AEBS Perception Stability Study of Intelligent Vehicles Based on C-NCAP

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Abstract: In order to evaluate the perception stability and performance assessment accuracy of the autonomous emergency braking system(AEBs) which is commonly marketed using the monocular cameras and millimeter-wave radar fusion scheme, the speed sensitivity and target recognition ability are analyzed through repeated tests with multiple working conditions as well as targets based on uncertainty. Then the influence on C-NCAP scoring is determined. The results show that the stability of AEBs manifests a downward trend with the increase of travel speed where it reduces more in ‘Car to Car moving (CCRm)’ condition than in ‘Car to Car stationary (CCRs)’ condition. There is influence of stability on C-NCAP scoring that is 3.23% on average, where the highest value is 6.57% in the high-speed test of CCRm when the lowest value is 2.14% in the high-speed test of CCRs. The trend of influence that changes with speed is opposite under the two working conditions of CCRm and CCRs. Greater influence is found for two-wheelers tests than for pedestrians cases.

1 INTRODUCTION

According to worldwide statistic on car accidents, almost 50 million road users get hurt and 1.3 million lose their lives due to traffic collision (WHO, 2015). For the public safe, Automotive are getting more intelligent at the present time, and active safety has become one of the hot topics in the field of auto safety. The development of advanced driver assist system contributes to reduce driving risk (European Comission, 2011)-(NHTSA, 2016). Autonomous Emergency Braking system (AEBs) is an important part of the active safety function. When a vehicle, pedestrian or two-wheeler suddenly appears in front of a moving vehicle with the failure of timely braking resulting in high risk of collision, the assistance of AEBs will help to avoid or mitigate the collision so that it substantially improves the road safety (Fildes B. et al., 2015). reported that compared to vehicles without AEBs, similar ones equipped with the system only encountered 62% rear-end collisions. Research of Teoh E. R. also shows that AEB intervened in 43% of rear-end crashes and about two thirds of these interventions involved auto-brake activation so that there was a significant reduction on number of crashes.

However, many studies of AEBs have focused on how to avoid collisions (Lee, J. et al., 2019), (Koglbauer, I. et al., 2018), and in fact accidents are still difficult to avoid in current traffic conditions. Research results (Cicchino, J. B., 2017)-(Haus S et al., 2019) have shown that although AEB can reduce the risk of death and injury in the target population, there are still about 40% of unavoidable accidents (Rosén E, 2010), which indicates that attention should be also paid on AEBs in crushing cases. A study by Guo Lei et al found that the impact injury to pedestrians was mainly determined by the collision speed, and pedestrians were prone to fractures of the lower limbs when the collision speed was greater than 41 km/h. Islam M reported that there were significant differences in pedestrian-injury severity in different speed cases. Also, Doecke S et al found that impact speed was found to have a highly significant positive relationship to risk of serious injury for all impact types. These reported results emphasize the importance of impact speed, which needs high level of stability. Therefore, to evaluate the active safety performance of a vehicle in a collision, the stability of speed drop during a collision is equally important in addition to avoiding the collision.

In order to protect the safety of consumers, many countries and regions have established their own automobile safety evaluation systems. In China, C-NCAP (China New Car Assessment Program) has become one of the important standards for evaluating the safety performance of new cars. And now it is an

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important basis and reference for Chinese consumers to choose a car. However, though C-NCAP provides comprehensive test cases for new cars, the perception uncertainty of sensors is not in the consideration of C-NCAP. Chengyong Niu et al has found that the AEBs sensors can be influenced by environmental factors, which will lead to significant fluctuations in the performance of automatic emergency braking. According to the scoring of the assessment process, in the case of the estimated value of the manufacturer not provided, the test is conducted only once, and even with the estimated value, only three tests are conducted. Therefore, the fluctuations could result in a certain level of uncertainty in the scoring of C-NCAP with limited tests.

