# V2V Communication-based AEB Validation in Traffic Accident Simulation Scenario


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## ABSTRACT

Autonomous Emergency Braking (AEB) system can effectively avoid traffic accidents and reduce the degree of casualties. However, AEB systems based on traditional sensors will have blind spots and are greatly affected by environmental factors. This paper proposes a Vehicle-to-Vehicle (V2V) communication-based AEB system, which can effectively obtain information such as the location and speed of surrounding vehicles. A traffic accident caused by the blocked view was used to test the effectiveness of the V2V communication-based AEB system. At the same time, this scenario is also used to test the radar-based AEB system. By testing two different AEB systems, it can be concluded that the V2V communication-based AEB can obtain the vehicle's motion state information to make certain predictions, and its AEB can be triggered in a more timely manner.



## CCS CONCEPTS

• Validation • Experimentation • Evaluation

## KEYWORDS

Autonomous Emergency Braking, Vehicle-to-Vehicle, Simulation test, Driving safety


## 1 Introduction

With the increasing number of vehicles, more and more traffic accidents have occurred, which have brought great safety hazards to human lives and property. Traffic safety is very important. Among the active safety technologies studied, Automatic Emergency Braking (AEB) can significantly reduce the casualties of accidents. Tan et al. [1] proposed that as the AEB market penetration rate reaches 100%, the number of deaths can be reduced by 13.2%, and the number of injuries can be reduced by 9.1%.

The AEB system is a technology that automatically applies braking force when the sensor detects a potential collision ahead. The AEB system can assist the driver in avoiding a collision, or when the collision is unavoidable, the AEB system can reduce the collision speed to reduce the collision damage and severity of the passengers on the car. AEB-equipped vehicles can reduce rear-end collision accidents by 38% when the speed is less than 50km/h [2]. The French report shows: In France, the use of the AEB system can reduce 63 (1.4%) deaths and 1569 (4%) serious traffic accidents each year [3].

AEB can effectively protect human safety and has received extensive attention from researchers. Shin et al. [4] proposed an adaptive AEB collision avoidance control strategy that considers the rear vehicle. When the vehicle was braking in an emergency, the output braking deceleration was considered whether it would cause the rear vehicle to brake and collide with the vehicle in time. Lee et al. [5] studied the performance of AEB on curved roads, and used curve coordinate transformation to consider the geometric elements of curved roads. In the study by Savino et al. [6], the AEB trigger algorithm derived based on the inevitable collision state has been studied. Research about integrating AEB with potential risk assessment strategies was conducted by Hamid et al. When the potential risk threshold of the obstacle ahead was violated, AEB would provide active braking intervention [7]. Sevil etc. incorporated friction estimation based on wheel slip rate into the AEB decision logic, considered the impact of road friction on parking distance, and proposed an adaptive system based on road friction [8].

Most of the studies mentioned above are aimed at improving the decision-making part of the AEB system and have not made relevant elaboration on the information of the timely perception of vehicles. The right decision cannot be made without effective perception. However, in some dangerous scenes, such as intersections, blind spots are caused by the occlusion of buildings. As a result, traditional sensors such as radar and cameras cannot detect in time and cannot trigger AEB in time at that scenes. The emergence of V2V communication technology can solve the problem of traditional sensor perception blind spots. Based on this, we propose a V2V communication-based AEB system.

The work of this paper is to restore and analyze a real traffic scenario using PC-Crash. It is analyzed that the accident is caused by the occlusion of the view. We use the occlusion elements in this traffic accident to test the performance of the radar-based AEB system and the V2V communication-based AEB system.

The main content of this paper is as follows: The second part describes and analyzes a real traffic accident scenario; The third section describes the AEB model and V2V communication model used in this paper; The fourth section simulates the real accident scenario and analyzes the results; Final section summarizes the full text and proposes the shortcomings of this article and the work to be done in the future.

## 2 Traffic Accident Scenario Research

There was a real traffic accident caused by the body of a truck blocking the view. As shown in Figure 1.

