Safety Evaluation Report of MOBATSim -AEB

according to ISO 26262, ISO 21448, EuroNcap

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Chapter 1. Introduction

This is a safety evaluation report for MOBATSim which according to three standards: ISO 26262, ISO 21448, EuroNCAP and generate a case study.

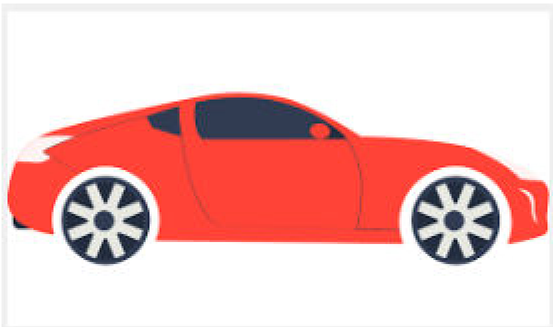

Figure 1.1. Style of the test vehicle.

Table 1.1. Parameters of the vehicle

long	width	height	mass	sensorRange	AEBdistance
4.7000000000000002	2	1.8	1800	25	100

Chapter 2. HARA

2.1. Scenario definition -laneMerge

The test scenario shows below which contains two traffic paticipants drive on a merged road, the trajectories of two vehicles are distinguished with different color .

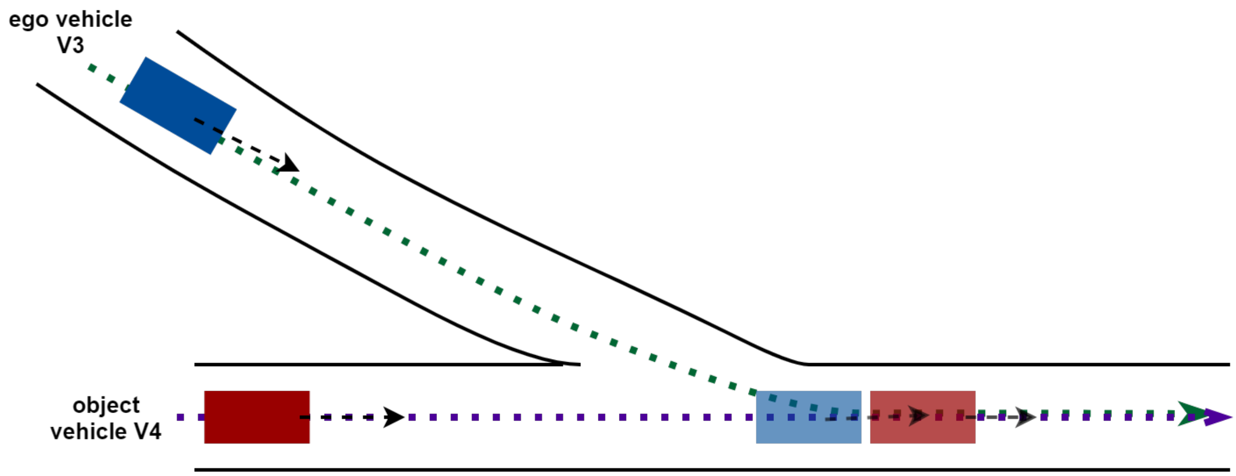

Figure 2.1. Test Scenario in MOBATSim

The road features of the test scenario are listed below:

