

# **Collision Avoidance Frontal Collisions**

**Truck-to-Vulnerable Road User**

## **Test Protocol**

Implementation November 2024

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## PREFACE

During the test preparation, vehicle manufacturers are encouraged to liaise with the laboratory and to check that they are satisfied with the way cars are set up for testing. Where a manufacturer feels that a particular item should be altered, they should ask the laboratory staff to make any necessary changes. Manufacturers are forbidden from making changes to any parameter that will influence the test, such as dummy positioning, vehicle setting, laboratory environment etc.

It is the responsibility of the test laboratory to ensure that any requested changes satisfy the requirements of Euro NCAP. Where a disagreement exists between the laboratory and manufacturer, the Euro NCAP secretariat should be informed immediately to pass final judgment. Where the laboratory staff suspect that a manufacturer has interfered with any of the set-up, the manufacturer's representative should be warned that they are not allowed to do so themselves. They should also be informed that if another incident occurs, they will be asked to leave the test site.

Where there is a recurrence of the problem, the manufacturer's representative will be told to leave the test site and the Euro NCAP secretariat should be immediately informed. Any such incident may be reported to the manufacturer and the person concerned may not be allowed to attend further Euro NCAP tests.

**DISCLAIMER:** Euro NCAP has taken all reasonable care to ensure that the information published in this protocol is accurate and reflects the technical decisions taken by the organisation. In the unlikely event that this protocol contains a typographical error or any other inaccuracy, Euro NCAP reserves the right to make corrections and determine the assessment and subsequent result of the affected requirement(s).

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## DEFINITIONS

Throughout this protocol the following terms are used:

**Heavy Goods Vehicle (HGV)** – a category N2 or N3 vehicle with gross mass exceeding 3,500 kg.

**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 64.4 km/h, without water delivery. Alternatively, the method as specified in UNECE R13-H.

**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.

**HGV-to-Pedestrian** – a collision between a vehicle and an adult or child pedestrian in its path running when no braking and/or steering is applied.

**HGV-to-Bicyclist** – a collision between a vehicle and an adult bicyclist in its path, when no braking and/or steering is applied.

**Borrow from source** – an HBNTap trajectory in which the VUT swings out on the approach to the intersection to accommodate the rear of the vehicle cutting in as it navigates the turn to the near side.

**Borrow from destination** – an HBNTap trajectory in which the VUT overshoots on the approach to the intersection to accommodate the rear of the vehicle cutting in as it navigates the turn to the near side.

**Large radius turn** – an HBNTap trajectory in which the VUT takes a wider line through the intersection at higher speed.

**Short vehicle only** – an HBNTap trajectory in which the trailer is uncoupled from the drawing vehicle (where appropriate) and the VUT navigates the intersection turn to the near side with reduced rear cut in.

**Vehicle Under Test (VUT)** – means the vehicle, or vehicle and trailer combination, tested according to this protocol with a pre-crash collision mitigation or avoidance system on board.

**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.

**Euro NCAP Pedestrian Target (EPTa)** – means the articulated adult pedestrian target used in this protocol as specified ISO 19206-2:2018.

**Euro NCAP Child Target (EPTc)** – means the articulated child pedestrian target used in this protocol as specified in ISO 19206-2:2018.

**Euro NCAP Bicyclist and bike Target (EBT)** – means the bicyclist and bike target used in this protocol as specified in ISO 19206-4:2020.

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

**T<sub>AEB</sub>** – the time where the AEB system activates. Activation time is determined by identifying the last data point where the filtered acceleration signal is below  $-1 \text{ m/s}^2$ , and then going back to the point in time where the acceleration first crossed  $-0.3 \text{ m/s}^2$ .

**T<sub>impact</sub>** – means the time at which the profiled line around the front end of the VUT coincides with the square box around the EPT or EBT as shown in Figure 0-1 and Figure 0-2 below.

**V<sub>impact</sub>** – means the speed at which the profiled line around the front end of the VUT coincides with the square box around the EPT or EBT as shown in Figure 0-1 and Figure 0-2 below.

