



Insurance Institute for
Highway Safety



Pedestrian Autonomous Emergency Braking Test Protocol (Version 1)

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DOCUMENT REVISION HISTORY

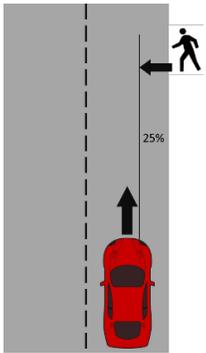
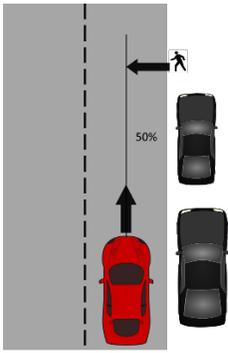
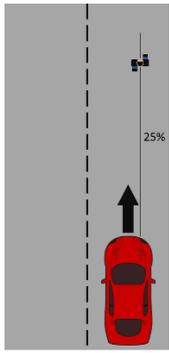
There are no previous versions of this document.

SUMMARY

This protocol describes the test procedure used to evaluate pedestrian autonomous emergency braking (P-AEB) systems on passenger vehicles similar to those that have been documented to help drivers avoid collisions with pedestrians (Highway Loss Data Institute, 2018). This protocol is available from the technical protocols section of the IIHS website (<http://www.iihs.org/iihs/ratings/technical-information/technical-protocols>).

The procedure simulates vehicle collisions with 1) an adult pedestrian crossing a street on a path perpendicular to the travel line of a vehicle, 2) a child pedestrian crossing a street from behind an obstruction on a path perpendicular to the travel line of a vehicle, and 3) an adult pedestrian near the edge of a road on a path parallel to the travel path of a vehicle. Ratings are based on a test vehicle's ability to avoid or mitigate pedestrian dummy collisions at 20 and 40 km/h (perpendicular path scenarios), and 40 and 60 km/h (parallel path scenario). A summary of these test scenarios is included in Table 1.

Table 1
P-AEB Test Scenarios

Parameter	Scenario		
	Perpendicular Adult (CPNA-25)	Perpendicular Child (CPNC-50)	Parallel Adult (CPLA-25)
Test vehicle speed	20, 40 km/h	20, 40 km/h	40, 60 km/h
Pedestrian target speed	5 km/h	5 km/h	0 km/h
Target direction	Crossing (R-to-L)	Crossing (R-to-L)	Facing away
Target path (relative to test vehicle)	Perpendicular	Perpendicular	Parallel
Pedestrian dummy size	adult	child	adult
Dummy articulation (fixed rate)	yes	yes	no
Overlap	25%	50%	25%
Obstructed	no	yes	no
Number of valid runs	5	5	5
Test diagram			

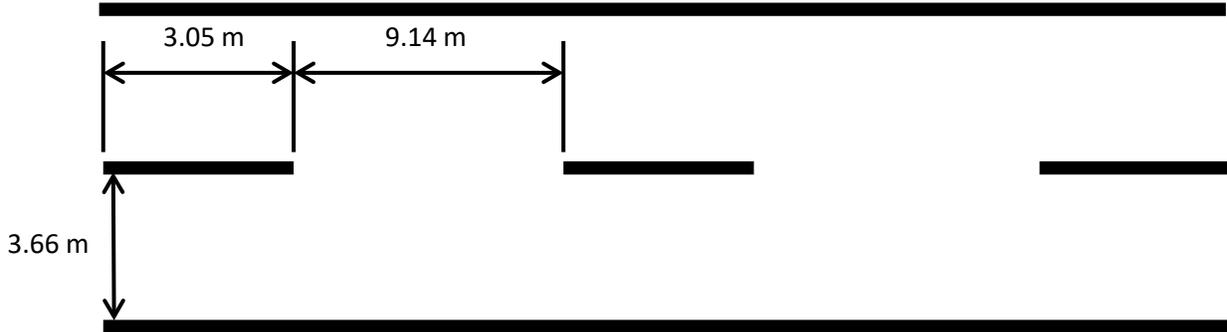
TEST ENVIRONMENT

Surface and Markings

Tests are conducted on a dry asphalt surface without visible moisture. The surface is straight and flat, with a 1% lateral slope for water management. The asphalt must be in good condition, free of potholes,