1. Single lane
2. Road length
3. lane width 3.7m
4. No traffic signal and traffic signal controller

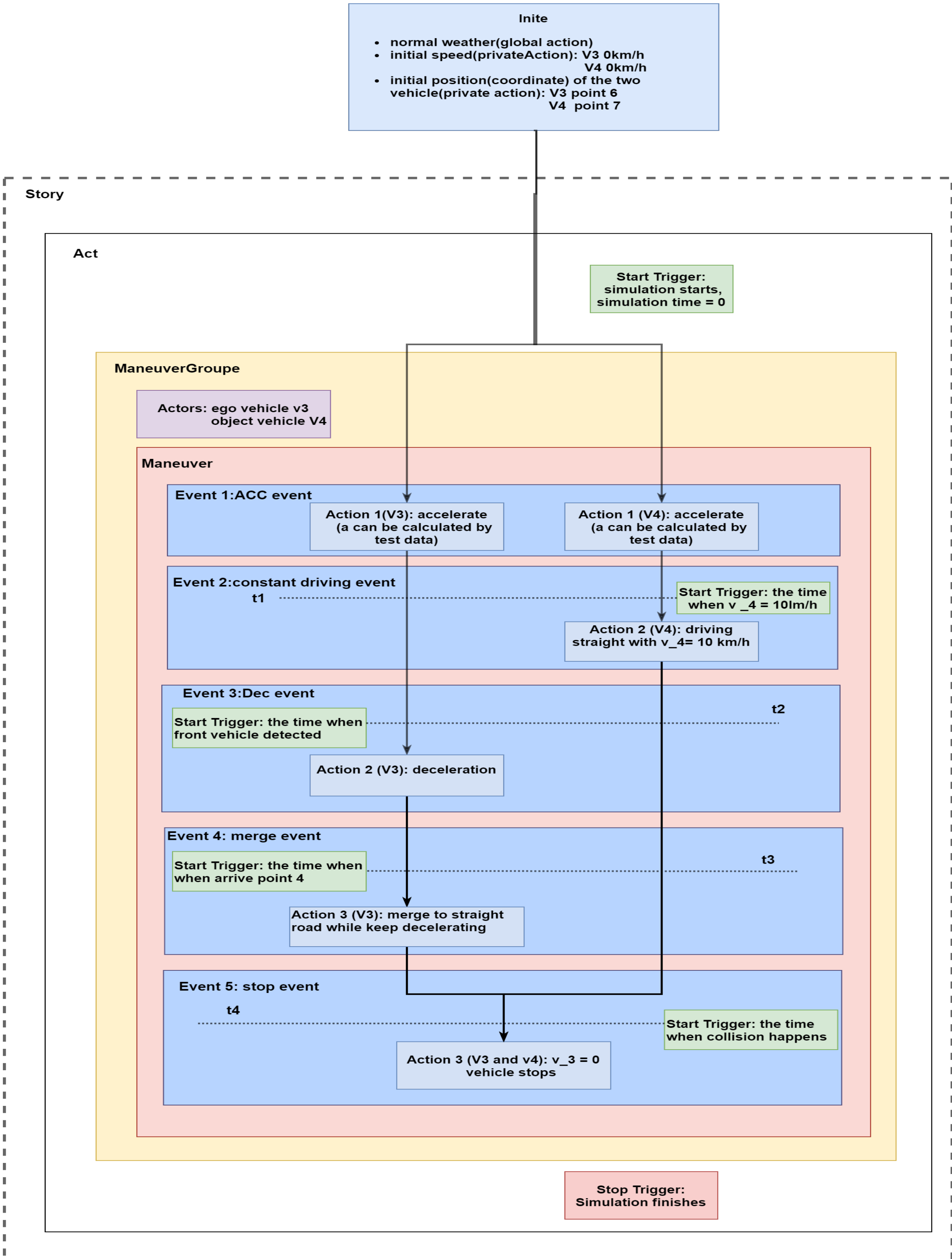

Figure 2.2. Scenario Definition under OpenScenario

2.2. Item Definition -AEB

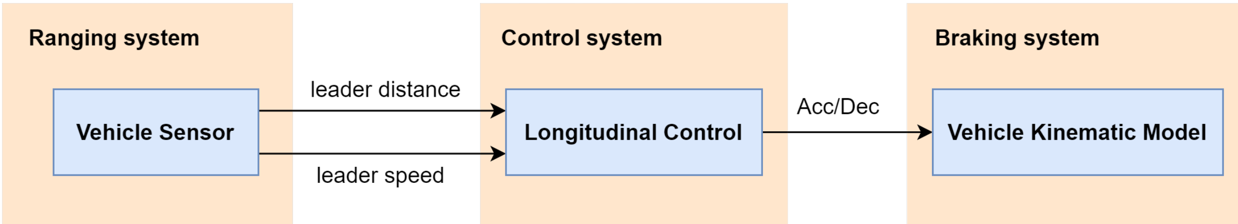

Figure 2.3. System block - Autonomous Emergency Brake (AEB) System in MOBATSim

1. Functionality: AEB detect leading vehicle with ranging system, with the caltulation of the control system, gives the braking command to the braking system.
2. Operational design domain: This AEB function is only appropriate for the MOBATSim platform, in which most of the roads are single lanes and no other vehicles drive alongside the leading vehicle.

2.3. Situation analysis and Hazard identification

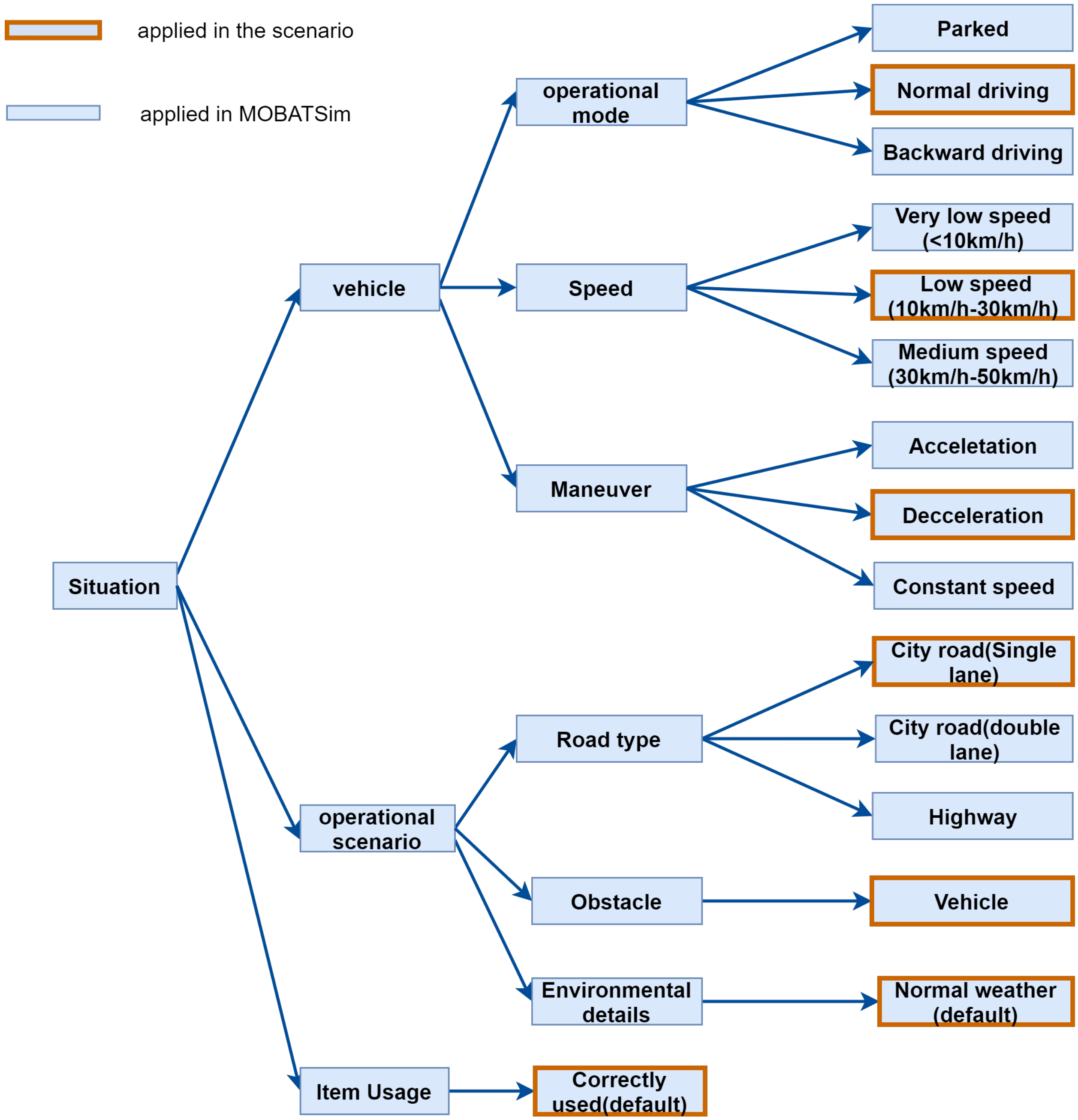

Figure 2.4. The situational analysis for specific scenario in MOBATSim

The situational analysis of the scenario "laneMerge" are listed below:

1. Operational mode: normal driving.
2. Operational scenario: Normal city road with single lane.
3. Environmental details: Normal weather (default)
4. Situational details: low speed (10km/h~30km/h)

5. Item usage: correctly used (default)

The exposure level is 3.