Based on the above discussion, perception stability study is essential for the active safety assessment of intelligent vehicles. And rare relevant researches can be found at present. In this paper, multiple course tests with different targets based on AEBs cases in C-NCAP (version 2021) are conducted and the results are further studied using uncertainty analysis according to *Evaluation and Expression of Uncertainty in Measurement*. The perception stability characteristic of AEBs is found when vehicle travels in various speed and under different target objects. Combined with the evaluation rule of C-NCAP, the influence of the perception stability on the score is discovered as well. The conclusion has practical significance for social traffic safety and provides data support for component manufacturers to improve sensor performance and design new fusion solutions. Also it presents a more objective perspective for car manufacturers and consumers with respect to C-NCAP evaluation scores, which may help to develop subsequent C-NCAP test protocols and more accurate scoring rules.

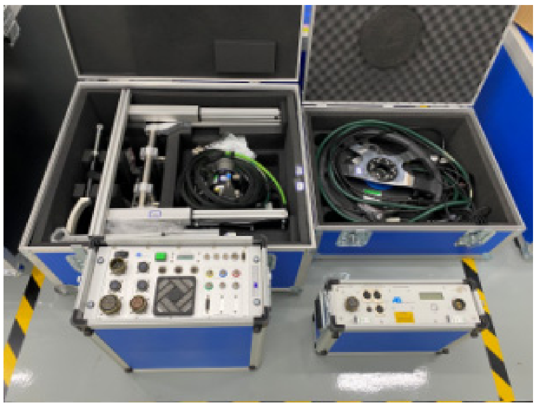
2 UNCERTAINTY ANALYSIS ON C-NCAP CASES

C-NCAP version 2021 tests for AEBs are divided into AEB CCR (vehicle-to-vehicle rear-end condition) and AEB VRU (vehicle-to-vulnerable road user), where AEB VRU can be divided into three types of crash objects, namely Ped (pedestrian), BTA (Pedestrian Target Adult), and STA (Scooter Target Adult). In this paper, based on the cases above respectively, repeated tests at different speed points will be conducted to analyze the uncertainty of the results. It should be noted that this paper only analyzes the speed at which collisions will occur, because cases that can avoid collisions do not need to consider the stability of the velocity drop.

2.1 Test Preparation

Tian-Yong studied that the sensing solution of AEBs using millimeter wave radar fused with camera, which well balances the cost and safety performance, has become the choice of a large number of car manufacturer nowadays. And in this paper, in order to gain representative results, the sample car is equipped with 5 cameras outside the vehicle as well as 3 millimeter wave radars and 6 ultrasonic radars. Besides, a identical sample has been tested based on CNCAP with a announced scoring rate of 82% when the average scoring rate in 2022 is 80.81% (Fanyu Liu, 2022).With the AEBs configuration and the C-NCAP scoring, the test results of the selected sample car posses representative and indicative value. Figure 1 (a) shows the prototype vehicle in the AEB CCR test scenario. Figures 1(b) and (c) show the equipment for testing (ABD driving robot system) and the test subjects (4A target dummies, including pedestrians, bicycles, and scooters). All the equipments of tests are in good conditions and the accuracy requirements can be met through measurement and inspection.

(a)Picture of the sample car in AEB CCR test.



(b)Steering, throttle and brake robot.

(c) Test objects: pedestrians, bicycles, and scooters.

Figure 1. Main hardware configurations of C-NCAP tests.

The uncertainty of the impact speed during the test is mainly influenced by:

1) **Uncertainty Introduced by the Test Method.** In the test process, the driver's ability to control the vehicle will inevitably produce random errors, such as whether the test vehicle speed is well stabilized in the standard test speed within the specified time frame. The unstable performance of the AEB sensor of the sample vehicle itself can also lead to systematic and random errors in the test. The state of the test sample vehicle will also produce systematic errors, such as the degree of vehicle break-in, tire pressure, and the degree of wear on the car's wheels.