bumps, and/or cracks that could cause the test vehicle to pitch or roll excessively. Testing is conducted in the right lane of a two-lane roadway. The roadway is marked with continuous solid white lane markers on the outsides and dashed white lane markers in the center. The lane widths are 3.66 m (12 ft), and the dashed lines are 3.05 m (10 ft) in length, separated by 9.14 m (30 ft). The width of the lines is 0.1 m (4 in). These dimensions are illustrated in Figure 1.

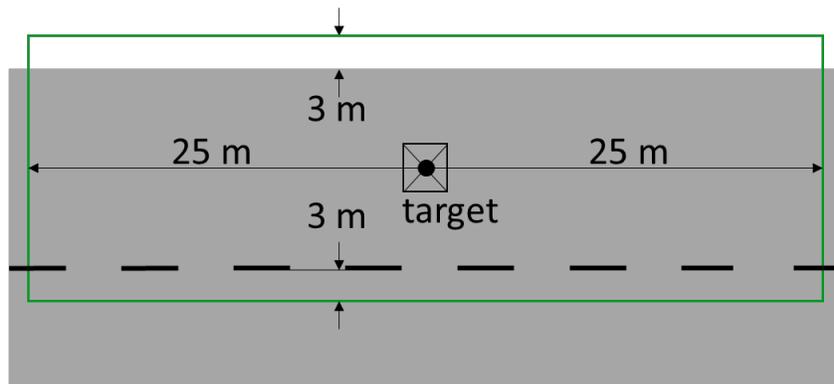
Figure 1
Lane Markings



Surroundings

During testing, no other vehicles, obstructions, or objects (except those prescribed in a test scenario) may be within a distance of 3 m on either side of the test lane or 25 m longitudinal distance from the test target. Overhead signs, bridges, gantries, or other significant structures within the lane must be more than 5 m above the ground. Open space requirements are illustrated in Figure 2.

Figure 2
Open Space Around Target



Ambient Conditions

Testing is not conducted during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, and/or ash. The ambient air temperature must be between 0°C (32°F) and 37.8°C (100°F) during testing. Peak wind speeds must be below 10 m/s to minimize target and test vehicle disturbance. Ambient illumination must be at least 2000 lux as measured on a plane parallel to the asphalt surface. The sun altitude from the horizon must be ≥ 15 degrees while testing is performed.

During testing, track-area ambient temperature and wind speed and direction will be measured and recorded at 1-minute intervals. Ambient light levels on top of the test vehicle will be recorded at 1 Hz.

TARGET

Pedestrian Target System for P-AEB Testing

4Active (4a) pedestrian test equipment will be used for this test (see <http://www.4activesystems.at/en/>). Static and articulating pedestrian dummies are shown in Figure 3. Pedestrian outer jackets must be free from rips, tears, deformation, and significant markings which could affect test results.

Figure 3
Pedestrian Targets



4activePA (child and adult articulating pedestrians)

4activePS (adult static pedestrian)

TEST VEHICLE PREPARATION

General

Tests must be undertaken using a new vehicle in the “as received” condition, with accumulated mileage between 200 and 5,000 miles as indicated on the odometer. Prior to commencing preparation and testing IIHS will ensure that:

1. The tires are new, original equipment tires inflated to the manufacturer’s recommended cold inflation pressure. If more than one recommendation is provided, the tires are inflated to the lightly loaded condition.
2. The fuel tank is filled to at least 90% of capacity with the appropriate fuel and maintained to at least 75% capacity throughout the testing.
3. All other fluid reservoirs are filled to at least their minimum indicated levels.
4. The vehicle will include a driver and all required equipment during testing. Where possible, the equipment will be placed on the passenger side of the vehicle. The vehicle test weight should not exceed the vehicle curb weight by more than 200 kg.

Instrumentation

The test vehicle will be equipped with an Oxford Scientific RT-Range inertial and GPS navigation system to measure and record speed, longitudinal and lateral acceleration, longitudinal and lateral position, yaw rate, and impact time. These data will be sampled and recorded at a frequency of 100 Hz.

