/s^2, 7 m/s^2, 8 m/s^2 and 9 m/s^2.The AEB detection angle, detection distance, trigger time TTC and braking deceleration are classified and combined 256 times, and the accident avoidance of each combination is recorded in a virtual environment.

Figure 4 shows the relationship between avoidance rate, car speed and AEB detection angle. When the car collision speed is higher than 80 km/h, the avoidance rate is the highest, followed by 60–80 km/h, 40–60 km/h, 20–40 km/h and below 20 km/h. When the car speed is higher than 80km/h, the change of detection angle does not affect the avoidance rate. When the car collision speed is 60–80 km/h, after the detection angle reaches 50°, the avoidance rate no longer increases. When the car collision speed is lower than 60 km/h, the avoidance rate increases with the increase of the detection angle. Accidents with car speed higher than 60 km/h are mainly avoidable in terms of time, which means that the car stopped before the original collision point and collision was avoided. While accidents lower than 60 km/h are mainly avoided in terms of space after the two-wheeler is detected, which means that the car has exceeded the original collision point and collision was avoided. The relationship between remaining parameters and avoidance rate can be seen through Fig. 5 to Fig. 15.

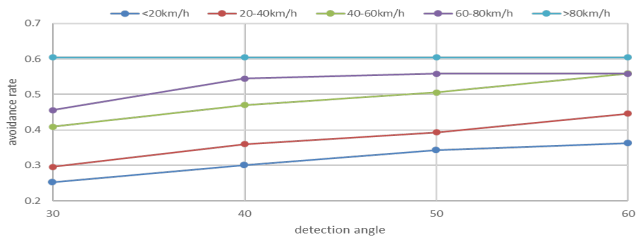

Fig. 4. Car speed, detection angle – avoidance rate.

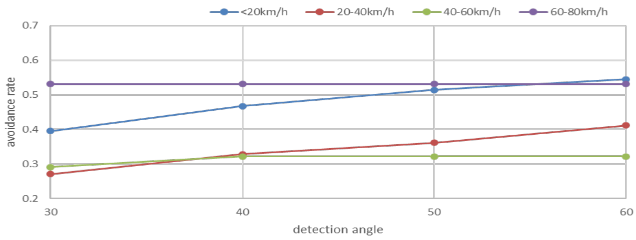

Fig. 5. Two-wheeler speed, detection angle – avoidance rate.

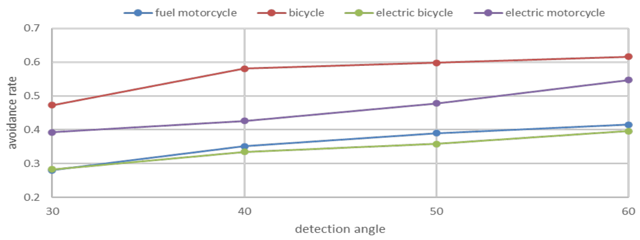

Fig. 6. Two-wheeler type, detection angle – avoidance rate.

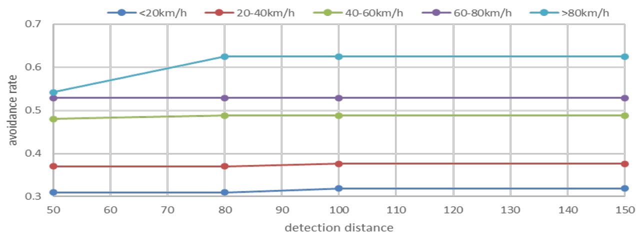

Fig. 7. Car speed, detection distance – avoidance rate.

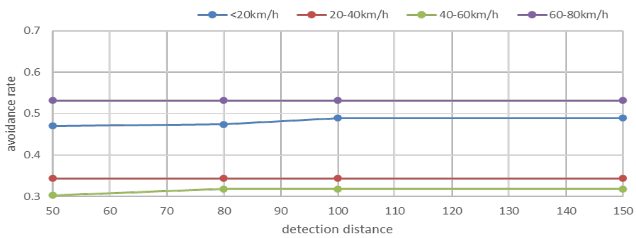

Fig. 8. Two-wheeler speed, detection distance – avoidance rate.