2) **The Component from the Linearity Error of the Device.** According to the requirements of appendix C 6.1.3.1 of C-NCAP version 2021, the speed accuracy of the device is required to be 0.1km/h. The speed accuracy of the model RT3002 high-precision gyroscope used in this paper is calibrated to 0.05km/h.

Considering the small error caused by the equipment and environment, when the vehicle deceleration is mainly controlled by the AEBs, the uncertainty in this study is mostly contributed by the sensor stability of the test vehicle.

From the perspective of uncertainty, this paper carries out variable control from the following aspects: on the one hand, for the test equipment and testers, the calibrated fixed base station differential GPS positioning equipment is used to ensure the high precision positioning of the vehicle, with a positioning accuracy of 0.02m. In addition, ABD driving robot with strict tuning is used to repeat the precise control of the vehicle, without changing the driver during the all tests. On the other hand, the environment and the state of the sample car during the tests also need to be ensured. The test site is CATARC Automotive test site of south China. Before conducting each test, it is confirmed that the ground is dry, flat with clear lane lines without rainfall, overheating and crosswind. Also the visibility is checked to be higher than 1km. Vehicle tire tread depth must be normal and the target location of each test is fixed.

2.2 Uncertainty Calculation of AEB-CCR

In C-NCAP version 2021, the scenario for CCR is defined as a two-vehicle rear-end crashing condition. Specifically, the test vehicle approaches the front vehicle from the rear at constant speed while the front vehicle is driving at low speed or stationary. Refer to Figure 2, where V_{VUT} is the speed of the test vehicle and V_{GVT} is the speed of the vehicle in front.

Figure 2. The test scene schematic of AEB CCR in C-NCAP.

According to the requirements of C-NCAP, all speed conditions of CCRs and CCRm are tested separately. If AEB is successfully triggered and a crash occurs, it is recorded as a valid test, and the effective crash speed is recorded until the valid test reaches 10 times. All the test result of CCR cases are listed in Table 1.

Table 1. The results of CCR test.

Case		CCRs					CCRm		
Initial speed (km/h)		40	50	60	70	80	60	70	80
1	Impact speed (km/h)	15.5	17.6	21.1	27.7	30.6	8.2	15.4	22.3
2		14	16.3	22.3	28.8	32.7	7.9	10	17.3
3		15.3	18.4	24.5	27.4	33.6	5.5	11.3	23.8
4		13.8	19.2	20.8	25.2	35.4	6.2	13.5	16.5
5		12.7	20.7	23.4	26.6	35.8	4.7	17.2	18.4
6		14.4	18.7	22.6	28.3	36.5	8.3	12.2	23.3
7		16.3	19.5	24.7	25.1	32.5	7.9	14.8	25.8
8		16	16.9	25.1	24.4	33.6	8	11.2	25.1
9		16.5	17.5	24.5	25.7	31.8	4.5	17.5	27.5
10		14.2	18.1	25.3	27.3	34.3	6.9	13.3	20.3

According to reference (Evaluation and Expression of Uncertainty in Measurement: JJF, 2012), the calculation procedure for the evaluation of uncertainty components is as follows:

1. Calculate the arithmetic average of 10 collision speeds for each speed case:

$$\overline{S} = \frac{1}{n}\sum_{i=1}^{n} S_i \qquad (1)$$

where n=10, S_i represents the crash speed of group i.

2. Calculate the variance S^2 and standard deviation S:

$$S^2(S) = \frac{1}{n-1}\sum_{i=1}^{n}(S_i - \overline{S})^2 \qquad (2)$$

$$S(S) = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(S_i - S)^2} \qquad (3)$$

3. Then the standard uncertainty u_a introduced by test method can be calculated through:

$$u_a = S(S)/\sqrt{n} = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}(Si - \overline{S})^2} \qquad (4)$$

4. The inertial GPS combined test system used in this paper, qualified by a third party, has an absolute velocity accuracy of ±0.05km/h, indicating that the half-width of the dispersion interval of the instrument measurements is a=0.05km/h, estimated as a rectangular distribution with confidence factor k=$\sqrt{3}$, then:

$$u_b = a / k \qquad (5)$$

where u_b is the uncertainty introduced by the equipment.