A Racelogic Video VBOX Pro will be used to overlay data obtained from the Oxford RT-Range onto a video recorded using a 30 FPS camera. One camera will be positioned with a driver perspective facing out of the front windshield. Other cameras may be used to verify impact and record forward collision warnings (FCW).

Table 2
Test Vehicle Instrumentation

Measurement	Equipment
Speed	Oxford RT-Range
Longitudinal and lateral acceleration	Oxford RT-Range
Longitudinal and lateral position	Oxford RT-Range
Yaw rate	Oxford RT-Range
Impact time	Oxford RT-Range
Forward collision warning	Racelogic VBOX

Table 3
Test Target Instrumentation

Measurement	Equipment
Speed	4activeSB
Position	4activeSB

Brake Warm-up and Maintenance

Before testing, 10 stops will be performed from a speed of 56 km/h (35 mi/h) with an average deceleration of approximately 0.5 to 0.6 g. Immediately following the series of 56-km/h stops, three additional stops will be performed from a speed of 72 km/h (45 mi/h) with sufficient brake pedal force to activate the vehicle's antilock braking system (ABS) for the majority of each stop. Following the series of 72-km/h stops, the vehicle will be driven at a speed of 72 km/h (45 mi/h) for 5 minutes to cool the brakes. If at any point during testing the test vehicle remains stationary for longer than 15 minutes, a series of three brake stops must be performed from a speed of 72 km/h (45 mi/h) to warm the brakes. The longitudinal deceleration of these stops should be roughly 0.7 g. During testing, a minimum of 3 minutes must elapse between the completion of the last warm-up stop and the onset of a valid test trial and/or between the completion of each individual test run.

P-AEB Initialization

Before P-AEB system performance can be properly assessed, some vehicles require a brief period of initialization. During this time, diagnostics to verify functionality and sensor calibrations are performed. If system initialization is required, IIHS will obtain and perform the appropriate procedure from the vehicle manufacturer.

P-AEB and FCW System Setting

P-AEB and/or FCW systems that have different in-vehicle settings for the timing of braking and warning application will be set to the middle setting, or next later setting if there is no middle setting.

TESTING

Pedestrian Target Speed

Pedestrian target speed will be controlled by the 4activeSB unit. The pedestrian target will travel at 5 ± 0.2 km/h (considered walking speed) for the perpendicular adult scenario. The pedestrian target will travel at 5 ± 0.2 km/h (considered running speed) for the perpendicular child scenario. The pedestrian target will be stationary for the parallel adult scenario.

Moving targets must accelerate to test speed within 1 m from start position and reach steady-state speed at least 2 m before reaching the impact/zero point.

Target Placement: Perpendicular Adult Test

An adult pedestrian target will be positioned 4 m away from the vehicle center line on a path perpendicular to the travel path of the test vehicle, crossing the lane from right-to-left, such that the test vehicle approaches the left side of the target and the vehicle's 25% overlap location intersects the vertical centerline of the target H-point at the impact/zero point. This is illustrated in Figure 4a.

Target Placement: Perpendicular Child Test

A child pedestrian target will be positioned 4 m away from the vehicle center line on a path perpendicular to the travel path of the test vehicle, crossing the lane from right-to-left, such that the test vehicle approaches the left side of the target and the vehicle's 50% overlap location intersects the vertical centerline of the target H-point at the impact/zero point.

Two vehicles from IIHS test categories will be used to obstruct visibility of the target: 1) a small car and 2) a midsize or large sport utility vehicle (SUV). The small car (1) will be positioned 1 m behind the

