EUROPEAN NEW CAR ASSESSMENT PROGRAMME
(Euro NCAP)

TEST PROTOCOL – AEB VRU systems

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Table of Contents

1 INTRODUCTION

Car-to-pedestrian impacts are one of the most frequent accidents happening on the roads due to driver distraction or misjudgement.

Typical accidents between cars and pedestrians occur at city speeds where the pedestrian crosses the path of the vehicle. These types of accidents with vulnerable road users usually coincide with severe injuries and leave the driver with very little reaction time to apply the brakes.

To support the driver in avoiding when possible or mitigating such crashes, car manufactures offer avoidance technology that reacts to the situation by autonomous braking and at higher speeds may issue warnings to alert the driver. Systems that specifically look for and react to vulnerable road users like pedestrians and cyclists are called AEB VRU systems.

This protocol specifies the AEB VRU test procedure, which is part of Pedestrian Protection.

Note:

AEB VRU scoring is conditional to the total points achieved in subsystem tests, i.e. the sum of pedestrian Headform, Upper Legform & Lower Legform scores.

- If the subsystem total test score is lower than 22 points, no points are available for AEB VRU, regardless whether the system is fitted and would achieve a good score.

2 DEFINITIONS

Throughout this protocol the following terms are used:

Peak Braking Coefficient (PBC) – the measure of tyre to road surface friction based on the maximum deceleration of a rolling tyre, measured using the American Society for Testing and Materials (ASTM) E1136-10 (2010) standard reference test tyre, in accordance with ASTM Method E 1337-90 (reapproved 1996), at a speed of 64.4km/h, without water delivery.

Autonomous emergency braking (AEB) – braking that is applied automatically by the vehicle in response to the detection of a likely collision to reduce the vehicle speed and potentially avoid the collision.

Forward Collision Warning (FCW) – an audiovisual warning that is provided automatically by the vehicle in response to the detection of a likely collision to alert the driver.

Vehicle width – the widest point of the vehicle ignoring the rear-view mirrors, side marker lamps, tyre pressure indicators, direction indicator lamps, position lamps, flexible mud-guards and the deflected part of the tyre side-walls immediately above the point of contact with the ground.

Car-to-VRU Farside Adult (CVFA) – a collision in which a vehicle travels forwards towards an adult pedestrian crossing it's path running from the farside and the frontal structure of the vehicle strikes the pedestrian at 50% of the vehicle's width when no braking action is applied.

Car-to-VRU Nearside Adult (CVNA-25) – a collision in which a vehicle travels forwards towards an adult pedestrian crossing it's path walking from the nearside and the frontal structure of the vehicle strikes the pedestrian at 25% of the vehicles width when no braking action is applied.

Car-to-VRU Nearside Adult (CVNA-75) – a collision in which a vehicle travels forwards towards an adult pedestrian crossing it's path walking from the nearside and the frontal structure of the vehicle strikes the pedestrian at 75% of the vehicles width when no braking action is applied.

Car-to-VRU Nearside Child (CVNC) – a collision in which a vehicle travels forwards towards a child pedestrian crossing it's path running from behind and obstruction from the nearside and the frontal structure of the vehicle strikes the pedestrian at 50% of the vehicle's width when no braking action is applied.

Vehicle under test (VUT) – means the vehicle tested according to this protocol with a pre-crash collision mitigation or avoidance system on board

Euro NCAP Pedestrian Target (EPTa) – means the adult pedestrian target used in this protocol as specified in ANNEX A

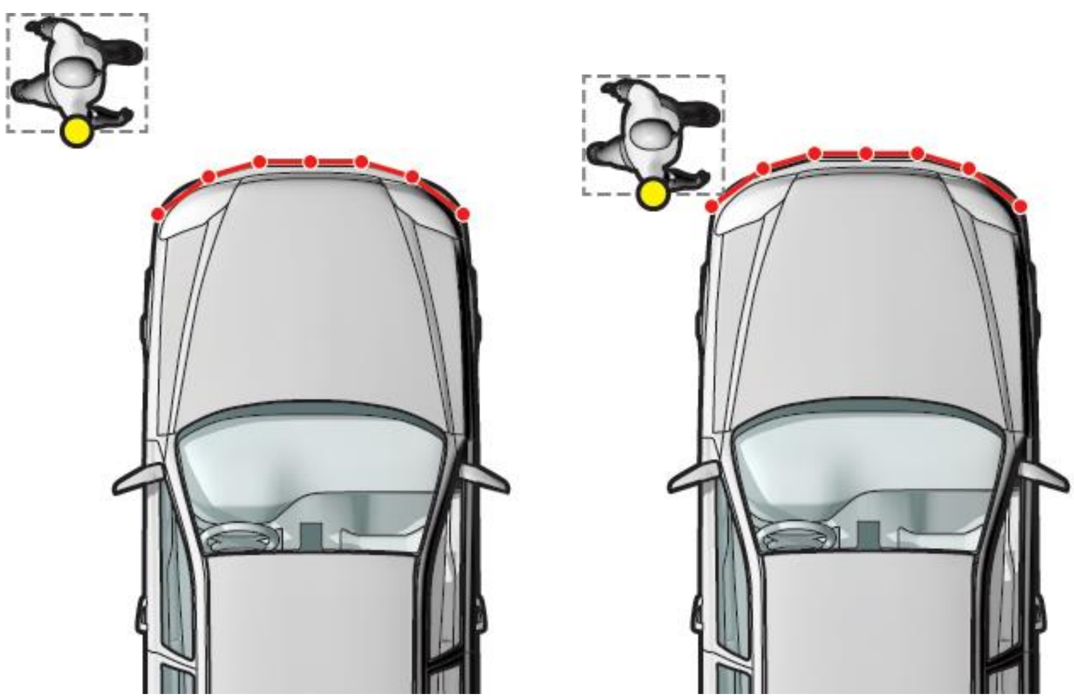
Euro NCAP Child Target (EPTc) – means the child pedestrian target used in this protocol as specified in ANNEX A

Time To Collision (TTC) – means the remaining time before the VUT strikes the EPT, assuming that the VUT and EPT would continue to travel with the speed it is travelling.