5. The synthetic uncertainty u_c and the final extended uncertainty U can be calculated by the following formula:

$$u_c = \sqrt{u_a^2 + u_b^2} \qquad (6)$$

$$U = u_c \cdot K \qquad (7)$$

where K is the inclusion factor and it is taken as 2 in this paper.

So the uncertainty results of CCR are listed in Table 2.

Table 2. AEB CCR uncertainty calculated results.

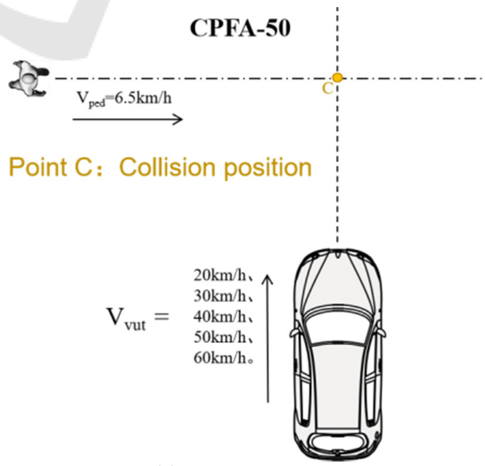
Parameter	CCRs					CCRm		
Initial speed(km/h)	40	50	60	70	80	60	70	80
Adverage of impact speed(km/h)	14.87	18.29	23.43	26.65	33.68	6.81	13.64	22.03
Mean squared error(km/h)	1.24	1.36	1.52	1.53	1.61	1.49	2.63	3.99
u_a(km/h)	0.39	0.43	0.48	0.48	0.51	0.47	0.83	1.26
u_b(km/h)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
u_c(km/h)	0.39	0.43	0.48	0.48	0.51	0.47	0.83	1.26
U(km/h)	0.79	0.86	0.96	0.97	1.02	0.94	1.67	2.52

The extended uncertainty U indicates the possible drift of impact speed value in this study. The confidence level of the test results in the interval of the impact speed V_{impact}±U is 95% based on the above calculation (Evaluation and Expression of Uncertainty in Measurement: JJF, 2012).

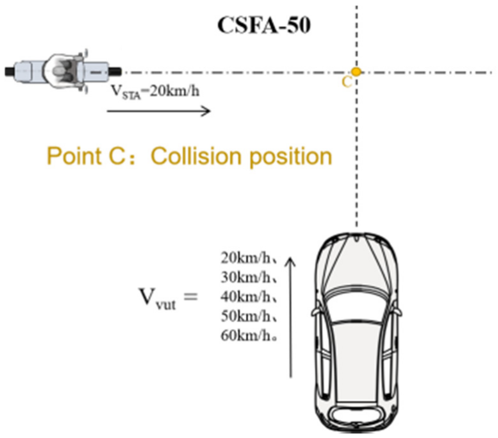
2.3 Uncertainty Calculation of AEB-VRU

In the scoring rules of C-NCAP, when it comes to VRU cases that are plotted in figure 3, there are only two kinds of scoring in cases with initial speed over 40km/h: if the speed drop at the time of the collision is less than 20km/h, the scoring rate is 0, otherwise it is 100%. So there will only be influence of impact speed uncertainty on cases with initial speed equal or less than 40km/h. Besides, during the tests, it is found that collision occurs only when the sample travels at 40km/h.