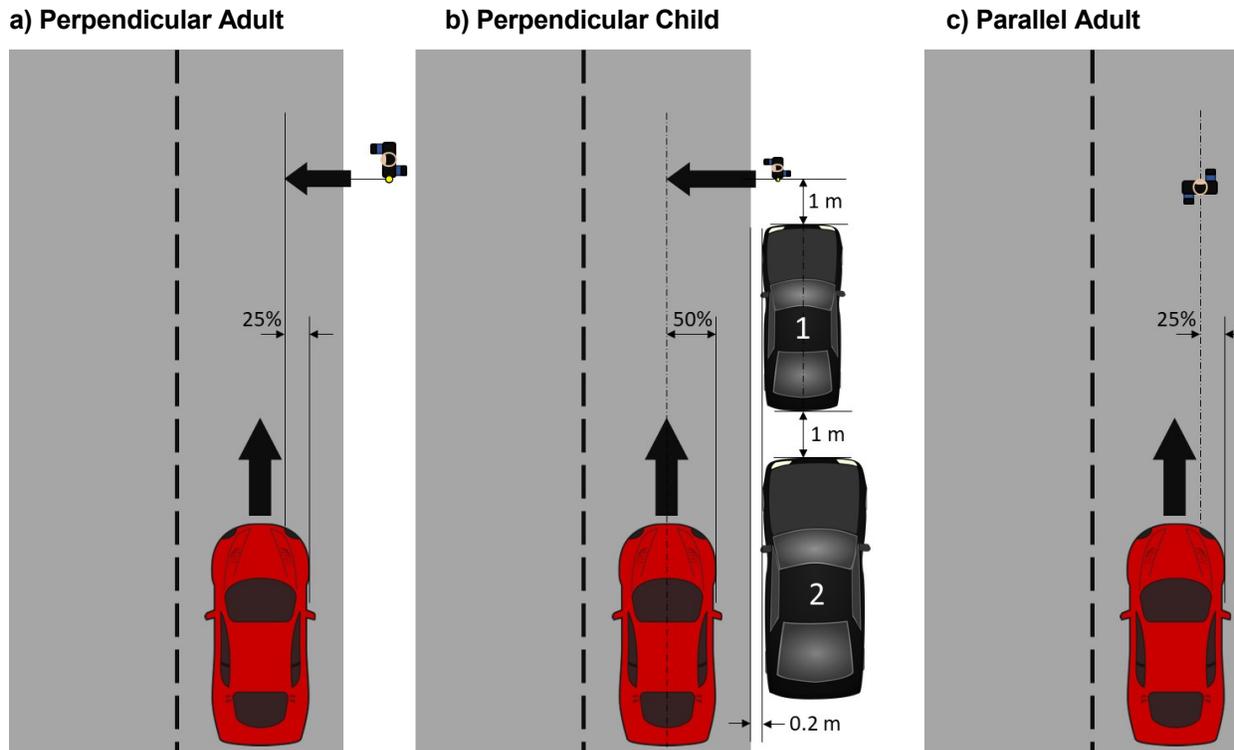
target travel path and 1 m ahead of the larger vehicle (2) with their left edges aligned 0.2 m away from the right edge of the test lane. This is illustrated in Figure 4b.

Target Placement: Parallel Adult Test

An adult pedestrian target will be positioned on a line parallel to the travel path of the test vehicle, facing away, such that the vehicle approaches the rear of the target, with the target's median plane aligned with the vehicle's 25% overlap location. Refer to Figure 4c.

Figure 4

Target Placement in Each Test Scenario



Test Trials

A total of five valid runs will be performed at each test speed. The overall speed reduction will be calculated based on the average of all five test runs.

Test Vehicle Width and Overlap Position

The test vehicle's width will be measured between the outermost body locations above the front wheel axle centerlines. Overlap position (25 or 50%) is based on a percentage of the vehicle's width measured from the front-right side.

Test Vehicle Speed

Tests are conducted at 20 and 40 km/h (perpendicular adult and perpendicular child scenarios), and at 40 and 60 km/h (parallel adult scenario).

Test Vehicle Approach

At the start of each test, the test vehicle will begin moving between 150 and 200 m from the target and gradually accelerate toward the target. For 20-, 40-, and 60-km/h tests, the approach phase begins 25, 50, and 75 m (corresponding to approximately 4.5 s TTC) before the target, respectively. The approach phase ends when the test vehicle impacts the target, or the test vehicle stops before making impact with the target. During the approach phase, the driver must do the following:

- modulate the throttle using smooth inputs to maintain the nominal test speed,
- use the least amount of steering input necessary to maintain the test vehicle in the center of the lane,
- avoid the use of abrupt steering inputs or corrections, and
- not touch the brake pedal.