T_{AEB} – means the time where the AEB system activates. Activation time is determined by identifying the last data point where the filtered acceleration signal is below -1 m/s^2, and then going back to the point in time where the acceleration first crossed -0.3 m/s^2

T_{FCW} – means the time where the audible warning of the FCW starts. The starting point is determined by audible recognition

Vimpact – means the speed at which the profiled line around the front end of the VUT coincides with the square box around the EPTa and EPTc as shown in the figure below.



3 REFERENCE SYSTEM

3.1 Convention

3.1.1 For both VUT and EPT use the convention specified in ISO 8855:1991 in which the x-axis points towards the front of the vehicle, the y-axis towards the left and the z-axis upwards (right hand system), with the origin at the most forward point on the centreline of the VUT for dynamic data measurements as shown in Figure 1.

3.1.2 Viewed from the origin, roll, pitch and yaw rotate clockwise around the x, y and z axes respectively. Longitudinal refers to the component of the measurement along the x-axis, lateral the component along the y-axis and vertical the component along the z-axis.

3.1.3 This reference system should be used for both left and right hand drive vehicles tested.

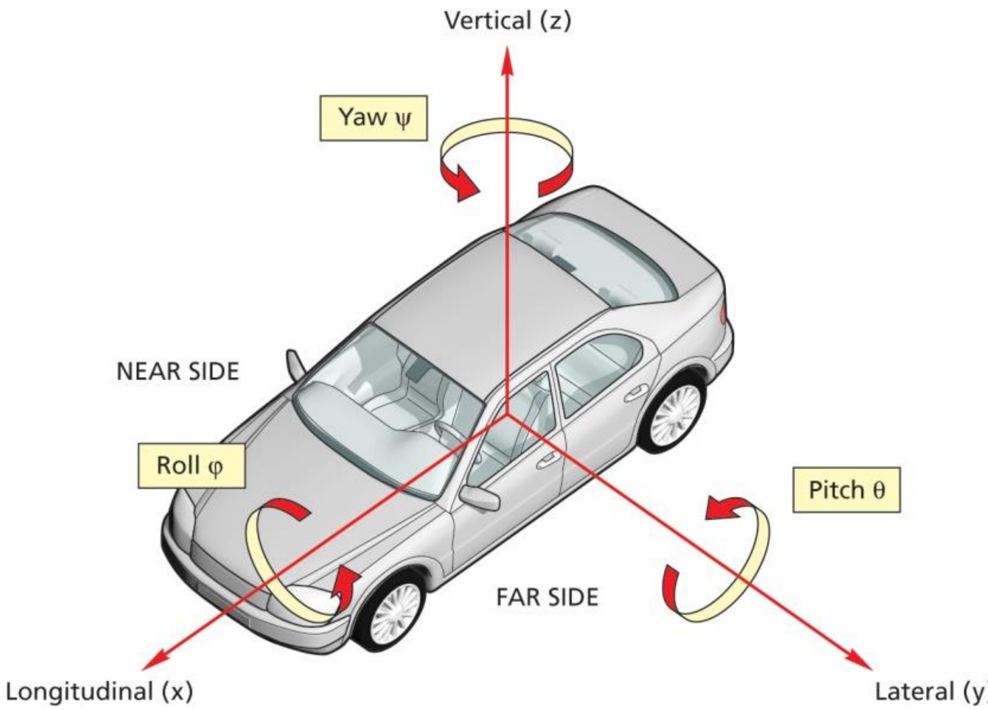


Figure 1: Coordinate system and notation

3.2 Lateral Offset

3.2.1 The lateral offset is determined as the lateral distance between the centre of the front of the VUT when measured in parallel to the intended straight lined path as shown in the figure below.

Lateral offset = Y_{VUT} error

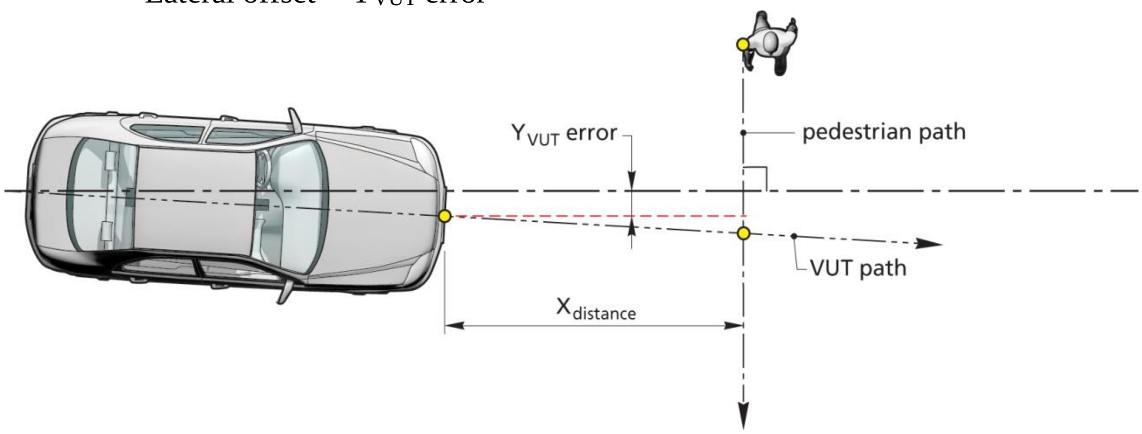


Figure 2: Lateral offset

3.3 Profiles for impact speed determination

3.3.1 A virtual profiled line is defined around the front end of the VUT. This line is defined by straight line segments connecting seven points that are equally distributed over the vehicle width minus 50mm on each side. The theoretical x,y coordinates are provided by the OEMs and verified by the test laboratory.