The hazards are caused by electronic malfunctions of target item shown below:

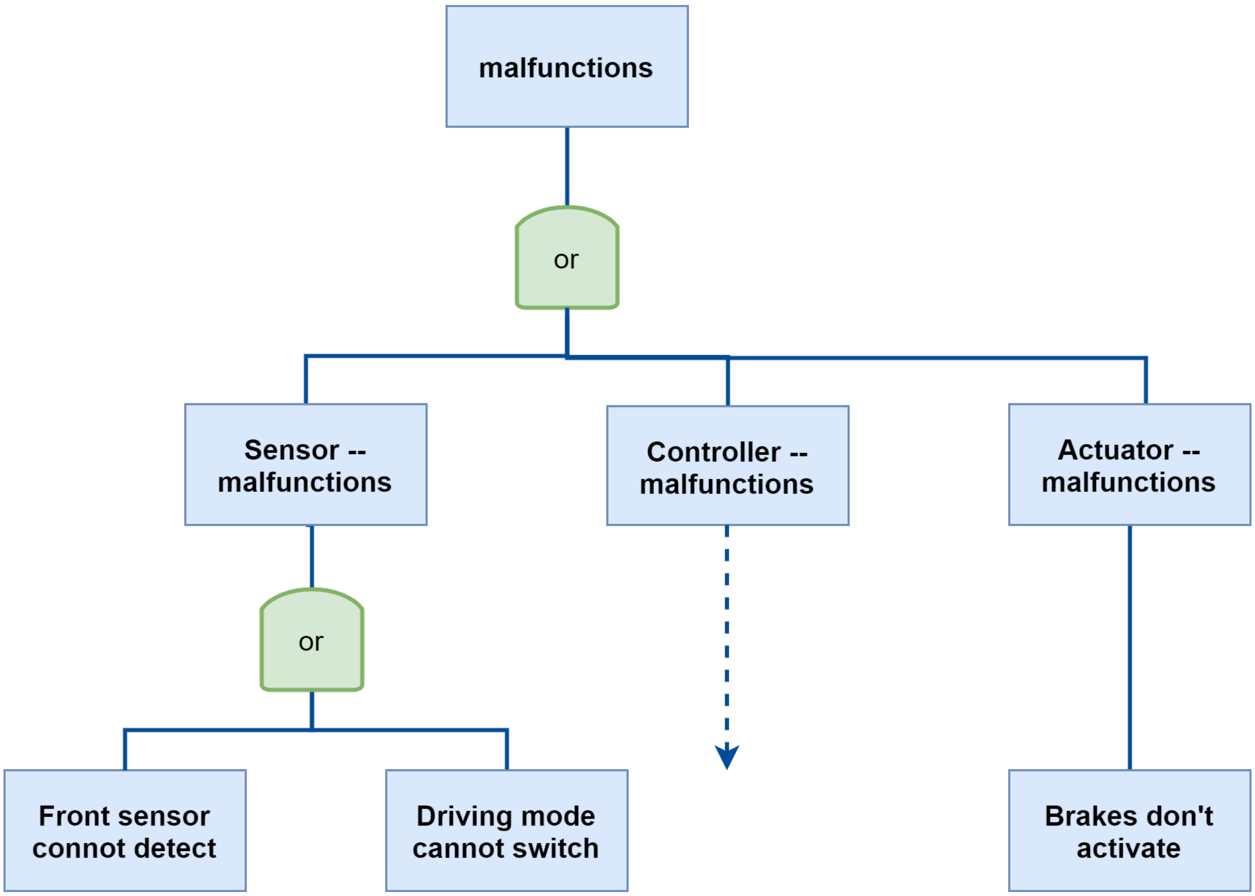

Figure 2.5. The malfunctions which should happends in AEB system in MOBATSim

The example of hazard identification of AEB is shown below:

1. Function: Autonomous Emergency Braking system shall apply a braking to slow down or stop, when there is a potential collision detected.
2. Malfunction: Function not activated. Eg: the sensor does not detected the front vehicle, or there is delay time for switching driving mode.
3. Malfunction details: The sensor of AEB does not detected the front vehicle, so there is no input data for control system, the control system has nosignal for braking system. The AEB function does not apply a braking.
4. Hazardous event: The ego vehicle has a front collision with the leading vehicle.
5. Event details: The unactivated AEB does not apply a braking when the ego vehicle is nearing the leading vehicle, the vehicle remains at the previous speed and has a crash with leading vehicle.

Collision in low speed, the severity level is 2

2.4. Hazardous event classification

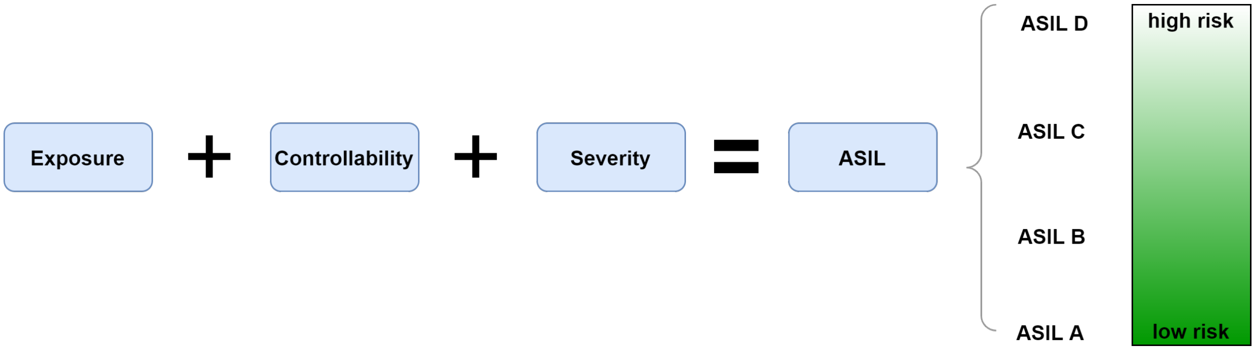

Figure 2.6. Exposure, Severity, and Controllability determin the ASIL level from low risk to high risk

According to above (Controllability level is 3, because the driver is out of the driving loop), the ASIL level of AEB in specific scenario shows below:

The ASIL level is ASIL B.

2.5. Safety goal and functional safety requirement

The Safety goal and functional safety requirements is shown in the list below:

1. Safety goal: The vehicle sensor of the AEB system shall reach the normal sensitivity.
2. Functional safety requirement 1: The AEB system shall ensure the accuracy of the algorithm in ranking system.
3. Malfunction details: The AEB system shall ensure the connection between vehicle model and control system has the proper functioning.