In order for the test to be considered valid, the following criteria must be met during the approach phase until impact with the target or activation of autonomous braking:

- vehicle speed must remain within ± 1.0 km/h of the nominal test speed
- yaw rate must remain within the range of ± 1 °/s, and
- lateral distance between the centerline of the test vehicle relative to the centerline of the lane must not exceed ± 0.1 m.

Activation of Autonomous Emergency Braking

The point at which the vehicle longitudinal deceleration reaches 0.5 m/s^2 will be considered the start of autonomous emergency braking.

Forward Collision Warning

Audible and visible forward collision warnings will be monitored and recorded in a video file. Onset timing of whichever warning occurs first will be recorded and used for scoring in some scenarios.

Impact Point

The impact point is measured using the Oxford system and is defined when and where the test vehicle first contacts the pedestrian target. A camera or tape switch may be used to verify impact. Prior to each test scenario, a zero point is established with the test vehicle and target aligned and touching at the impact location.

DATA ANALYSIS

Lateral and Longitudinal Positions

Lateral and longitudinal positions will be measured in meters, and the raw data will be used to evaluate the vehicle position.

Longitudinal Acceleration

Longitudinal acceleration will be measured with an accelerometer in m/s^2 . The raw data is digitally filtered with a 12-pole phaseless Butterworth filter with a cutoff frequency of 6Hz.

Speed

Speed will be measured in km/h and the raw data will be used to evaluate speed.

Speed Reduction

Speed reduction is calculated by subtracting the test vehicle speed at the time of impact from the test vehicle speed prior to the activation of autonomous emergency braking. The test vehicle speed before activation of autonomous braking will be calculated based on the average speed for 0.1 second prior to the activation of autonomous emergency braking. If the test vehicle does not contact the target, the impact speed is considered to be zero.

Yaw Rate

The yaw rate will be measured in degrees per second. The raw data is digitally filtered with a 12-pole phaseless Butterworth filter with a cutoff frequency of 6Hz.

SCORING AND RATING SYSTEM

Points will be awarded per Table 3 based on the average speed reduction value from five test runs at each speed in each test scenario. Decimal values will be truncated. A 1-point credit is also given for vehicles with an average FCW timing greater than or equal to 2.1 seconds time-to-collision in the five 60-km/h parallel runs. Partial credit will not be given for FCW.

Table 3
Points Awarded for
Average Speed Reduction

Speed Reduction Range (km/h)	Points
0 to 8	0.0
9 to 18	0.5
19 to 28	1.0
29 to 38	1.5
39 to 48	2.0
49 to 58	2.5
59 to 61	3.0

Two weighting factors will be applied: 70% on the perpendicular subscore and 30% on the parallel subscore. The product of each weighting operation is rounded to the nearest tenth of a point. The total score is the sum of the two weighted subscores. An example score using the maximum possible points is shown in Table 4. The final rating scale is shown in Table 5.

Table 4
Scoring Protocol
Maximum Points Example

Perpendicular Scenarios

Adult Test Score		Child Test Score		Total Score	Weighted Score (70%)
20 km/h	40 km/h	20 km/h	40 km/h		
1.0	2.0	1.0	2.0	6.0	4.2

Parallel Scenario

Adult Test Score			Total Score	Weighted Score (30%)
40 km/h	60 km/h	60 km/h FCW ≥ 2.1		
2.0	3.0	1.0	6.0	1.8

Overall Score

Perpendicular Weighted Score	Parallel Weighted Score	Total Score
4.2	1.8	6.0

Table 5
Final Rating Boundaries

Final Rating

Total score < 1	No credit
1 \geq total score < 3	Basic
3 \geq total score < 5	Advanced
Total score \geq 5	Superior

REFERENCE

Highway Loss Data Institute. 2018. Effect of Subaru EyeSight on pedestrian-related bodily injury liability claim frequency. *HLDI Bulletin*, 34(39). Arlington, VA.