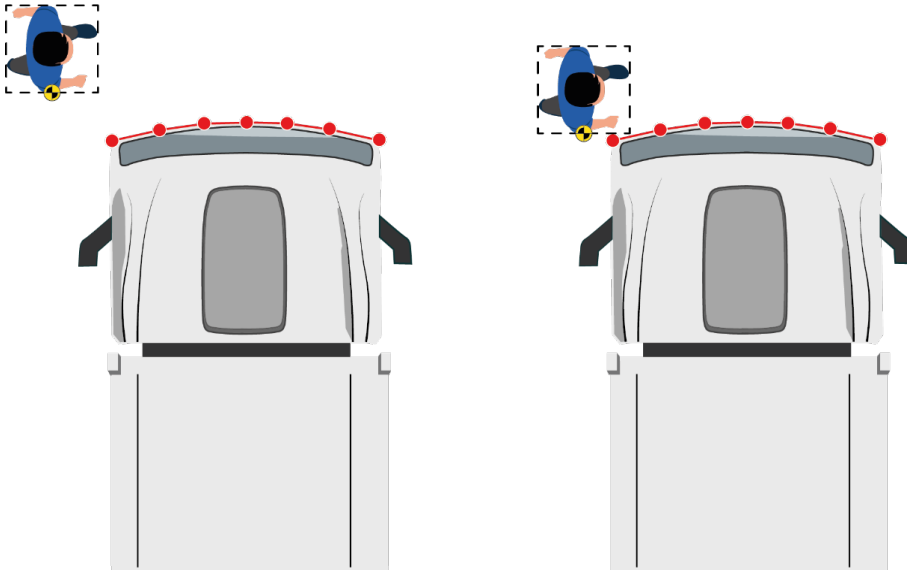


Figure 0-1 Front profile and EPT

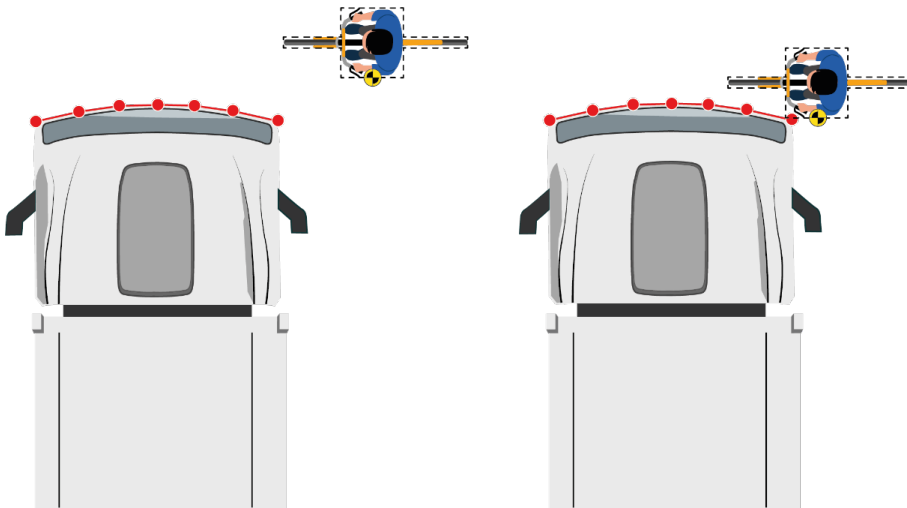


Figure 0-2 Front profile and EBT

**V<sub>rel\_test</sub>** – means the relative speed between the VUT and the EPT or EBT by subtracting the longitudinal velocity of the EPT or EBT from that of the VUT at the start of the test.

**V<sub>rel\_impact</sub>** – means the relative speed at which the VUT hits the EPT or EBT by subtracting the velocity of the EPT or EBT from V<sub>impact</sub> at the time of collision.