Chapter 3. SOTIF

3.1. Functional and System Specification

The functional description is shown in the list below:

1. System goals: The AEB system It is responsible for detecting the leading vehicle and provides the longitudinal control to decelerate when the distance between two vehicles is shorter than the AEB distance (the distance that the AEB system is active).
2. Anticipated Use Case: In MOBATSim, the AEB system is activated when the ego vehicle is about to meet (distance is smaller than AEB distance) another vehicle at road merge, or drive close to near (distance is smaller than AEB distance) the front vehicle..
3. System Dependencies: The AEB system in MOBATSim is a relatively independent system which only relies on vehicle sensor to provide important data. It only detects the vehicles(stationary and moved), but not available for other road users and road infrastructure.

The system description is shown in the list below:

1. Sensor: the block Vehicle sensor in the perception part of MOBATSim is the sensor part in the AEB system, which aims to detect the front vehicle in the same route or the next route and output the leader speed and leader distance of the leading vehicle.
2. Longitudinal Control: The longitudinal speed control trajectory planner part of MOBATSim is the longitudinal controller in the AEB system. It takes the leader speed and leader distance as input, and output longitudinal acceleration command.
3. Vehicle Kinematic Model: The block Vehicle Kinematic 3DOF Single Track is taken as the actuator of the AEB system which changes the speed according to the acceleration command.

3.2. Hazard Identification and Risk Assessment

The potential hazards are shown in the list below:

1. H1: The ego vehicle has collition with another vehicle.
2. H2: The ego vehicle departs from the road.

The potential hazardous events with Severity S>0, Controllability C>0 are shown in the list below:

1. The ego vehicle has front collition with object vehicle while performs the lane merge. (H1)
2. The ego vehicle has front collition with leading vehicle on the sigle lane road after the lane merge. (H1)
3. The ego vehicle has departs from the lane one the curved road while it tries to steering and merge to the straight road. (H2)

3.3. Identification and Evaluation of Trigger Events

The potential triggering events are shown in the list below:

1. TE−1 The detection range of the front sensor in AEB system is limited. (H1)
2. TR−2 The driving mode in the sensor algorithm has relative long delay time. (H1)
3. TR−3 The noise interferes the proper functioning of the front sensor in AEB system. (H1)
4. TR − 4 The value of the minimum deceleration of the longitudinal control system is not appropriate (too big).

3.4. Functional Modification to Reduce SOTIF Risk

The possible vehicle-level safety goals derived from the hazards are shown in the list below:

1. SG−1 The ego vehicle shall decclelerate early enough when approching the intersection. (H1)
2. SG−2 The ego vehicle shall keep a appropriate velocity while on curved road. (H2)

The mitigation Measures for the AEB system with relevant safety goal are shown in the list below:

1. MM−1 Extend the detection range of the front sensor in AEB system. (SG−1)
2. MM−2 Improve the sensor algotighm to a shorter reponse time. (SG−1)
3. MM−3 Change the minimum deceleration to a appropriate value. (SG−2)

Chapter 4. Case study ofAEB

In this chapter, the test results of several cases are presented. For the sake of simplicity, only the data from vehicle_3 is shown here The performance of the AEB is determined by KPIs: minimum TTC, minimum distance, and relative impact speed .

4.1. Test results of malfunction one: time delay in driving mode switching

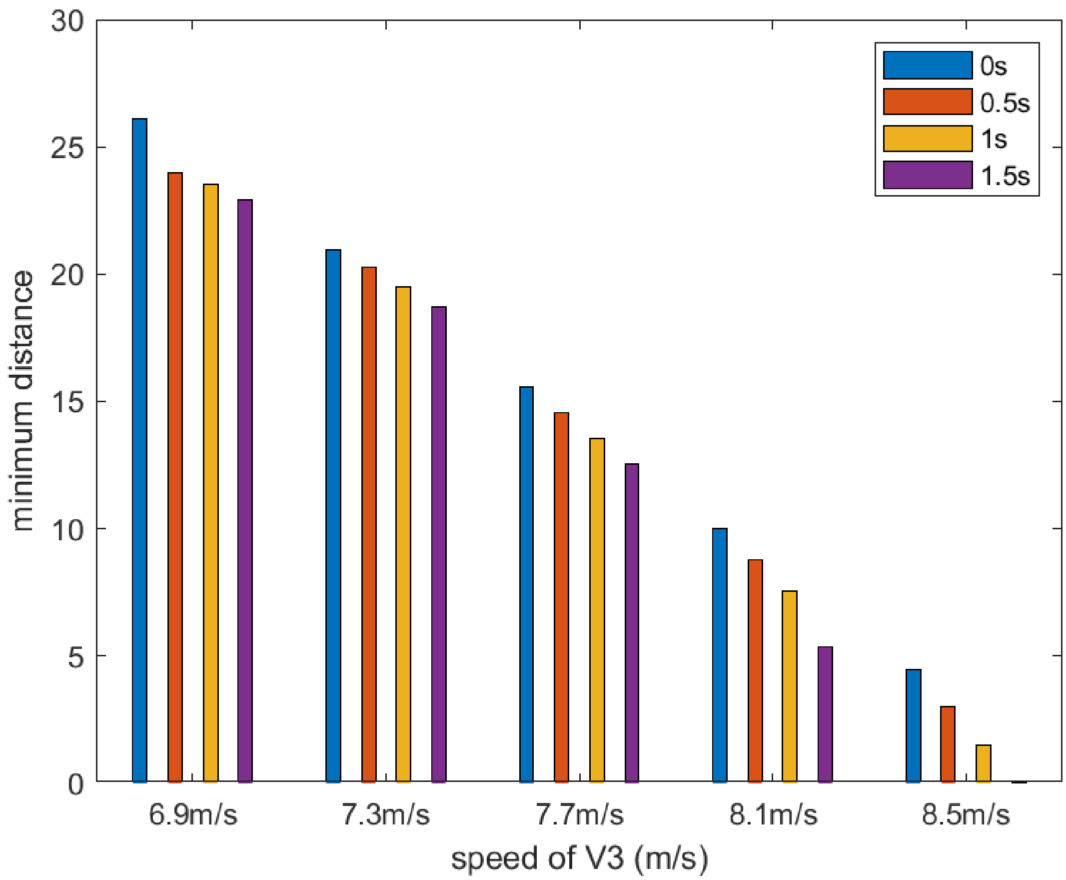

Figure 4.1. The minimum distance between two vehicles under different time delay of vehicle 3.