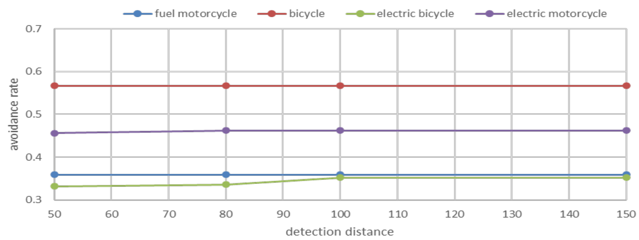

Fig. 9. Two-wheeler type, detection distance – avoidance rate.

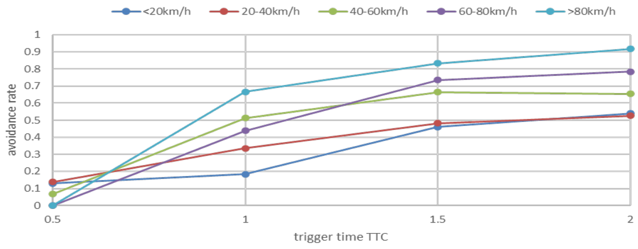

Fig. 10. Car speed, TTC – avoidance rate.

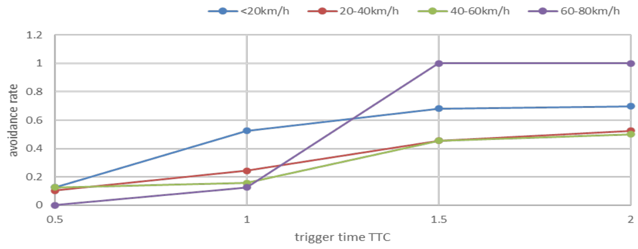

Fig. 11. Two-wheeler speed, TTC – avoidance rate.

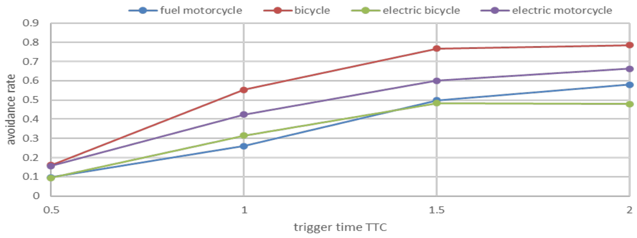

Fig. 12. Two-wheeler type, TTC – avoidance rate.

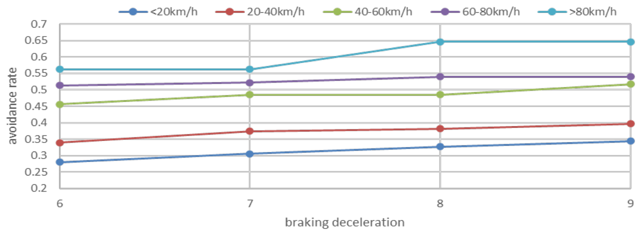

Fig. 13. Car speed, braking deceleration –avoidance rate.

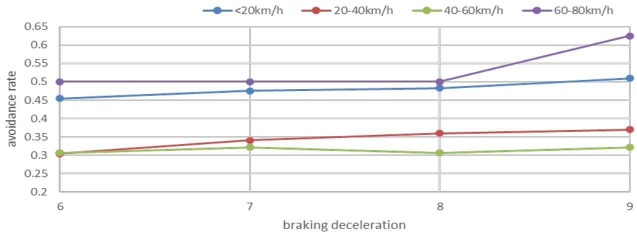

Fig. 14. Car speed, braking deceleration – avoidance rate.

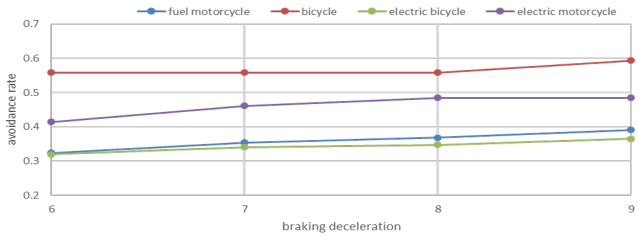

Fig. 15. Two-wheeler speed, braking deceleration – avoidance rate.

III. INITIAL FINDINGS

Binary logistic regression was used to further explore the correlation between the avoidance rate and factors such as car speed, two-wheeler type, two-wheeler speed, detection angle, detection distance, TTC and brake deceleration. The results of 48,128 combinations of 188 accident cases were analyzed by binary logistic regression. The likelihood ratio showed that the regression model was significant (Chi-square was 11731.98, P<0.001). Corresponding partial regression coefficient values, Wald test, odds ratio (OR) and significance parameters are shown in Table I.