# 1 INTRODUCTION

An analysis of European road traffic crash data revealed that collisions with pedestrians account for 16 % of fatalities in HGV collisions, and bicyclists a further 10 %. International crash data does not offer easy breakdowns of crash type. However, a Euro NCAP study of police reported collisions occurring in the UK generally, and London specifically, identified that circa 40 to 45 % of all HGV to pedestrian fatalities occur when an HGV moving at normal traffic speeds collides with a pedestrian crossing in front of it, or walking ahead of it longitudinally. In urban areas about 20 % of pedestrian fatalities occur in those situations. Regarding bicyclists, circa 17 % of all HGV to bicyclist fatalities fall within the scope of the crossing and longitudinal scenarios, and circa 2 % of those occurring in urban areas.

Regarding HGV near side turning, the study identified that circa 3 % of all HGV to pedestrian fatalities fall within the scope of the near side turning scenarios, and circa 6 % of those occurring in urban areas. Regarding bicyclists, circa 22 % of all HGV to bicyclist fatalities fall within the scope of the near side turning scenarios, and circa 40 % of those occurring in London. Highway infrastructure is a defining factor in the nature of HGV to bicyclist near side turning collisions, affected by junction size and whether the HGV and bicyclist share the same road space or if a dedicated cycle lane is provided, offset from the vehicle lane.

Typical incidents occur in busy urban environments when the HGV is moving off or turning at low speed and enters into conflict with a pedestrian or bicyclist crossing or passing alongside. The vast majority of such collisions occur in daylight. The initial collision often occurs at low speed and regularly goes undetected because of the large HGV to VRU mass ratio and vehicle noise masking signs of the impact, and the large vehicle size and elevated driving position meaning the event is remote from the driver and/or not directly visible. The near-vertical front and sides of the HGV regularly cause the VRU to be knocked down and the significant injury mechanism is often the wheels overrunning the VRU, especially when turning as the rear axle(s) cut in.

To support the driver in avoiding collisions with VRUs, vehicle manufactures offer collision avoidance technology that monitors the road and traffic environment and has the ability to warn the driver of an imminent collision, support adequate braking and/or ultimately stop the vehicle by itself.

Whilst regulation makes AEB VRU a mandatory requirement for new HGVs in 2028, Euro NCAP strives to accelerate fitment ahead of this time and drive performance improvements to ensure robust and effective operation in a broad range of real-world collision types. To this end, the Euro NCAP scheme builds on the regulatory requirement by:

- Incorporating additional challenging real-world collision scenarios with walking and running adult and child pedestrians, cycling bicyclists, impact points offset from the centreline of the HGV and line of sight obstructions reminiscent of urban environments
- Rewarding systems that automatically intervene to apply braking when an HGV is in conflict with a VRU in critical near side turning collisions (Regulation only requires information and warning in this scenario)
- Encouraging higher speed operation and performance by offering maximum reward for avoiding collisions at higher test speeds

This protocol specifies the test procedures, which are used to evaluate system performance in a repeatable and reproducible manner for the HGV safety rating scheme.

## 2 REFERENCE SYSTEM

### 2.1 Convention

For the VUT EPT and EBT 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 2-1.

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.

This reference system should be used for both left hand drive (LHD) and right-hand drive (RHD) vehicles tested. Figure 2-1 show the near and far side of the vehicle for a left-hand drive (LHD) vehicle. The far side always corresponds to the hand of drive, and therefore swaps sides accordingly for a right-hand drive (RHD) vehicle.