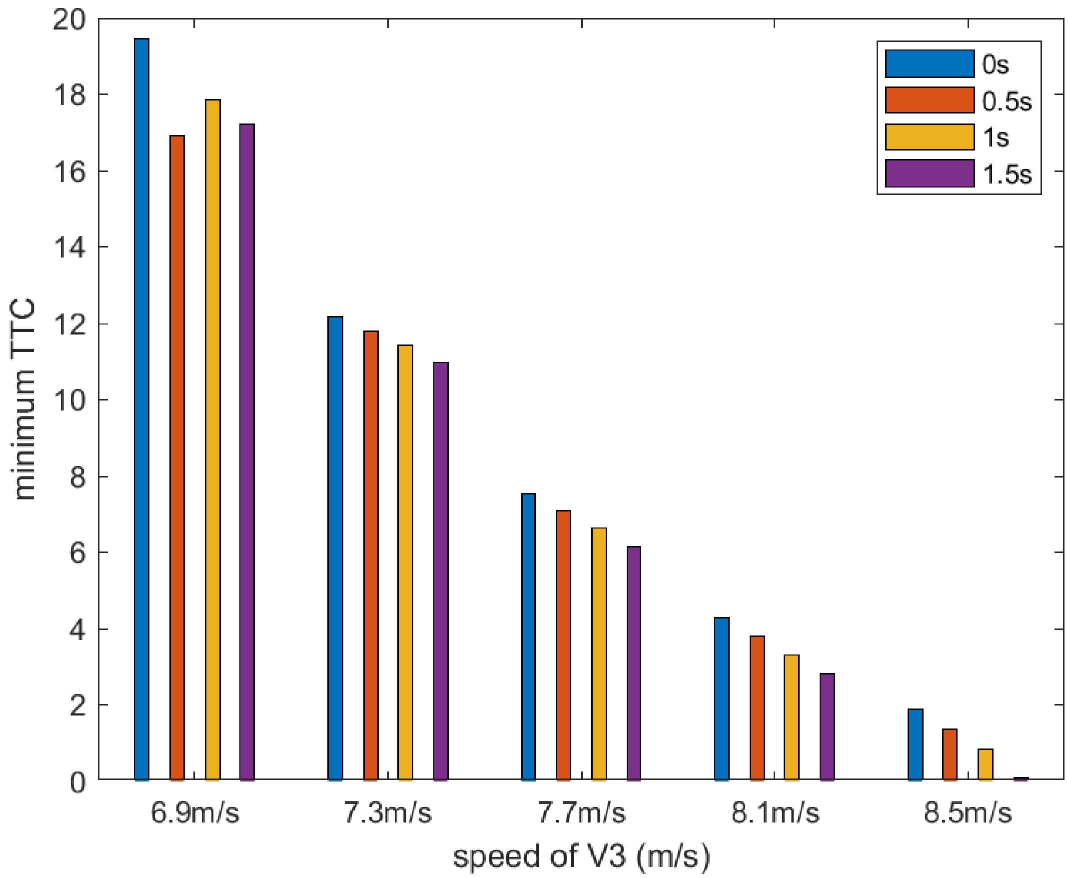

Figure 4.2. The minimum TTC under different time delay of vehicle 3.

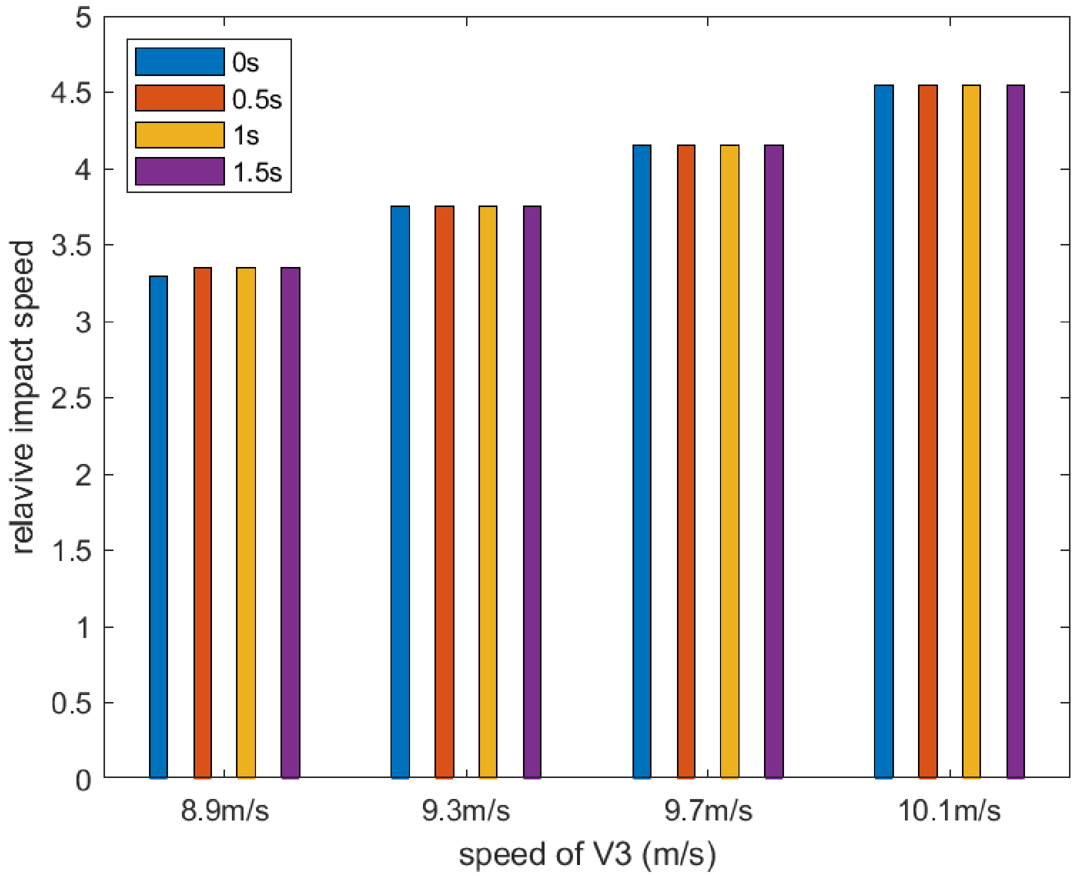

Figure 4.3. The relative impact speed between two vehicles under different time delay of vehicle 3.