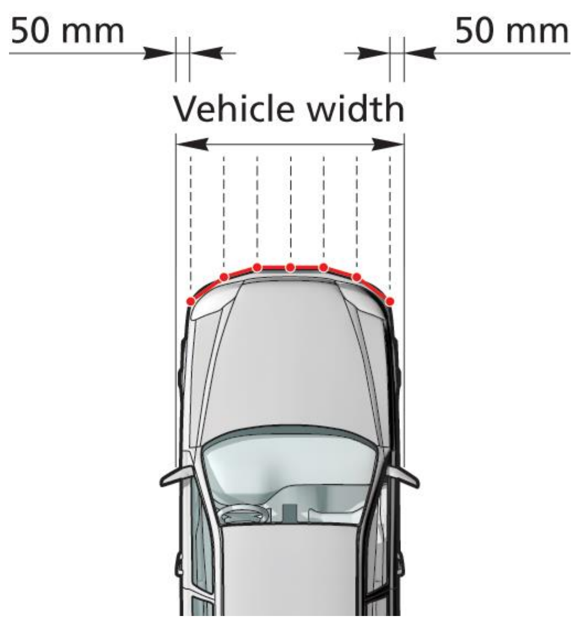


Figure 3: Virtual profiled line around vehicle front end

3.3.2 Around the EPT a virtual square box is defined which is used to determine the impact speed. The dimensions of this virtual box are shown in Figure 4 below.

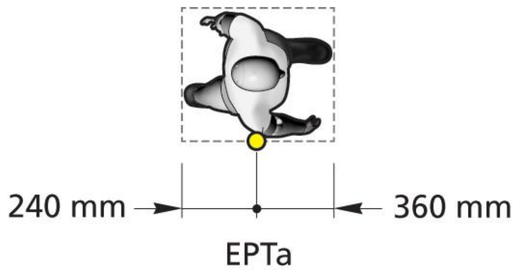


Figure 4: Virtual box dimensions around EPTa and EPTc

4 MEASURING EQUIPMENT

4.1.1 Sample and record all dynamic data at a frequency of at least 100Hz. Synchronise using the DGPS time stamp the EPT data with that of the VUT.

4.2 Measurements and Variables

4.2.1	Time	**T**
	• T_0 equals TTC = 4s	$\mathbf{T}_0$
	• T_{AEB}, time where AEB activates	$\mathbf{T}_{AEB}$
	• T_{FCW}, time where FCW activates	$\mathbf{T}_{FCW}$
	• T_{impact}, time where VUT impacts EPT	$\mathbf{T}_{impact}$
4.2.2	Position of the VUT during the entire test	$\mathbf{X}_{VUT}$, $\mathbf{Y}_{VUT}$
4.2.3	Position of the EPT during the entire test	$\mathbf{Y}_{EPT}$
4.2.4	Speed of the VUT during the entire test	$\mathbf{V}_{VUT}$
	• V_{impact}, speed when VUT impacts EPT	$\mathbf{V}_{impact}$
4.2.5	Speed of the EPT during the entire test	$\mathbf{V}_{EPT}$
4.2.6	Yaw velocity of the VUT during the entire test	$\dot{\boldsymbol{\Psi}}_{VUT}$
4.2.7	Longitudinal acceleration of the VUT during the entire test	$\mathbf{A}_{VUT}$
4.2.8	Steering wheel velocity of the VUT during the entire test	$\mathbf{\Omega}_{\mathbf{VUT}}$

4.3 Measuring Equipment

4.3.1 Equip the VUT and EPT with data measurement and acquisition equipment to sample and record data with an accuracy of at least:

- VUTspeed to 0.1km/h;
- EPT speed to 0.01km/h;
- VUT lateral and longitudinal position to 0.03m ;
- EPT lateral position to 0.03m ;
- VUT yaw rate to 0.1°/s;
- VUT longitudinal acceleration to 0.1m/s^2;
- VUT steering wheel velocity to 1.0 °/s.

4.4 Data Filtering

4.4.1 Filter the measured data as follows:

4.4.1.1 Position and speed are not filtered and are used in their raw state.

4.4.1.2 Acceleration with a 12-pole phaseless Butterworth filter with a cut off frequency of 10Hz.

4.4.1.3 Yaw rate with a 12-pole phaseless Butterworth filter with a cut off frequency of 10Hz.

5 EURO NCAP PEDESTRIAN TARGET

5.1 Specification

5.1.1 Conduct the tests in this protocol using the Euro NCAP Pedestrian Target (EPTa and EPTc) dressed in a black shirt and blue trousers, as shown in Figure 5 below. The EPT replicates the visual, radar, LIDAR and PMD attributes of a typical pedestrian, and is impactable at differential speeds up to 60km/h without causing significant damage to the VUT or EPT.

Figure 5: Euro NCAP Pedestrian Targets (EPTa and EPTc)

5.1.2 To ensure repeatable results the propulsion system and EPT must meet the requirements as detailed in ANNEX A.

5.1.3 The EPT is designed to work with the following types of sensors:

- Radar (24 and 77 GHz)
- LIDAR
- Camera
- PMD

When a manufacturer believes that the EPT is not suitable for another type of sensor system used by the VUT but not listed above, the manufacturer is asked to contact the Euro NCAP Secretariat.

6 TEST CONDITIONS

6.1 Test Track

6.1.1 Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%. The test surface shall have a minimal peak braking coefficient (PBC) of 0.9.