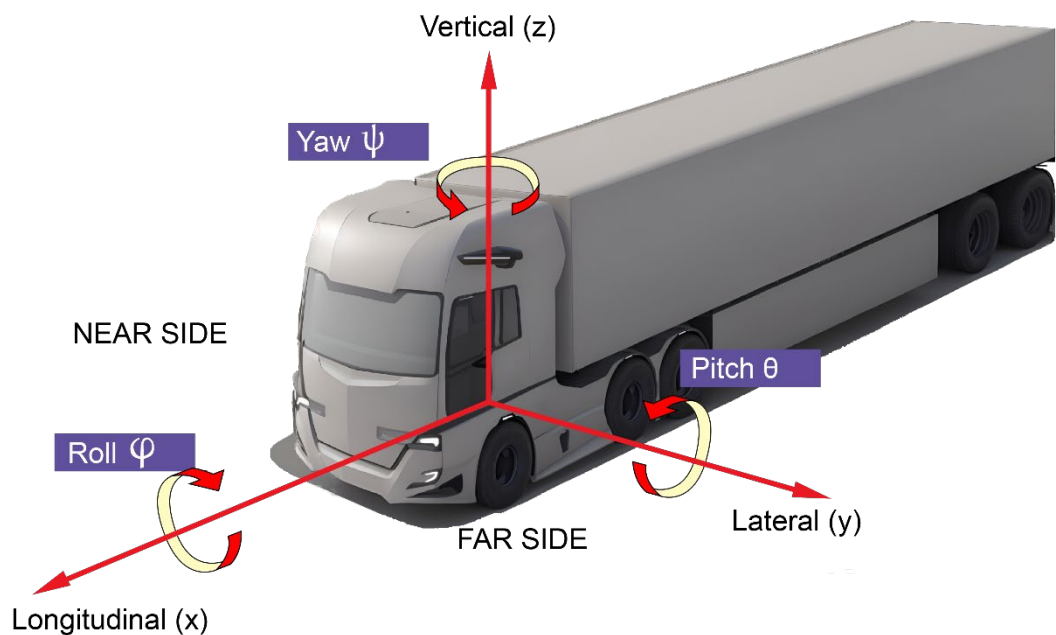


Figure 2-1 Coordinate system and notation (LHD & RHD) and near side – far side for LHD vehicle



## 2.2 Lateral Path Error

The lateral offset is ( $Y_{VUT}$  error) 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 **Error! Reference source not found.** below.

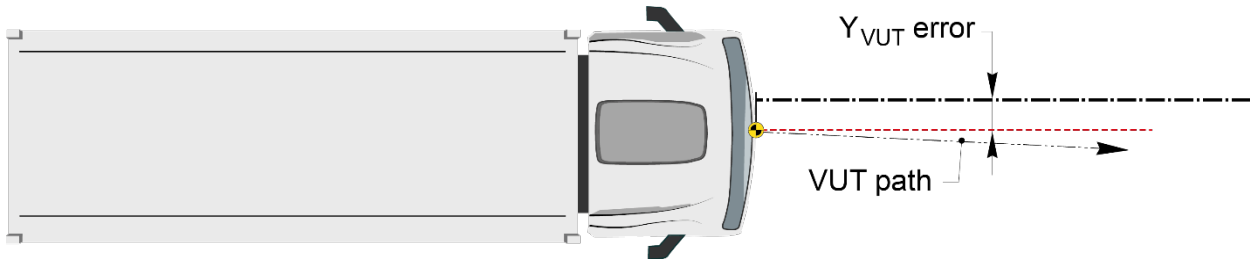


Figure 2-2 Lateral path error

## 2.3 Profile for Impact Speed Determination

A virtual profiled line is defined around the front end of the VUT as shown in Figure 2-3. This line is defined by straight line segments connecting seven points that are equally distributed over the vehicle width minus [150] mm on each side. The theoretical x,y coordinates are provided by the manufacturer and verified by the test laboratory.