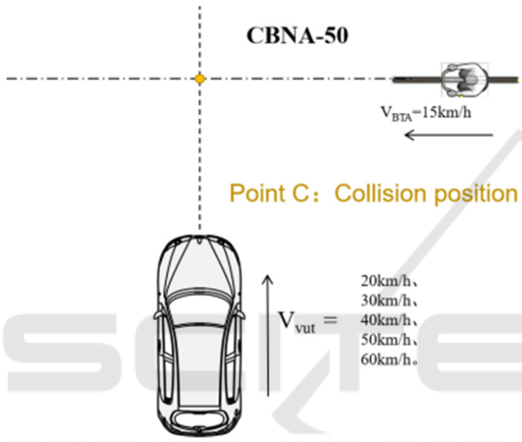
As shown in figure 3, the selected cases of VRU test are CPFA, CSFA and CBNA that respectively mean an adult pedestrian travel from the left side of the sample velocity direction to the collision position, a two wheel bicycle rider travel from the left side of the sample velocity direction to the collision position and a two wheel scooter travel from the right side of the sample velocity direction to the collision position. The reference points are at the shoulder for pedestrian, at the bottommost part of the crankshaft of the bracket for bicycle, at the most forward place for scooter. '50' means the collision happen at the middle of the width of the car. None offset case is in the consideration that it will be presented in the future study.



(a) CPFA test case



(b) CSFA test case



(c) CBNA test case

Figure 3. VRU test scenes schematic in C-NCAP.

V_{vut}, V_{Ped}, V_{STA} and V_{BTA} indicate the initial speed of the vehicle under test, the adult pedestrian, the scooter and the bicycle, respectively.

Results of ten tests for all cases of VRU are listed in Table 3.

Table 3. Impact speed results of AEB VRU.

Case		CPFA	CBNA	CSFA
Initial speed(km/h)		40	40	40
1	Impact Speed (km/h)	10.3	12.3	11.8
2		9.7	13.3	13.8
3		11.7	13.5	13.4
4		10.5	12.5	10.9
5		9.1	13.6	14.1
6		10.2	10.7	11.2
7		10.7	11.5	12.7
8		10.6	13.8	11.3
9		9.9	10.2	10.3
10		8.4	10.7	13.8

Similarly, using Eqs. (1)-(7), the uncertainty assessment results for AEB_VRU can be obtained and Table 4 lists the calculated results for CPFA, CBNA, and CSFA, showing the degree of dispersion of the impact speed.

Table 4. AEB VRU uncertainty calculated results.

	CPFA	CBNA	CSFA
Initial speed(km/h)	40	40	40
Average impact speed(km/h)	10.11	12.21	12.33
Mean squared error(km/h)	0.96	1.44	1.47
u_a(km/h)	0.30	0.45	0.46
u_b(km/h)	0.03	0.03	0.03
u_c(km/h)	0.31	0.46	0.46
U(km/h)	0.61	0.91	0.93

3 DISCUSSION

3.1 Analysis of Test Results

From the course test and uncertainty analysis in the previous chapter, it can be seen that the impact speed rises with V_{vut} in CCRs condition: when V_{vut} is 40km/h, the average impact speed is 14.87km/h and the speed drop is 25.13km/h, while when V_{vut} is 80km/h, the average impact speed is 33.68km/h and the speed drop is 46.32km/h. This indicates that higher initial speed leads to higher impact speed though AEBs is involved. Same conclusion is shown in Figure 4 that though the speed drop rises, cases with higher initial speed may result in higher impact speed with greater possibility of collision. Moreover, histogram in figure 5 shows that the uncertainty also increases with rising initial speed. At V_{vut}=40km/h, U value is 0.79km/h, and the interval of impact speed results is [14.08,15.66]km/h. These results increase to be 1.02km/h and [32.66,64.67]km/h at higher V_{vut}=80km/h where the value of U is up 29% compared to case at V_{vut}=40km/h. This illustrates that in an emergency braking scenario against a stationary vehicle in front, the dynamic sensing capability and accuracy of the camera and radar fusion scheme may decrease as the vehicle travels at higher speed, exhibiting a more erratic performance.