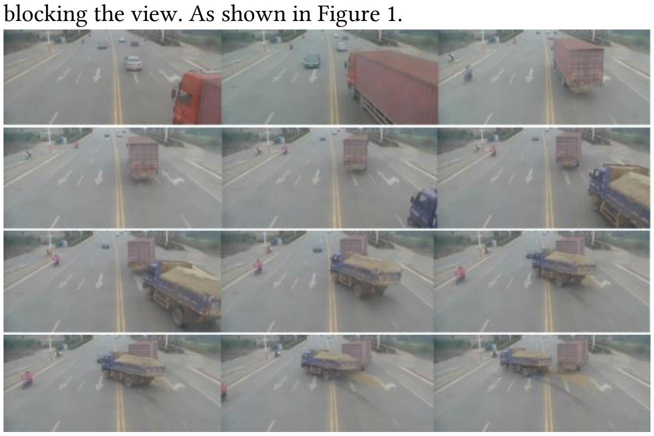

**Figure 1: Traffic accident video screenshot**

This accident occurred at the intersection of China's provincial arterial road and village road. A red cargo originally went straight and turned right until it approached the right-turn fork. It suddenly changed to the left straight-going lane at a speed of about 30km/h and slowed down significantly, and made a right turn with a large turning radius at a speed of about 10km/h to enter the right-turn fork. The following blue sand truck was going straight on the right lane at a speed of 40km/h. Because the red cargo in front turned right, it blocked the direction of the blue truck from going straight. To avoid a collision with the red cargo, the blue truck slowed down and drove left into the opposite lane to avoid it. However, it unexpectedly collided with a black car with a speed of about 65km/h from the opposite direction.

We obtained the accident video from the roadside surveillance video. In order to reproduce the accident scenario, we performed the following steps:

1. Use drones to take aerial photographs of the accident area to confirm the structure of the road.
2. On-site survey of road width and other dimensions to draw a map of the accident scene.
3. By repeatedly watching surveillance videos from different perspectives, determine the trajectory of the accident vehicle and the speed of the vehicle.

We used the above information to reconstruct this scenario using PC-Crash. The reconstructed scenario restored the driver's perspective so that the cause of the traffic accident could be analyzed from the perspective of the accident vehicle. In the following content, we analyzed the accident from the perspective of the sand truck and the black car.

Analyzed from the perspective of the blue sand truck, the truck mistook the intention of the cargo for going straight. When the cargo started to turn right, it blocked the way of the sand truck from going straight. At the same time, the body of the cargo obscured the sight of the oncoming vehicle from the opposite direction. The blue truck did not understand the situation of the oncoming vehicle. In order to avoid the cargo, the blue truck slowed down and drove into the opposite lane. As a result, the blue sand truck collided with a black car going straight in the opposite direction. Figure 2 shows the scenario of an accident restored from the perspective of the sand truck.

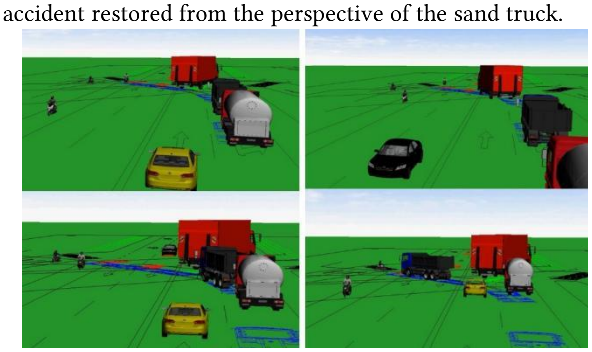

**Figure 2: The perspective of the blue sand truck in the accident**

Analyzed from the perspective of the black car, due to the oblique occlusion of the cargo, the car driver's view of the opposite direction was blocked. The car cannot observe the blue sand truck. It wasn't until the blue sand truck came across the double yellow line that the black car found the blue truck, and the collision could not be avoided at this time. Figure 3 shows the scenario of an accident restored from the perspective of the black car.

It can be concluded from this accident scenario that there is a design problem in the road. The curvature of the right turn of the road is too large, which is not conducive to the smooth right turn of large vehicles. The direct cause of this accident is that the blue truck and black car have blind spots due to the obstruction of the view, and they cannot respond correctly in time when the danger occurs.

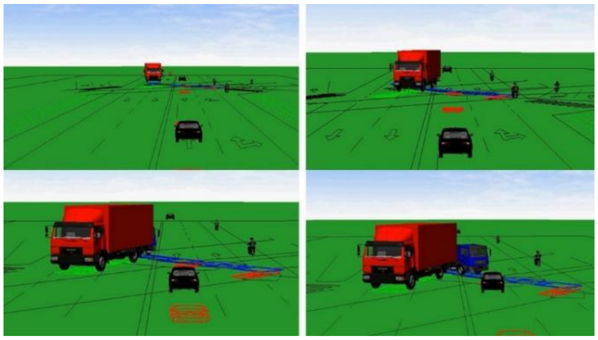

**Figure 3: The perspective of the black car in the accident**

Regarding the situation where the driver fails to respond in time, can the AEB system be triggered in this situation, thereby reducing the severity of the accident? Aiming at the situation where the field of view is blocked, we propose an AEB system based on V2V. Utilize the emergency situation in this accident scenario to test the AEB system. Meanwhile, in order to study the performance of the V2V communication-based AEB system, the AEB system based on the radar sensor and the AEB system based on the V2V are tested in this scenario respectively for comparison.