4.2. Test results of malfunction two: sensor failure

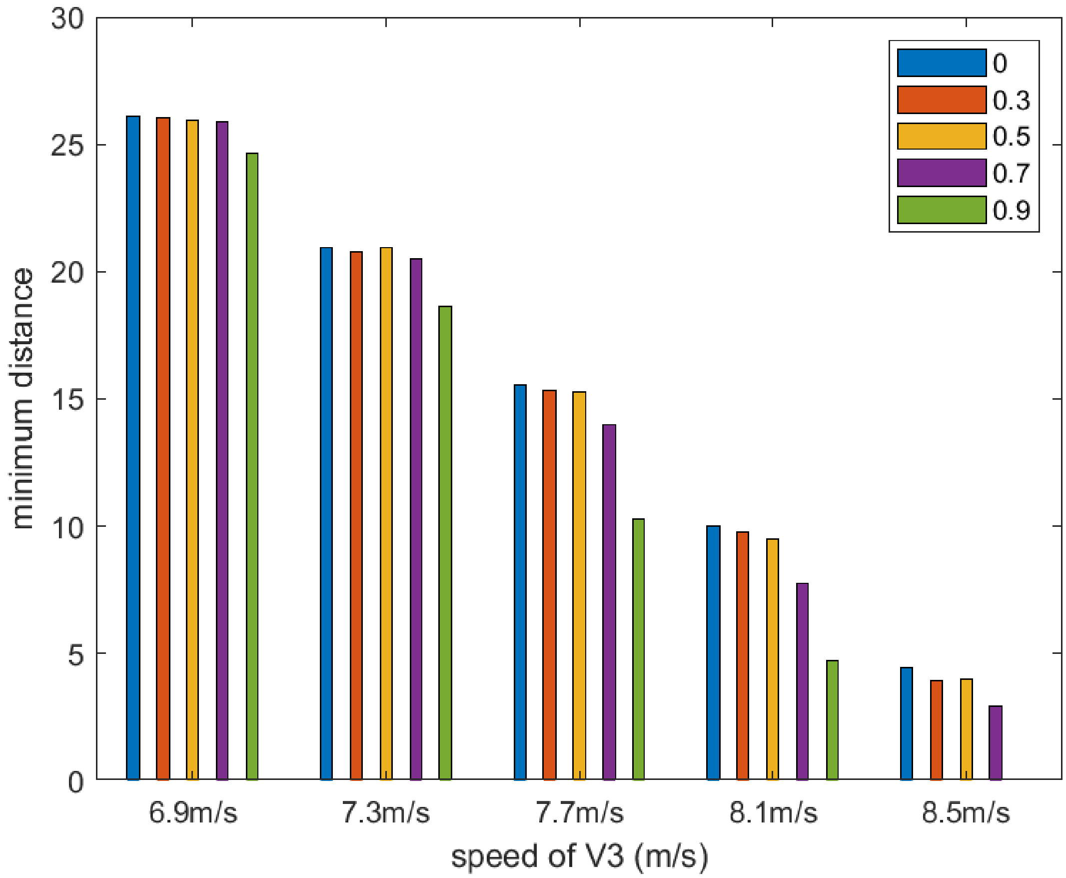

Figure 4.4. The minimum distance between two vehicles under different failure rate of vehicle 3.

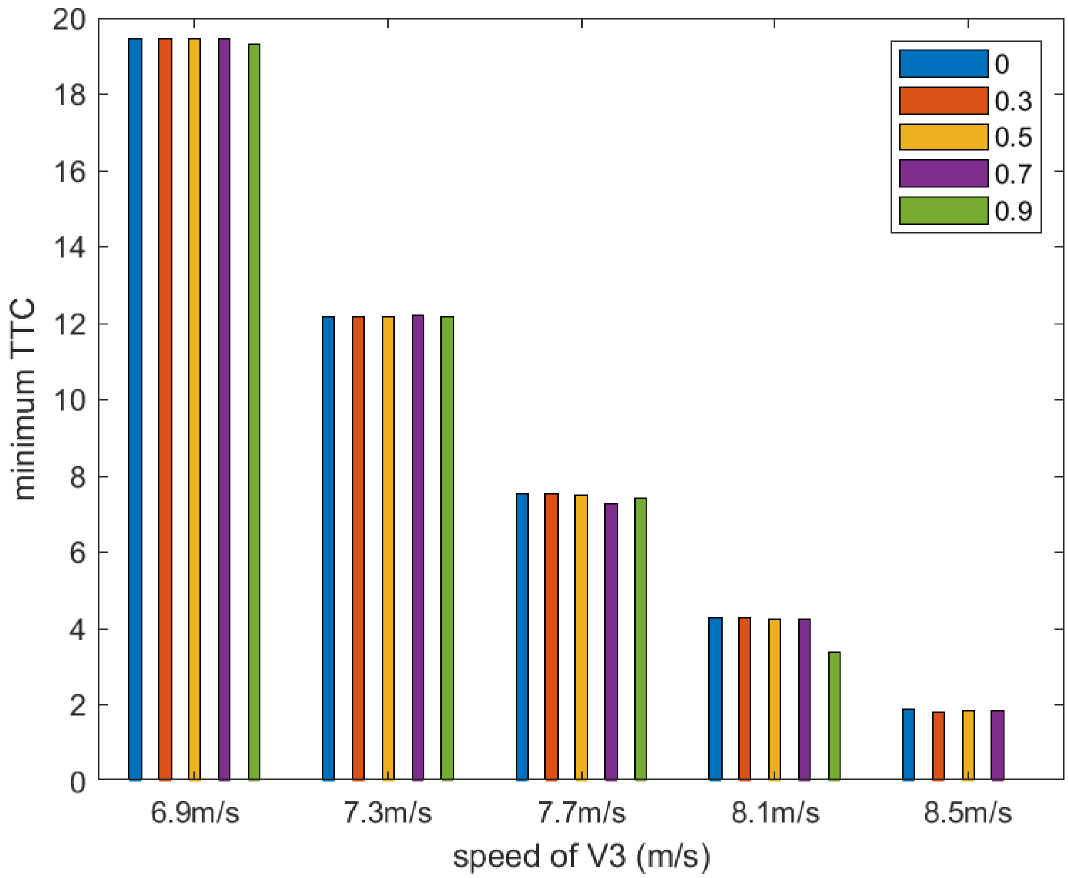

Figure 4.5. The minimum TTC under different failure rate of vehicle 3.