6.1.2 The surface must be paved and may not contain any irregularities (e.g. large dips or cracks, manhole covers or reflective studs) that may give rise to abnormal sensor measurements within a lateral distance of 3.0m to either side of the test path and with a longitudinal distance of 30m ahead of the VUT when the test ends.

6.1.3 The presence of lane markings is allowed. However testing may only be conducted in an area where typical road markings depicting a driving lane may not be parallel to the test path within 3.0m either side. Lines or markings may cross the test path, but may not be present in the area where AEB activation and/or braking after FCW is expected.

6.2 Weather Conditions

6.2.1 Conduct tests in dry conditions with ambient temperature above 5°C and below 40°C.

6.2.2 No precipitation shall be falling and horizontal visibility at ground level shall be greater than 1km. Wind speeds shall be below 10m/s to minimise EPT and VUT disturbance.

6.2.3 Natural ambient illumination must be homogenous in the test area and in excess of 2000 lux for daylight testing with no strong shadows cast across the test area other than those caused by the VUT or EPT. Ensure testing is not performed driving towards, or away from the sun when there is direct sunlight.

6.2.4 Measure and record the following parameters preferably at the commencement of every single test or at least every 30 minutes:

a) Ambient temperature in °C;
b) Track Temperature in °C;
c) Wind speed and direction in m/s;
d) Ambient illumination in Lux.

6.3 Surroundings

6.3.1 Conduct testing such that there are no other vehicles, highway furniture, obstructions, other objects or persons protruding above the test surface that may give rise to abnormal sensor measurements within a lateral distance of 6.0m on the driver side and 4.0m on the passenger side of the VUT test path, 1.0m around of the EPT and within a longitudinal distance of 30m ahead of the VUT when the test ends (Figure 6).

6.3.2 Test areas where the VUT needs to pass under overhead signs, bridges, gantries or other significant structures are not permitted.

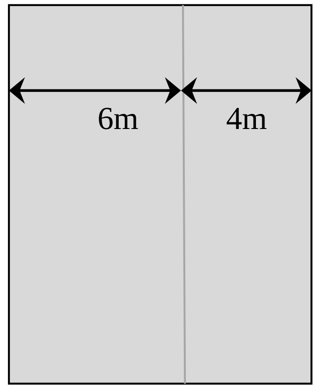


Figure 6: Free surroundings

6.3.3 The general view ahead and to either side of the test area shall comprise of a wholly plain man made or natural environment (e.g. further test surface, plain coloured fencing or hoardings, natural vegetation or sky etc.) and must not comprise any highly reflective surfaces or contain any vehicle-like silhouettes that may give rise to abnormal sensor measurements.

6.4 VUT Preparation

6.4.1 <u>AEB and FCW System Settings</u>

6.4.1.1 Set any driver configurable elements of the AEB and/or FCW system (e.g. the timing of the collision warning or the braking application if present) to the middle setting or midpoint and then next latest setting similar to the examples shown in Figure 7.

		Setting 1	**Setting 2**		
Early		Setting 1	**Setting 2**	Setting 3	Late
	Setting 1	Setting 2	**Setting 3**	Setting 4	

Figure 7: AEB and/or FCW system setting for testing

6.4.2 <u>Deployable Pedestrian/VRU Protection Systems</u>

When the vehicle is equipped with a deployable pedestrian/VRU protection system, this system shall be deactivated before the testing commences.

6.4.3 <u>Tyres</u>

Perform the testing with new original fitment tyres of the make, model, size, speed and load rating as specified by the vehicle manufacturer. It is permitted to change the tyres which are supplied by the manufacturer or acquired at an official dealer representing the manufacturer if those tyres are identical make, model, size, speed and load rating to the original fitment. Use inflation pressures corresponding to least loading normal condition.

Run-in tyres according to the tyre conditioning procedure specified in 7.1.3. After running-in maintain the run-in tyres in the same position on the vehicle for the duration of the testing.

6.4.4 Wheel Alignment Measurement

The vehicle should be subject to a vehicle (in-line) geometry check to record the wheel alignment set by the OEM. This should be done with the vehicle in kerb weight.

6.4.5 Unladen Kerb Mass

6.4.5.1 Fill up the tank with fuel to at least 90% of the tank's capacity of fuel.

6.4.5.2 Check the oil level and top up to its maximum level if necessary. Similarly, top up the levels of all other fluids to their maximum levels if necessary.

6.4.5.3 Ensure that the vehicle has its spare wheel on board, if fitted, along with any tools supplied with the vehicle. Nothing else should be in the car.

6.4.5.4 Ensure that all tyres are inflated according to the manufacturer's instructions for the least loading condition.

6.4.5.5 Measure the front and rear axle masses and determine the total mass of the vehicle. The total mass is the 'unladen kerb mass' of the vehicle. Record this mass in the test details.

6.4.5.6 Calculate the required ballast mass, by subtracting the mass of the test driver and test equipment from the required 200 kg interior load.

6.4.6 Vehicle Preparation

6.4.6.1 Fit the on-board test equipment and instrumentation in the vehicle. Also fit any associated cables, cabling boxes and power sources.

6.4.6.2 Place weights with a mass of the ballast mass. Any items added should be securely attached to the car.

6.4.6.3 With the driver in the vehicle, weigh the front and rear axle loads of the vehicle.

6.4.6.4 Compare these loads with the "unladen kerb mass"

6.4.6.5 The total vehicle mass shall be within ±1% of the sum of the unladen kerb mass, plus 200kg. The front/rear axle load distribution needs to be within 5% of the front/rear axle load distribution of the original unladen kerb mass plus full fuel load. If the vehicle differs from the requirements given in this paragraph, items may be removed or added to the vehicle which has no influence on its performance. Any items added to increase the vehicle mass should be securely attached to the car.