The last of the independent variable category was used as the reference group (odds ratio OR=1). The correlation analysis results in Table I show that the probability of collision avoidance is highest when the car speed is higher than 80 km/h (OR=1), and that the probability is about 28.3% of the reference group when car speed is lower than 20 km/h. Bicycle accident has the highest probability of avoiding collision (OR=1.792), followed by electric motorcycle (55.8%), and fuel motorcycle was reduced to 32.4% of the reference group. When the two-wheeler speed is 60–80 km/h, the probability of collision avoidance is the highest (OR=1). When speed is 40–60 km/h and 20–40 km/h, the probability is reduced to about 28.4% and 23.2% of the reference group, respectively. When the AEB detection angle is 60°, the probability of collision avoidance is the highest (OR=1). When the detection angle is 30° the probability of avoiding collision is about 49% of the reference group. When the detection angle increases, the probability increases. When the AEB detection range is 150 m, the probability of collision avoidance is the highest (OR=1), and when the detection range is 50 m, the probability is the lowest but reaches 95.8% of the reference group. When the AEB trigger time TTC is 2 s, the probability is the highest (OR=1), and when the TTC is 0.5 s, the probability is only 6.9% of the reference group. When braking deceleration is 9 m/s^2, the probability is the highest (OR=1). When braking deceleration is 6 m/s^2, the probability is about 73% of the reference group. With increase of braking deceleration, the probability increases gradually.

The next step of research needs to further clarify the quantitative relationship between the accident avoidance rate and different parameters, similar to the binary logistic regression model, which has important reference significance for the parameter setting of the AEB system.

TABLE I
CORRELATION ANALYSIS OF AVOIDABLE ACCIDENT INFLUENCING FACTORS

Factor		β	Wald	OR（95% CI）	p
Car speed	<20	-1.261	219.801	0.283	0.001
	20-40	-1.107	172.641	0.330	0.001
	40-60	-0.669	59.878	0.512	0.001
	60-80	-0.408	20.043	0.665	0.001
	>80	0	0	1	0
Two-wheeler type	fuel motorcycle	-0.544	346.536	0.580	0.001
	bicycle	-0.233	22.465	1.792	0.001
	electric bicycle	-0.835	745.087	0.434	0.001
	Electric motorcycle	0	0	1	0
Two-wheeler speed	<20	-0.342	10.895	0.710	0.001
	20-40	-1.259	150.738	0.284	0.001
	40-60	-1.461	184.319	0.232	0.001
	60-80	0	0	1	0
Detection angle	30	-0.714	556.169	0.490	0.001
	40	-0.385	167.532	0.681	0.001
	50	-0.201	46.068	0.818	0.001
	60	0	0	1	0
Detection distance	50	-0.043	2.067	0.958	0.151
	80	-0.029	0.918	0.972	0.338
	100	0.000	0.000	1.000	1.000
	150	0	0	1	0.377
TTC	0.5	-2.671	5377.870	0.069	0.001
	1	-1.163	1669.650	0.313	0.001
	1.5	-0.220	64.587	0.803	0.001
	2	0	0	1	0
Braking deceleration	6	-0.314	109.517	0.730	0.001
	7	-0.158	28.155	0.854	0.001
	8	-0.092	9.587	0.912	0.002
	9	0	0	1	0

IV. DISCUSSION

The ability of the AEB system to detect and avoid accidents has certain limitations. When the detection range exceeds 50 m, the avoidance rate change slightly with the increase in detection distance. The car speed is positively correlated with the avoidance rate, while the two-wheeler speed is negatively correlated with the avoidance rate when it is lower than 60 km/h. The AEB detection angle, trigger time TTC and braking deceleration are all positively correlated with the avoidance rate. The change of trigger time TTC has the greatest influence. The avoidance rate when TTC is set as 2 s is more than three times that when TTC is set at 1 s, and 16 times that when TTC is set at 0.5 s. Therefore, measures to improve road adhesion coefficient under special conditions, such as rain, snow and ice, and AEB control strategy under special conditions should be fully considered.

This study only theoretically analyzes the correlation between each influencing factor and the avoidance rate. The effect of the AEB system’s sensor sensing efficiency and of actual road conditions on braking deceleration are not considered. This means the actual avoidance rate may be lower than the theoretical value.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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