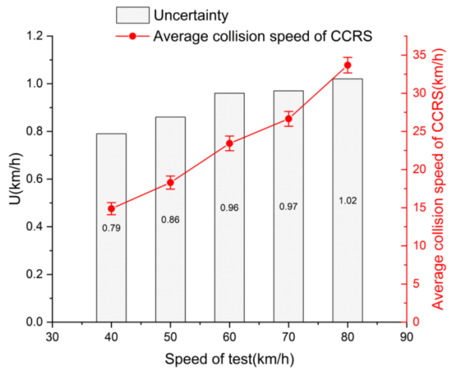


Figure 4. Uncertainty and impact speed results at various initial speed in CCRs cases.

In cases of CCRm, similar characteristics are found compared to CCRS, but also new features are shown. Red line in Figure 5 indicates the rise of impact speed with higher initial vehicle speed: when V_{vut} is 60km/h, average impact speed is 6.81km/h and relative speed drop ΔV_{rel} is 33.19km/h, while when V_{vut} is 80km/h, average impact speed is 22.03km/h and relative speed drop ΔV_{rel} is 37.97km/h. The intervals of impact speed with V_{vut} =[60,70,80]km/h are [5.87,7.75]km/h, [11.97,15.31]km/h, [19.51,24.55]km/h, respectively. It can be seen that as the test vehicle speed increases, ΔV_{rel} also increases. However, compared to CCRs, ΔV_{rel} is found to be larger at the same V_{vut}. Combined with the subjective driver perception during the tests, this may be due to the fact that the sensor may mistakenly identify the vehicle in front as stationary and issue a more aggressive braking command when the dynamic recognition capability is not sufficient.

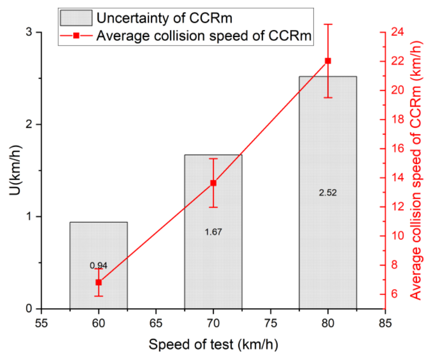


Figure 5. Uncertainty and impact speed results at various initial speed in CCRm cases.

Figure 6 compares the variation of ΔV_{rel} with V_{rel} for the two operating conditions of CCRm and CCRs. It illustrates that ΔV_{rel} may be larger at low speed conditions in CCRm, but the rate of change is higher in CCRs, indicating that ΔV_{rel} tends to be the same for both cases as V_{rel} increases.

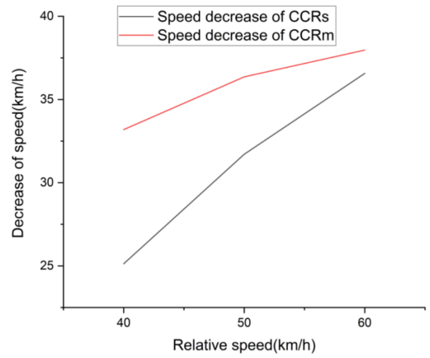


Figure 6. Comparison of ΔV_{rel} of CCRs and CCRm with the same V_{rel}.

For the C-NCAP road vulnerable user test, this paper conducted CPFA, CBNA, CSFA in the test vehicle speed of 40km / h working conditions respectively and the uncertainty comparison results obtained can be seen in Figure 7. The results showed that the average values of impact speed for pedestrian crossing, bicycle crossing and motorcycle crossing are 10.11km/h, 12.21km/h and 12.33km/h, respectively, with the extended uncertainty values of 0.61km/h, 0.91km/h and 0.93km/h, and the collision speed intervals are [9.5,10.72]km/h, [11.3. 13.12]km/h, [11.4,13.26]km/h. Among these three operating conditions, the pedestrian crossing scenario is the one with the lowest impact speed and uncertainty values. In contrast, when facing bicycles and motorcycles, the impact speed and uncertainty magnitude are very close, and the AEB system shows similar performance in front of both objects, probably due to the more similar morphology and behavior of both, while the more complex morphology and posture make higher performance requirements for sensors than pedestrian recognition.