6.4.6.6 Repeat paragraphs 6.4.6.3 and 6.4.6.4 until the front and rear axle loads and the total vehicle mass are within the limits set in paragraph 6.4.6.5. Care needs to be taken when adding or removing weight in order to approximate the original vehicle inertial properties as close as possible. Record the final axle loads in the test details. Record the axle weights of the VUT in the ‘as tested’ condition.

6.4.6.7 Verify the x-y coordinates for the virtual front end vehicle contour given by the manufacturer. When the coordinates given are within 10mm of those measured by the test laboratory, the coordinates as provided by the manufacturer will be used. When the coordinates are not within 10mm, the coordinates as measured by the laboratory will be used.

7 TEST PROCEDURE

7.1 VUT Pre-test Conditioning

7.1.1 General

7.1.1.1 A new car is used as delivered to the test laboratory.

7.1.1.2 If requested by the vehicle manufacturer, drive a maximum of 100km on a mixture of urban and rural roads with other traffic and roadside furniture to 'calibrate' the sensor system. Avoid harsh acceleration and braking.

7.1.2 Brakes

7.1.2.1 Condition the vehicle's brakes in the following manner:

- Perform twenty stops from a speed of 56km/h with an average deceleration of approximately 0.5 to 0.6g.
- Immediately following the series of 56km/h stops, perform three additional stops from a speed of 72km/h, each time applying sufficient force to the pedal to operate the vehicle's antilock braking system (ABS) for the majority of each stop.
- Immediately following the series of 72km/h stops, drive the vehicle at a speed of approximately 72km/h for five minutes to cool the brakes.
- Initiation of the first test shall begin within two hours after completion of the brake conditioning

7.1.3 Tyres

7.1.3.1 Condition the vehicle's tyres in the following manner to remove the mould sheen:

- Drive around a circle of 30m in diameter at a speed sufficient to generate a lateral acceleration of approximately 0.5 to 0.6g for three clockwise laps followed by three anticlockwise laps.
- Immediately following the circular driving, drive four passes at 56km/h, performing ten cycles of a sinusoidal steering input in each pass at a frequency of 1Hz and amplitude sufficient to generate a peak lateral acceleration of approximately 0.5 to 0.6g.
- Make the steering wheel amplitude of the final cycle of the final pass double that of the previous inputs.

7.1.3.2 In case of instability in the sinusoidal driving, reduce the amplitude of the steering input to an appropriately safe level and continue the four passes.

7.1.4 AEB/FCW System Check

7.1.4.1 Before any testing begins, perform a maximum of ten runs at the lowest test speed the system is supposed to work, to ensure proper functioning of the system.

7.2 Test Scenarios

7.2.1 The performance of the VUT AEB system is assessed in the CVFA, CVNA-25, CVNA-75 and CVNC scenarios as shown in Figure 8abc.

7.2.2 For testing purposes, assume a straight line path equivalent to the centreline of the lane in which the collision occurred, hereby known as the test path. Control the VUT with driver inputs or using alternative control systems that can modulate the vehicle controls as necessary to perform the tests.