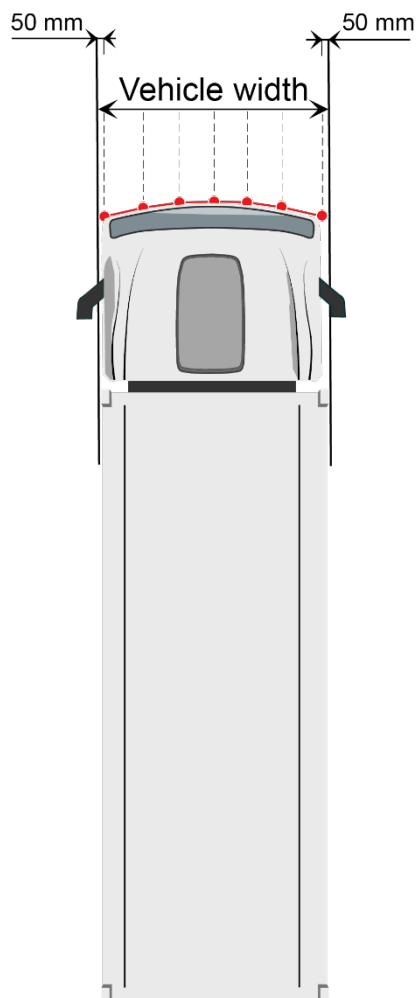


Figure 2-3 Virtual profiled line around the VUT front end

Around the EPT a virtual box is defined which is used to determine the impact speed. The dimensions of this virtual box are shown in Figure 2-4. For crossing scenarios, the reference point of the EPT is the HIP point and for the longitudinal scenario a virtual point where the centreline of the dummy crosses the virtual box.

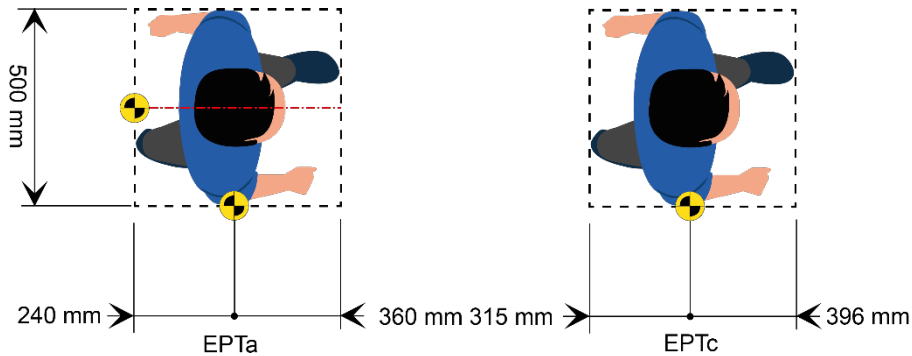


Figure 2-4 Virtual box dimensions around EPTa and EPTc

Around the EBT a virtual box is defined which is used to determine the impact speed. The dimensions of this virtual box are shown in Figure 2-5. For crossing scenarios, the reference point of the EBT is the centre of the bottom bracket (crank shaft) (dashed line in Figure 2-5) and for the longitudinal scenario the most rearward point on the rear wheel is used.