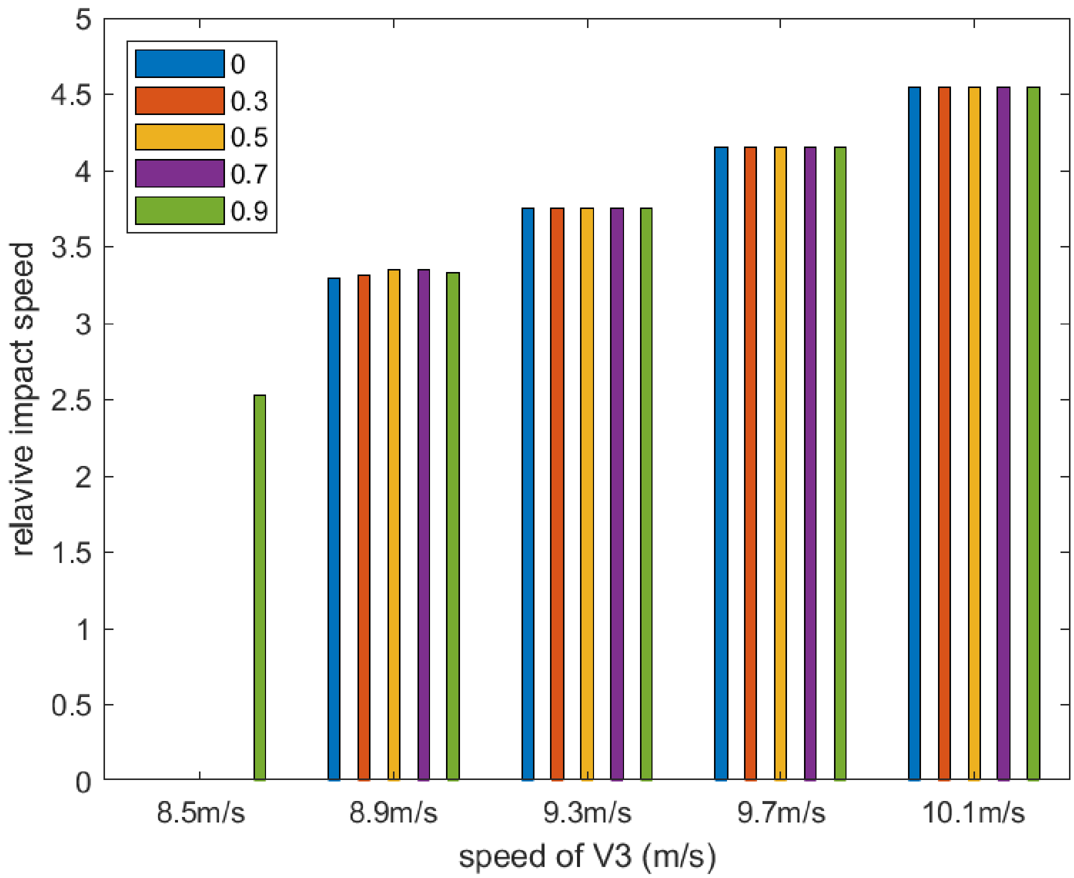

Figure 4.6. The relative impact speed between two vehicles under different failure rate of vehicle 3.

4.3. Test results of malfunction one: time delay in driving mode switching

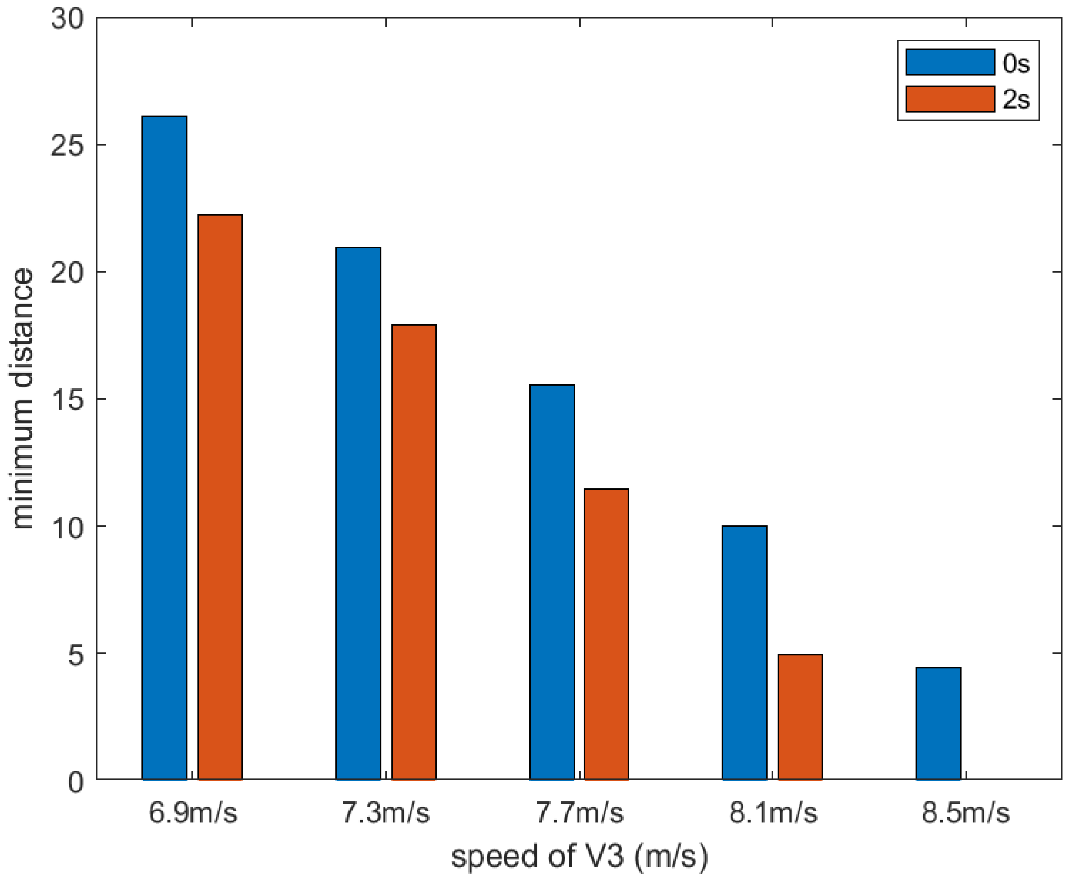

Figure 4.7. The minimum distance between two vehicles under sensor limitation-time delay of 2s.