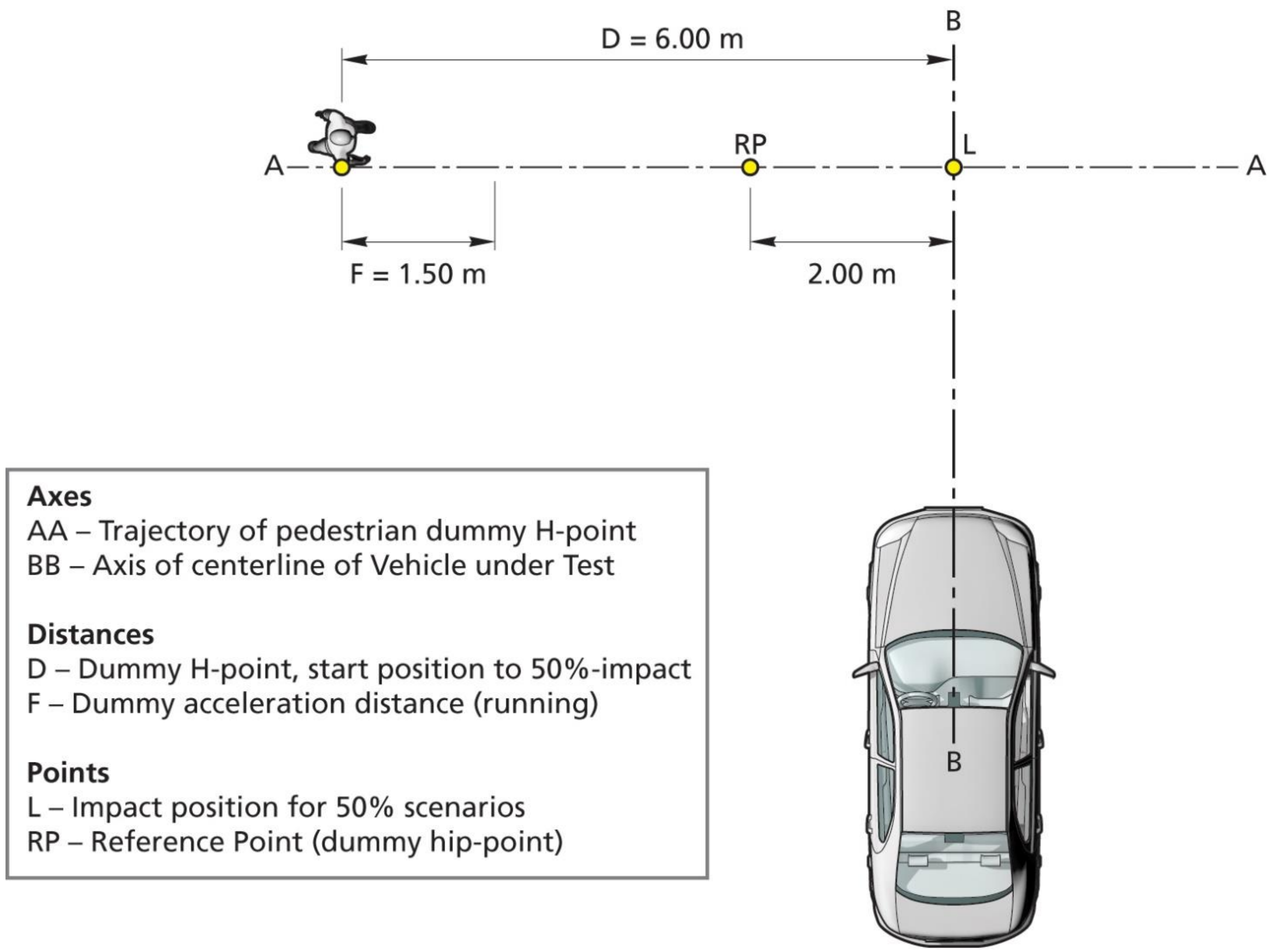


Figure 8a: CVFA scenario, Adult running from Farside

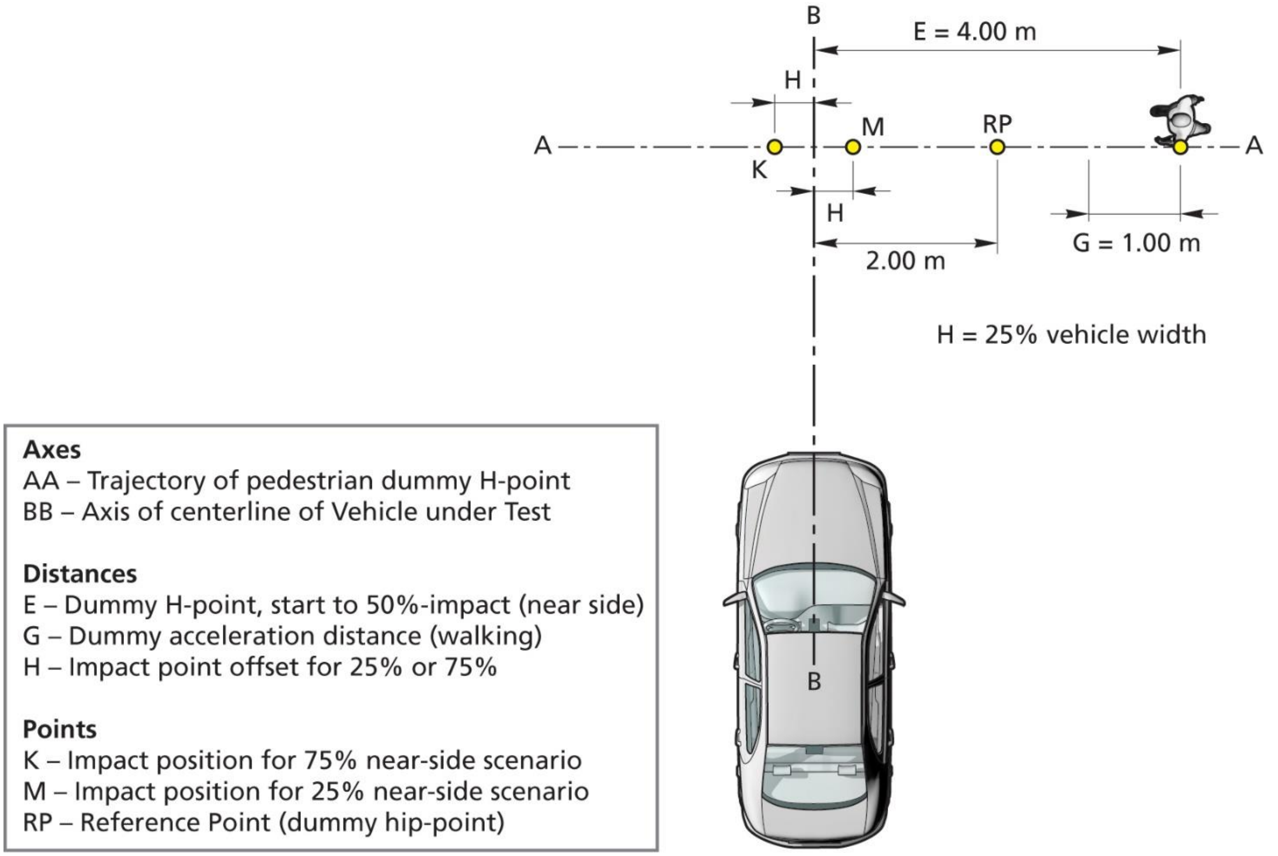


Figure 8b: CVNA-25 & CVNA-75 scenarios, Walking Adult from Nearside

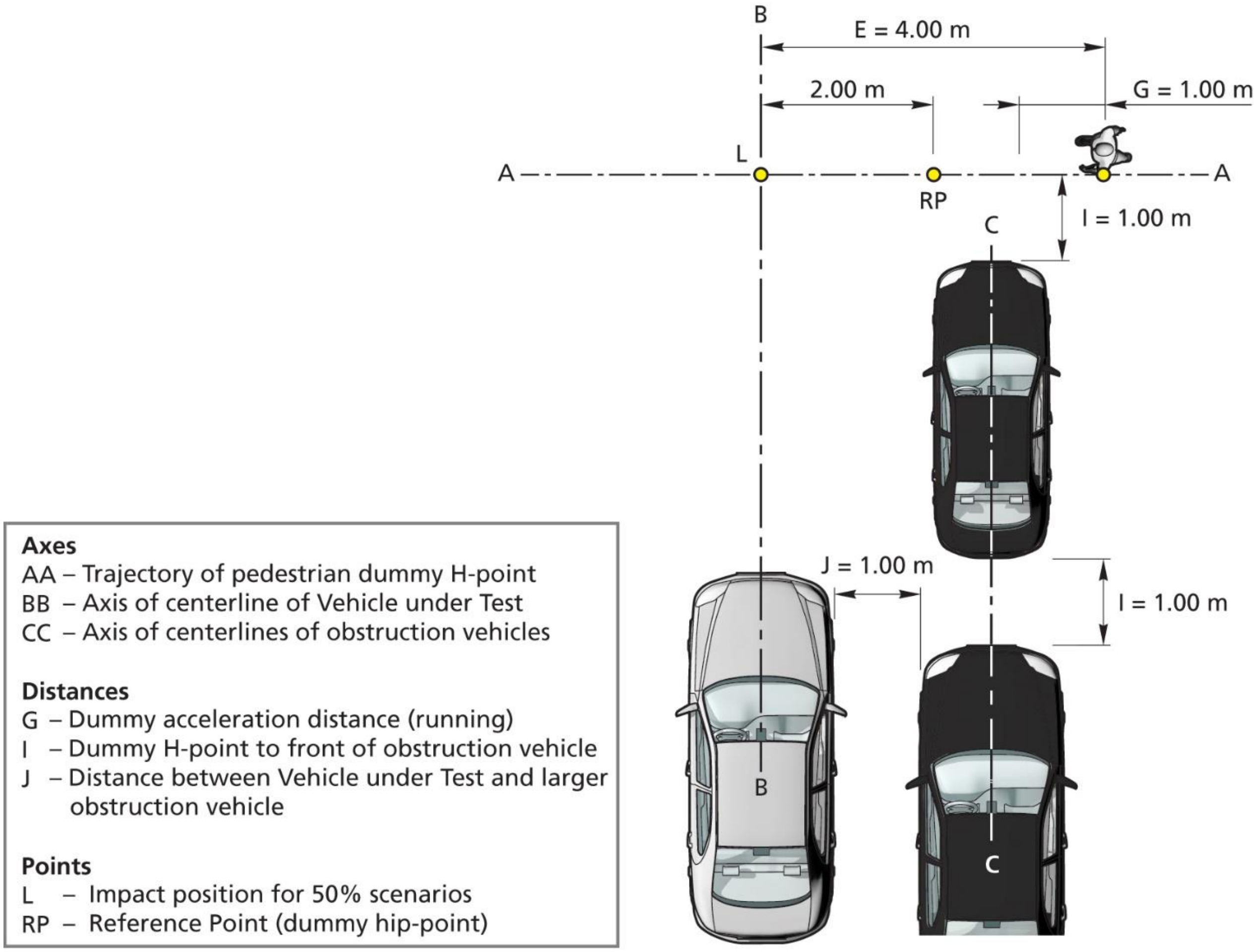


Figure 8c: CVNC scenario, Running Child from Nearside from Obstruction vehicles (see Annex B)

7.2.3 All tests will be performed with 5 km/h incremental steps (see 7.4.4) within the speed range of 20-60 km/h.

7.2.4 For the CVNA-75 scenario the following additional tests are performed

- Test speed of 20km/h with an EPTa speed of 3 km/h
- Test speed of 10 and 15 km/h with an EPTa speed of 5 km/h

7.3 Test Conduct

7.3.1 Before every test run, drive the VUT around a circle of maximum diameter 30m at a speed less than 10km/h for one clockwise lap followed by one anticlockwise lap, and then manoeuvre the VUT into position on the test path. If requested by the OEM an initialisation run may be included before every test run. Bring the VUT to a halt and push the brake pedal through the full extent of travel and release.

7.3.2 For vehicles with an automatic transmission select D. For vehicles with a manual transmission select the highest gear where the RPM will be at least 1500 at the test speed.

7.3.3 Perform the first test a minimum of 90s and a maximum of 10 minutes after completing the tyre conditioning, and subsequent tests after the same time period. If the time between consecutive tests exceeds 10 minutes perform three brake stops from 72 km/h at approximately 0.3g.