# 3 Experimental Model

## 3.1 AEB Model

First, we introduce the AEB model in this paper. The AEB model used in this article is a simple model based on Time-To-Collison (TTC) and lateral distance threshold.

When the following car and the preceding car in Figure 4 maintain the current state of motion and the speed of the following car is greater than the preceding car, there will be a collision between following vehicle and the preceding car. $X_f$, $Y_f$ and $V_f$ respectively represent the longitudinal position, lateral position and velocity of the black vehicle. $X_p$ , $Y_p$ and $V_p$ respectively represent the longitudinal position, lateral position and velocity of the red vehicle. We use the indicator which is called Time-To-Collision to calculate the collision risk between two vehicles. The $TTC$ is expressed as:

$$TTC = \frac{D_x}{V_f - V_p}$$

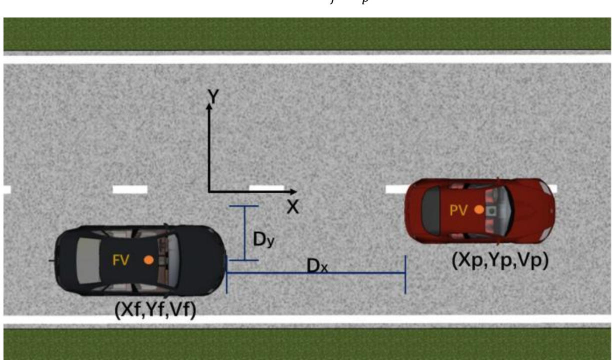


**Figure 4: Collision situation involving a black car and a red car**

Among them, $D_x$ refers to the distance between two vehicles. TTC is only effective when the speed of the following vehicle is greater than that of the preceding vehicle. As the value of TTC decreases, the situation faced by the two vehicles becomes more dangerous.

It is not enough to only consider the longitudinal distance. When two vehicles are not in the same lane, no matter how small the $TTC$ is, AEB should not be triggered. Lateral distance is a very important indicator, which is included in the decision of AEB in this paper. By calculating $D_y$, which is expressed as：

$$D_y = |Y_f - Y_p|$$

Among them, $Y_f$, $Y_p$ are expressed as the coordinates of the following car and the preceding car. When $D_y$ is less than the threshold, it indicates that there is a great probability that the two cars are in the same lane. If the TTC triggers the longitudinal distance alarm when $D_y$ is less than the threshold, the AEB of the following car will be triggered.

## 3.2 V2V Communication Model

V2V refers to Vehicle-to-Vehicle communication. Through the transmission equipment on the vehicle, the vehicle's speed, position, and other information are sent out to realize the transmission of information between vehicles. After receiving the information transmitted by other vehicles, the vehicle can calculate the road traffic conditions around the vehicle, thereby making safer and more efficient decisions. The wireless transmission characteristics of V2V can accurately determine the position of the vehicle in the blind area of the visual field.

A sensor, V2XTransceiver provided in PreScan can give the vehicle the ability to receive and transmit information. V2XTransceiver is installed on multiple vehicles to make the vehicles have V2V capability. Vehicles equipped with V2XTransceiver will have two modules in Simulink. One is the transmitting module. Users can input the information they want to transmit into that module. The other receiving module is to output the received information in the form of a message array.

It should be noted that V2X messages are transmitted in the form of broadcast. The order of the messages output by V2X in the message array is arbitrary and needs to be sorted according to the characteristic information in the messages.

# 4 Simulation

## 4.1 Experimental Scenario Setting

The experimental scenario is built from a real traffic accident scenario in part 2 based on PreScan and Simulink platform.

The scenario was simplified to a certain extent to focus on testing the AEB system. We ignored the impact of other vehicles and focused on three vehicles related to the accident. The black car represents the opposing car in the accident, the long truck represents the red cargo, and the gray truck represents the blue sand truck. The test road was a two-way four-lane road with 184.5m length, each lane was 3.45m wide, and the road surface was dry concrete. The scenario is shown in Figure 5. With a black car as the test vehicle, a radar-based AEB system and a V2V communication-based AEB system were tested in this scenario.