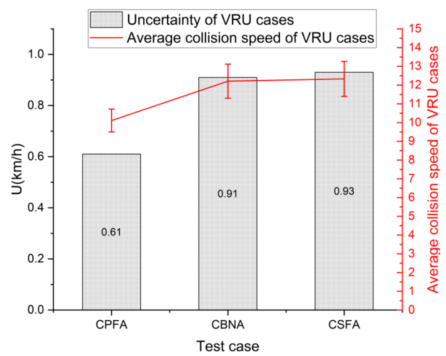


Figure 7. Uncertainty and impact speed results at various initial speed in VRU cases.

3.2 Influence on C-NCAP Scoring

According to the scoring rules of C-NCAP version 2021, the score rate of each test speed point in AEB CCR and AEB VRU is $P=(V_{rel,test}-V_{rel,impact})/V_{rel,test}$ where $V_{rel,test}$ is the relative speed of the test vehicle and the front vehicle at the beginning of the test and $V_{rel,impact}$ is the relative speed of the test vehicle and the front vehicle at the time of collision. Based on the score rate, the specific scores are calculated as follow:

$$S_{score}= P\cdot i\cdot j\cdot k \tag{8}$$

where P represents the score rate, i represents the speed weight, j is the scene weight, and k is the full scene score. All the parameters in equation (8) can be seen in the following Table 5:

Table 5. Parameters for calculating the final score in equation (8).

Parameter	V_{vut}	k	i	j
CCRs	40	4	3/14	1/2
	50	4	1/14	1/2
	60	4	3/14	1/2
	70	4	1/14	1/2
	80	4	1/7	1/2
CCRm	60	7	1/8	1/2
	70	7	3/16	1/2
	80	7	3/16	1/2
CPFA	40	2	2/7	1/2
CBNA	40	4	2/7	1
CSFA	40	4	1/3	1

Then the influence of uncertainty on score can be calculated using the same equations. Combined with the intervals of results of each cases conducted in previous chapters, the upper and lower extremes of the scores due to the uncertainty in the AEB series of C-NCAP tests and the magnitude of the one-sided fluctuations can be directly obtained. The calculated results are given in Table 6. It is shown that all tests in this study receive a total score of 4.06 based on average impact speed. Furthermore, considering the uncertainty, the extreme value of the score is 4.20 for the high level and 3.92 for the low level, with a difference of 0.28 and a one-sided error of 0.14.

Table 6. Score result and influence of uncertainty.

Case	V_{vut}	Score of average impact speed	Total score	Extreme value For high level	Extreme value For Low level	One-side error
CCRs	40	0.27	4.06	4.20	3.92	0.14
	50	0.09				
	60	0.26				
	70	0.09				
	80	0.17				
CCRm	60	0.36				
	70	0.48				
	80	0.42				
CPFA	40	0.21				
CBNA	40	0.79				
CSFA	40	0.92				

There are 11 test cases in total conducted in this study that generate the one-side error of 0.14 in score. However, C-NCAP has 75 cases which means that the final error can be far more than it with more influencing factor in different offset rates and light conditions.

The one-side error for every single case can be calculated through

$$\text{influence level} = \frac{\text{one - side error}}{\text{average score}}\cdot 100\% \tag{9}$$

that the result represents the influence of uncertainty caused by stability of AEBs sensors on the score of every single case and it is plotted in Figure 8. The black dash line is the average level which is 3.23%.

Figure 8 indicates the following conclusions:

1) In CCRs cases, though the uncertainty increases with rising Vvut, the influence level decreases with maximum of 3.12% in 40km/h and minimum of 2.14% in 80km/h. Moreover, each case of CCRs has lower influence level than average and the differences between them are not obvious. This indicates AEBs has more stable sensitivity of speed and has a relatively mature technology in car-to-vehicle stationary conditions.