Between tests, manoeuvre the VUT at a maximum speed of 50km/h and avoid riding the brake pedal and harsh acceleration, braking or turning unless strictly necessary to maintain a safe testing environment.

7.4 Test Execution

7.4.1 Accelerate the VUT and EPT to the respective test speeds.

7.4.2 The test shall start at T_0 (4s TTC) and is valid when all boundary conditions are met between T_0 and T_{AEB}/T_{FCW}:

- Speed of VUT (GPS-speed)	Test speed + 0.5 km/h
- Lateral deviation from test path	0 ± 0.05 m
- Yaw velocity	0 ± 1.0 °/s
- Steering wheel velocity	0 ± 15.0 °/s
- Speed of EPT during steady state	
- CVFA	8 ± 0.2 km/h
- CVNA	5 ± 0.2 km/h
- CVNC	5 ± 0.2 km/h
- EPT Steady state	
- Nearside	3.0 m from vehicle centerline
- Farside	4.5 m from vehicle centerline

7.4.3 The end of a test is considered when one of the following occurs:

- V_{VUT} = 0km/h
- Contact between VUT and EPT
- EPT has left the VUT path

7.4.4 For manual or automatic accelerator control, it needs to be assured that during automatic brake the accelerator pedal does not result in an override of the system. The accelerator pedal needs to be released when the initial test speed is reduced by 5 km/h. There shall be no operation of other driving controls during the test, e.g clutch or brake pedal.