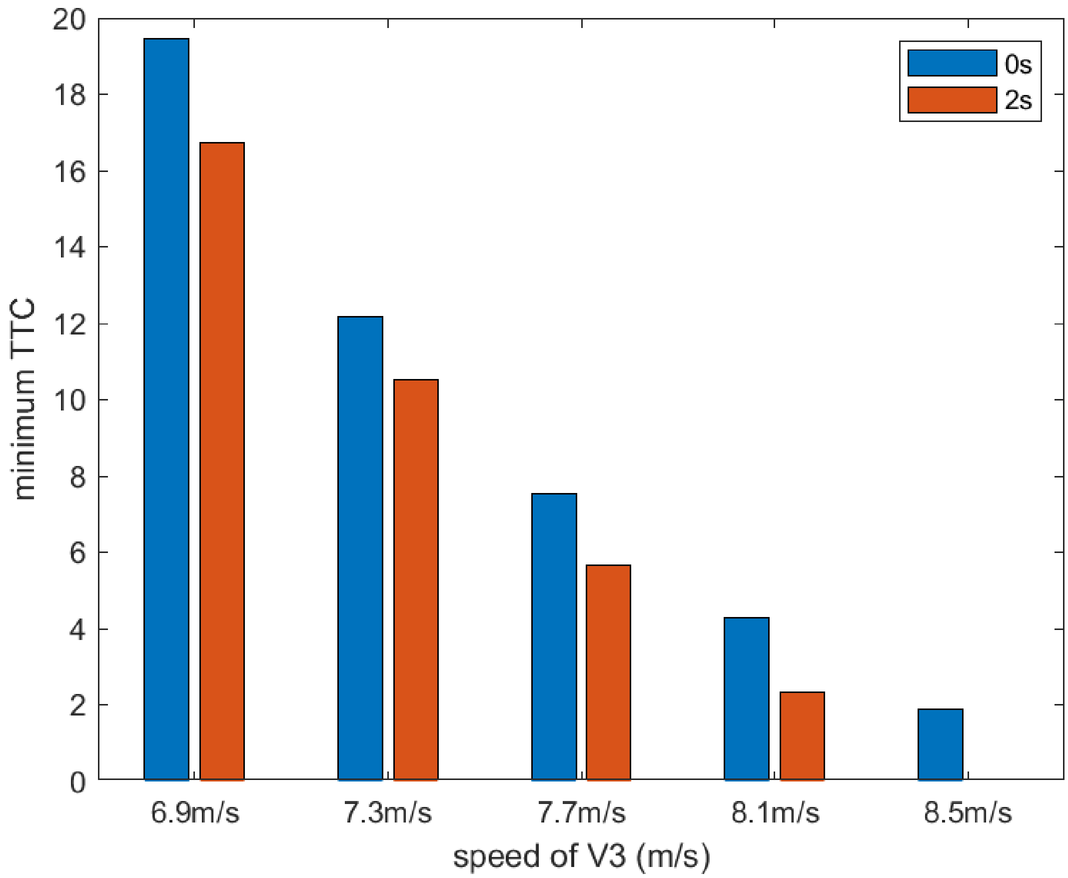

Figure 4.8. The minimum TTC under sensor limitation-time delay of 2s.

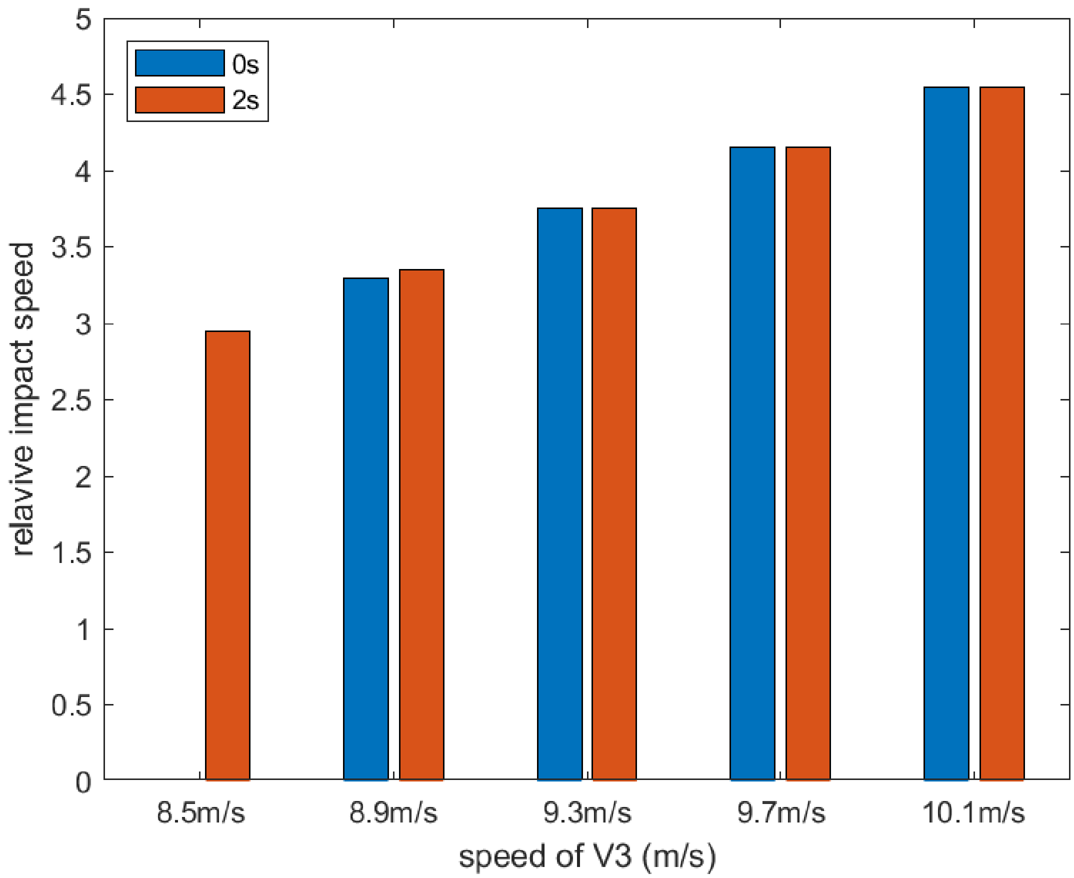

Figure 4.9. The relative impact speed between two vehicles under sensor limitation-time delay of 2s.

4.4. AEB score according to EuroNCAP

Table 4.1. The AEB score according to EuroNCAP (speed in km/h).

VehicleTestSpeed	Factor	relaImpactSpeed	score
"34.92"	" 0"	"14.9399"	"0"
"34.92"	"0.5"	"14.9399"	"0"
"34.92"	" 1"	"14.9399"	"0"
"34.92"	"1.5"	"14.9399"	"0"
"34.92"	"0.3"	"14.9399"	"0"
"34.92"	"0.5"	"14.9399"	"0"
"34.92"	"0.7"	"14.9399"	"0"
"34.92"	"0.9"	"14.9399"	"0"
"34.92"	" 2"	"14.9399"	"0"