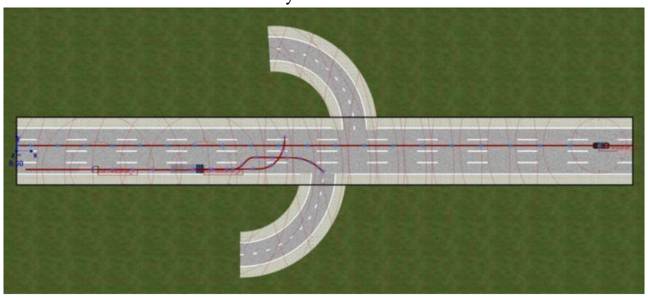

**Figure 5: Simulation scenario to test AEB**

## 4.2 AEB Based on Radar

Millimeter wave radar is a common sensor in the AEB system, which can have a measurement range of 100-200 meters. We adjusted the Technology Independent Sensor (TIS) provided in Prescan to the radar working mode, setting the detection distance to 100m, the horizontal scanning angle to 60 degrees and the vertical scanning angle to 6 degrees. Install the TIS sensor on the black car, and its output data in Simulink is shown in Figure 6.

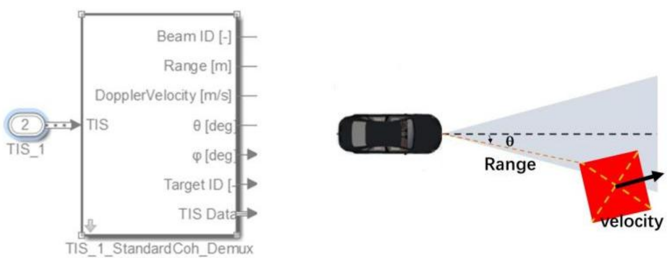


**Figure 6: TIS sensor output module in Simulink**

Among them, Beam ID refers to the beam that scans the object. When the object is not scanned, the default value of the Beam ID is 0. Range refers to the distance between the sensor and the closest point of the scanned object. DopplerVelocity refers to the relative speed between a vehicle equipped with a radar and the scanned object. $\theta$ refers to the angle of the radar scan.

Introduce the above data into AEB's decision-making system. Only when Beam ID is not 0, the decision starts. First, Range and DopplerVelocity are used to solve the TTC. Then we compare the TTC with the threshold, which is set to 1.0s. Summala points out that in a fairly urgent situation, at TTC of about 4.0 seconds, unalerted drivers are able to react to an obstacle by braking at an average latency of 1.0 to 1.3 seconds[9], so this paper takes the time threshold as 1.0s. When TTC is less than the human brake reaction time, AEB will take emergency automatic braking measures to reduce the severity of the accident. Use Range and $\theta$ to find the lateral distance between the two vehicles. When the lateral distance $D_y$ is less than 2m, the vehicle in front has a high probability of being in the lane or invading into the lane. AEB is only triggered when TTC and lateral distance are both triggered. When AEB is triggered, the black car will use the simple kinematics model provided in the PreScan to brake with an acceleration of 0.8G.

## 4.3 AEB Based on V2V

To realize V2V communication, we install the V2XTransceiver provided by PreScan on three vehicles in the experimental scenario and set the transmission distance to 100m. The long truck and the gray truck constantly distribute their speed, heading angle, and X, Y coordinates in the scenario as shown in Figure 4. The black car accepts information from the other two vehicles. The decision of the AEB system is being carried out on the black car.

As mentioned in part 3, the V2V message based on PreScan is in the form of broadcast, and the message needs to be resolved. Since there are two vehicles, the long truck and the gray truck, the black car will receive two sets of messages. Each set of information does not necessarily correspond to the information of a single vehicle, as can be seen in the first set of information before solution in the Figure 7 below. The ID received in 1.05s-1.7s is 2, and the ID received after 1.7s-6s is 1. After 1.7s, the information with ID 2 is sent to the second group of messages, which is not conducive to use relevant data to make an AEB decision. This paper uses the SenderID in the transmission message to analyze and classify the signals, and integrate the information sent by the gray truck with SendID of 1, and the information sent by the long truck with SendID of 2.