7.4.5 The subsequent test speed for the next test is incremented with 5km/h. Stop testing when the actual speed reduction seen in the tests above 40 km/h is less than 20 km/h or when the manufacturer predicts no performance

7.4.6 When the impact speed recorded in the test differs from the manufacturer predicted performance by more than 5 km/h, the test shall be repeated a further two times for monitoring purposes. These results will be discussed between Euro NCAP and manufacturer to determine which results are to be used for the assessment (most representative) for the vehicle under test.

ANNEX A EPT SPECIFICATIONS

A.1 Pedestrian Target Dimensions

The tables and figured below specify the dimensions of the target dummies used.

Table A.1: Euro NCAP Adult Pedestrian Target (EPTa) dimensions

Description	Dimension
Total height in walking posture	1800 ± 20mm
H-point height	923 ± 20mm
Heel to heel distance - Longitudinal - Lateral	 315 ± 20mm 147 ± 10mm
Step width	600 ± 20mm
Shoulder width	500 ± 20mm
Torso depth	235 ± 10mm
Front hand to back side	530 ± 20mm
Torso angle	85 ± 1 deg
Upper arm angle - Non-struck side - Struck side	 60 ± 2 deg 110 ± 2 deg
Support tube in driving direction	5 ± 2 deg
Weight	Max 4 kg

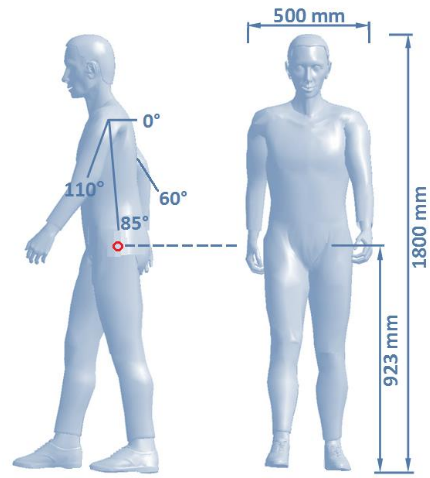
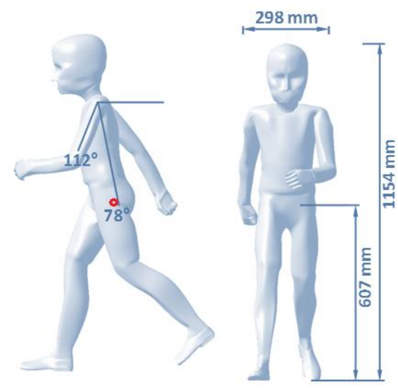


Table A.2: Euro NCAP Child Pedestrian Target (EPTc) dimensions

Description	**Dimension**
Total height in running posture	1154 ± 20mm
H-point height	607 ± 20mm
Heel to heel distance - Longitudinal - Lateral	 494 ± 20mm 129 ± 10mm
Step width	711 ± 20mm
Shoulder width	298 ± 20mm
Torso depth	139 ± 10mm
Front hand to back side	362 ± 20mm
Torso angle	78 ± 1 deg
Upper arm angle - Non-struck side - Struck side	 50 ± 2 deg 112 ± 2 deg
Support tube in driving direction	5 ± 2 deg
Weight	Max 2 kg



A.2 Pedestrian Target visual and infrared properties

The targets must be clothed with a long-sleeved shirt in the colour black and long trousers in blue. Skin surface parts (face and hands) have to be finished with a non-reflective flesh-coloured texture or paintwork.

The infrared (IR) reflectivity (within 850-910nm wavelength) of the clothes and “skin” shall be within 40-60%. For the hair this shall be within 20-60%.

The colour of stiffening ropes must be light grey and low optical reflective.

Textile specification outer cover:

- Area weight: < 300 g/m²
- Water resistance (AATCC 127): > 600 mm
- strength (ASTM D5034): > 350 lbs
- light fastness (AATCC 169): > 6000 h
- wear resistance ASTM (D3884): > 500 cycles

A.3 Pedestrian Target Articulation

The legs of the dummy shall be articulated to mimic the leg movement of a real pedestrian. Specific corridors between which the targets needs to be within and a corresponding test method will be introduced in a later stage when independent measurement tools are available.

A.4 Pedestrian Target radar properties

The radar reflective characterisitics of the pedestrian targets should be similar to a real pedestrian of the same size. Specific corridors between which the targets needs to be within and a corresponding test method will be introduced in a later stage when independent measurement tools are available.

A.4.1 Doppler Effect of Articulation

The micro-Doppler effect shall be comparable to a real pedestrian and a homogenous distribution of the RCS over the whole dummy height must be ensured. Specific corridors between which the targets needs to be within and a corresponding test method will be introduced in a later stage when independent measurement tools are available.

ANNEX B OBSTRUCTION VEHICLE DIMENSIONS

B.1 Smaller obstruction vehicle

The smaller obstruction vehicle should be of the category Small Family Car and is positioned closest to the pedestrian path. The smaller obstruction vehicle should be within the following geometrical dimensions and needs to be in a dark colour.

	Vehicle Length	**Vehicle width (without mirrors)**	**Vehicle Height**	**Bonnet length (till A pillar)**	**BLE height**
Minimum	4100 mm	1700 mm	1300 mm	1100 mm	650 mm
Maximum	4400 mm	1900 mm	1500 mm	1500 mm	800 mm

B.2 Larger obstruction vehicle

The larger obstruction vehicle should be of the category Small Offroad 4x4 and is positioned behind the smaller obstruction vehicle. The larger obstruction vehicle should be within the following geometrical dimensions and needs to be in a dark colour.

	Vehicle Length	**Vehicle width (without mirrors)**	**Vehicle Height**
Minimum	4300 mm	1750 mm	1500 mm
Maximum	4700 mm	1900 mm	1800 mm