2) The performance in CCRm of Figure 8 is contrary to which in CCRs. The influence level grow rapidly with higher Vvut that it is 2.86% in 60km/h and 6.57% in 80km/h. Furthermore, the results of 70km/h and 80km/h are significantly higher than the

average level and 2 to 3 times larger than that of other scene cases. This founding shows high sensitivity of speed of the sensor perception stability in front moving vehicle recognition which may caused by a misjudgment of the front distance to the target.

3) For VRU tests, the results are corroborated with the previous analysis for Figure 5. The influence level is 2.08% for Ped while for BTA and STA it becomes obviously larger that is around the average level. The influence level for Ped of 2.08% which is the lowest value among all tests shows the most stable capability for pedestrian recognition.

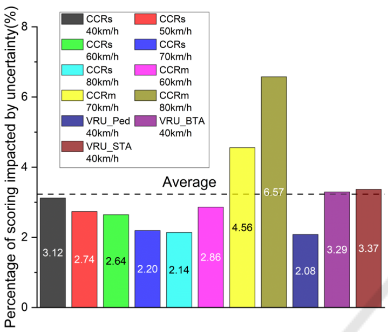


Figure 8. Influence level of uncertainty on C-NCAP score.

4 CONCLUSIONS

This study analyzes the stability of AEBs sensor perception through uncertainty calculation based on C-NCAP test cases. Five kinds of tests are selected which are CCRs, CCRm, VRU_Ped, VRU_BTA and VRU_STA and each of these test has been repeated for 10 times at all initial speeds that would cause collision. The characteristics of the AEBs sensing stability are obtained and the influence level of the impact speed uncertainty on C-NCAP score is further analyzed. Main findings are as follow:

1. As vehicle speed increases, even if the AEB system is functional, the impact speed of the vehicle will still increase accordingly resulting in a higher risk of injury in the event that a collision cannot be avoided. At the same time, the sensor performance stability of the AEB system shows a significant downward trend: the value of U at 80km/h rises by 29% compared to which at 40km/h in CCRs; the value of U at 80km/h rises by 168% compared to which at 60km/h in CCRm. The stability of the AEBs is worse in recognizing a front moving vehicle.

2. When the relative speed between two vehicles is low, the impact speed under CCRm would be lower than it is under CCRs. However, they tend to be consistent with higher relative speed.

3. The 11 cases in this study generates a one-side error of 0.14 for C-NCAP score. Furthermore, it can be inferred that the error will be much larger for all 75 cases according to C-NCAP with various offset rates and light conditions.

4. It is interesting that though the value of U increase with rising vehicle speed, the influence level of it on C-NCAP score has the opposite trend in CCRs cases, which is lower than the average level under all test with different vehicle speed. The average level is 3.23%, compared to which the influence level of CCRm cases is significant larger especially under high speed which is the highest value of 6.57% among all conducted cases. This finding shows high sensitivity of speed of the sensor perception stability in front moving vehicle recognition.

5. For VRU cases, the value of U and the influence level on score of Ped case is obviously lower than other two cases that are around average level. It indicates that pedestrian recognition may be relatively more stable and the more complex morphology and posture makes higher performance requirements for sensors on bicycle and scooter recognition.

The above conclusions have safety implications for social traffic that drivers are not recommended to rely on AEBs and let down their guard while the vehicle is travelling. The perception stability characteristics of AEBs provide reference for component manufacturers to improve sensor performance and design new fusion solutions. Finally, in the evaluation of the active safety of the vehicle, there are errors in the score caused by uncertainty, which provides a more objective perspective for ordinary consumers to understand the vehicle performance information through C-NCAP, and also provides support for the subsequent C-NCAP to improve the test protocols and develop more accurate scoring rules.

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