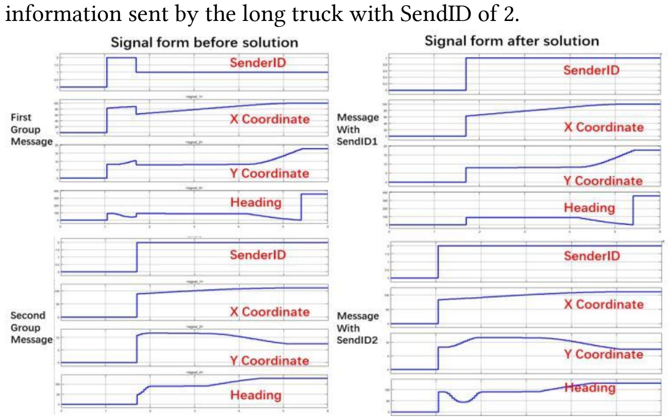


**Figure 7: V2X signal calculation and sorting**

After integrating the information, we use the vehicle's X, Y coordinates and the coordinates of others obtained by V2V communication to calculate the relative longitudinal and lateral distance. The relative speed is calculated from the speed of the vehicle itself and the speed of others, so as to calculate the TTC. In addition to judging whether two vehicles are in the same lane based on lateral distance, the vehicle's position can also be predicted based on the heading angle and the lateral distance of the vehicle transmitted by V2V. This is based on a major advantage of V2V, which can obtain information that is hard for traditional sensors to obtain.

## 4.4 Experimental Results and Discussion

Two AEB systems were assigned to the black car in Figure 5 to test the performance of the two AEB systems.

The test result of the radar-based AEB system in PreScan is shown in Figure 8. At 5.2s, the black car with the AEB system based on radar collided with the gray truck. The initial speed of the black car was 65km/h, and the speed at the time of the collision was 60.48km/h. There is a deceleration of 4.52km/h.

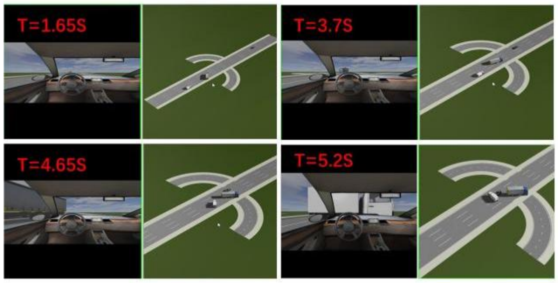


**Figure 8: Test results in PreScan for radar based AEB**

The specific AEB trigger signal of the radar-based AEB system is shown in Figure 9. The TTC was triggered at 3.4s. Since the cars were moving in opposite directions, the TTC quickly exceeded the threshold. The main determinant of AEB triggering was the lateral distance and triggered at 4.6s, as shown in Figure 8. It was because when the long truck turned right, the lateral distance between the rear of the long truck and the black car was 1.9m that triggered the lateral distance condition. After that, the long truck left with the black car, the long truck no longer triggered AEB. In 4.85s, the distance between the gray truck and the black car was less than 2m. AEB was triggered again to slow down the black car.


**Figure 9: The specific trigger signal of radar-based AEB**

The data output by the radar sensor in the test is shown in Figure 10. Before 4.7s, black indicated the relevant data of the long truck detected by the radar sensor, and blue indicated the data of the detected gray truck. After 4.7s, the long truck drove out of the detection range of the radar sensor, and black no longer indicated the long truck but gray truck. At the same time, it could be found from Figure 10 that the blue waveform was intermittent. This was because, at certain moments, the gray truck was blocked by the long truck, and the radar sensor could not detect the gray truck. The radar sensor's perception of vehicle information will be affected by object occlusion. This characteristic will bring certain limitations to the use of radar sensors.

The test result of the V2V communication AEB system in PreScan is similar to Figure 8. But in 5.25s, the black car collided with the gray truck, and the speed of the black car at the time

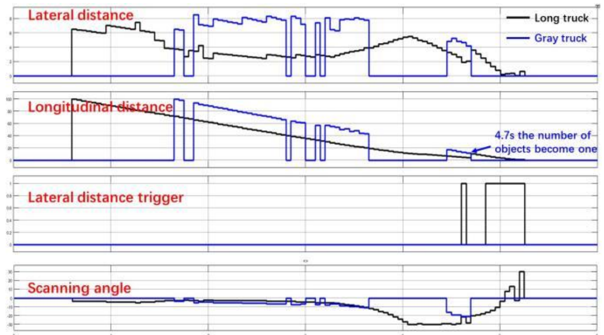


**Figure 10: Output data of radar**

of the collision was 53.64km/h. There is a deceleration of 11.36km/h.

The AEB trigger signal under V2V is shown in Figure 11. TTC also exceeded the threshold at 3.4s. At 4s, the distance between the rear of the long truck and the black car was less than 2m, which triggered the lateral distance condition and continued to 4.2s.

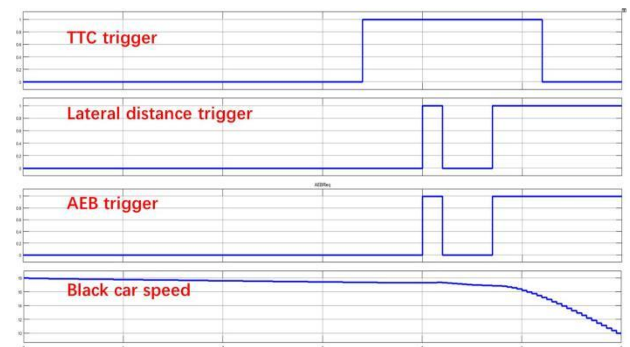


**Figure 11: Specific trigger signal of V2V-based AEB**

The gray truck triggered the lateral distance trigger at 4.7s, which was 0.15s earlier than the radar-based AEB system. This was because under the decision of the V2V communication-based AEB system, there was another condition will trigger the lateral distance. For example, the gray truck in Figure 8, when it ran to 4.65s, its lateral distance between black car was about 3.06m, and the heading angle of the gray truck was still facing the opposite direction at this time and was greater than the heading angle under the normal lane change operation. It was a very abnormal situation and should be paid attention to in advance. The heading angle of the vehicle could be obtained through V2V. The consideration of this situation should be added to the lateral distance trigger condition. When the angle between the vehicle body and the horizontal line exceeds 48 degrees, and the lateral distance is less than 3m, the lateral condition will be triggered, which is essentially the prediction of the future motion state of the relevant vehicle obtained by V2V.

The data output by V2V in the test is shown in Figure 12. It could be seen that the data obtained through V2V was morecontinuous and stable, and was not affected by physical occlusion.

Based on the above simulation results, we can see that both the Radar-based AEB system and the V2V communication-based AEB system can be triggered in this accident and automatically

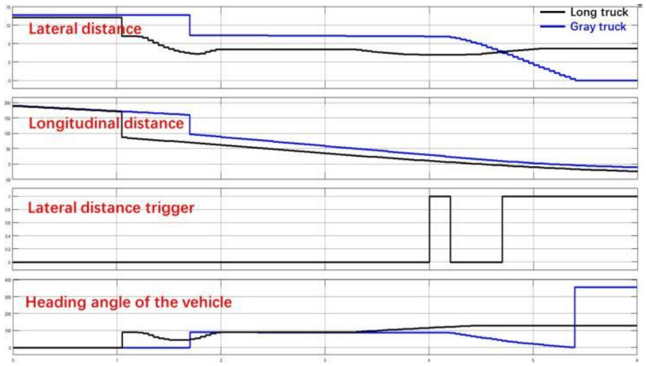


**Figure 12: Output data of V2V**

brakes to reduce the severity of the accident. Among them, the Radar-based AEB system can decelerate the vehicle by 4.52km/h, the V2V communication-based AEB system can decelerate the vehicle by 11.36km/h. It can be concluded that the V2V-based AEB has a better performance due to its predictive ability, and the data obtained based on the V2V is more stable and will not be affected by occlusion.

## 5 Conclusion

AEB is a typical representative of active safety technology. In emergencies, autonomous braking can effectively reduce accident injuries and even avoid accidents. However, AEB based on traditional sensors has the problem of untimely and unstable perception when the visual field is blocked.

With the continuous development of vehicle network technology in recent years, vehicle network technology can solve the problem of perception in blind areas of vision. This paper combines vehicle network technology with vehicle safety technology, and proposes a V2V communication-based AEB model. Using a traffic accident caused by obstruction of the view, the radar-based AEB and the V2V communication-based AEB are tested respectively. The results show that the V2V communication-based AEB model can predict abnormal vehicle driving by acquiring vehicle-related data. It is triggered earlier than the radar-based AEB system, so that the vehicle reduces more speed before a collision occurs.

However, it should be noted that in reality, not all vehicles have V2V capabilities. In future work, we can use those vehicles with V2V capabilities to distribute the vehicle information sensed by other sensors of their own, which can restore partial V2V scenarios. We can carry out research on driving active safety technology for partial V2V scenarios.

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