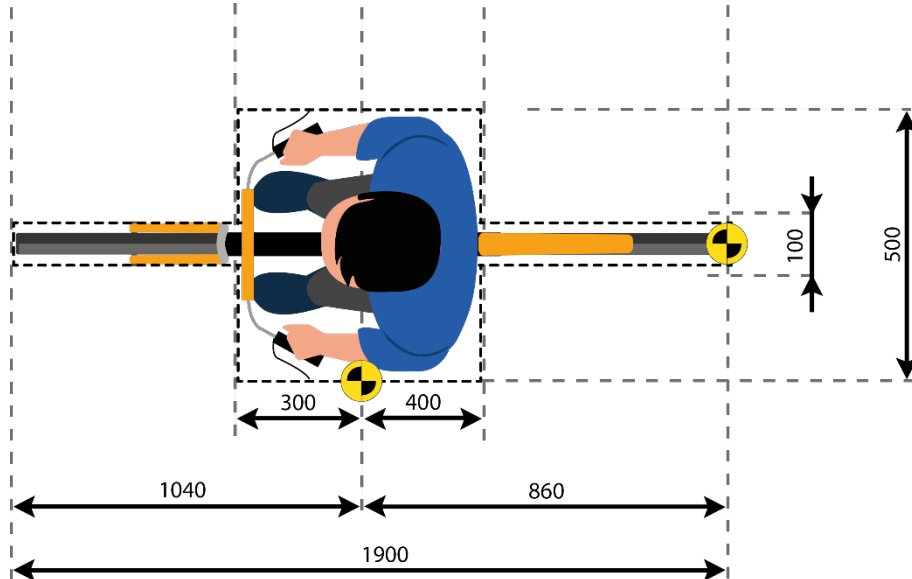


Figure 2-5 Virtual box dimensions around EBT

### 3 MEASURING EQUIPMENT

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

#### 3.1 Measurements and Variables

Time	$T$
$T_0$ equals TTC = 4.0 s except for:	$T_0$
HPFA, HPNA, HBNA and HPNCO : $T_0$ starts when the target enters the steady state distance (0.5 s after EPT acceleration phase). For VUT, $T_0$ = TTC 4.0 s	
$T_{AEB}$ , time when AEB activates	$T_{AEB}$
$T_{FCW}$ , time when FCW activates	$T_{FCW}$
$T_{impact}$ , time when VUT impacts the target	$T_{impact}$
Position of the VUT during the entire test	$X_{VUT}, Y_{VUT}$
Position of the target during the entire test	$X_{EPT} / X_{EBT}$ $Y_{EPT} / Y_{EBT}$
Speed of the VUT during the entire test	$V_{VUT}$
$V_{impact}$ , speed when VUT impacts the target	$V_{impact}$
$V_{rel\_impact}$ , relative speed when VUT impacts the target	$V_{rel\_impact}$
Speed of the target during the entire test	$V_{EPT} / V_{EBT}$
Acceleration of the VUT during the entire test	$A_{VUT}$
Yaw velocity of the VUT during the entire test	$\dot{\Psi}_{VUT}$
Steering wheel velocity of the VUT during the entire test	$\Omega_{VUT}$

#### 3.2 Measuring Equipment

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

- VUT and target speed to 0.1 km/h
- VUT and target lateral and longitudinal position to 0.03 m
- VUT heading angle to 0.1 °
- VUT and target yaw rate to 0.1 °/s
- VUT and target longitudinal acceleration to 0.1 m/s<sup>2</sup>
- VUT steering wheel velocity to 1.0 °/s

#### 3.3 Data Filtering

Filter the measured data as follows:

- Position and speed are not filtered and are used in their raw state
- Acceleration, yaw rate, steering wheel velocity and force are filtered with a 12-pole phaseless Butterworth filter with a cut off frequency of 10 Hz

## 4 TARGET SYSTEMS

### 4.1 Euro NCAP Pedestrian and Bicyclist targets

Conduct the tests in this protocol using the Euro NCAP Pedestrian Target (EPTa and EPTc) and Euro NCAP Bicyclist and bike Target (EBT) dressed in a black shirt and blue trousers, as shown in Figure 4-1. The EPT and EBT replicate the visual, radar, LIDAR and PMD attributes of a typical pedestrian and bicyclist respectively and is impactable without causing significant damage to the VUT.



Figure 4-1 Euro NCAP Pedestrian Target (adult and child) and Bicyclist and bike Targets (EPTa, EPTc and EBT)

To ensure repeatable results, the propulsion system and VRU target must meet the requirements as detailed in ISO 19206 Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions:

- Part 2:2018: Requirements for pedestrian targets (articulated targets only)
- Part 4:2018: Requirements for bicyclist target

The EPT and EBT are designed to work with the following types of sensors:

- Radar (24 and 76 to 81 GHz)
- LIDAR
- Camera
- Ultrasonic sensors

When a manufacturer believes that the EPT or EBT 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.

## 5 SYSTEM PERFORMANCE DATA

### 5.1 Pedestrian and Bicyclist Crossing and Longitudinal

The vehicle manufacturer is requested to provide the Euro NCAP Secretariat with colour data (expected impact speeds are not required) detailing the AEB performance of the VUT in the pedestrian and bicyclist test scenarios.

All data should be supplied by the manufacturer before any testing begins, preferably with delivery of the test vehicle(s).

Data should be provided for each test scenario and test speed according to the colour scheme in Figure 5-1 for HPFA-50, HPNA-25, HPNA-75 and HBNA-50, Figure 5-2 for HPLA-25 and HPLA-50 and Figure 5-3 for HBLA-25 and HBLA-50.

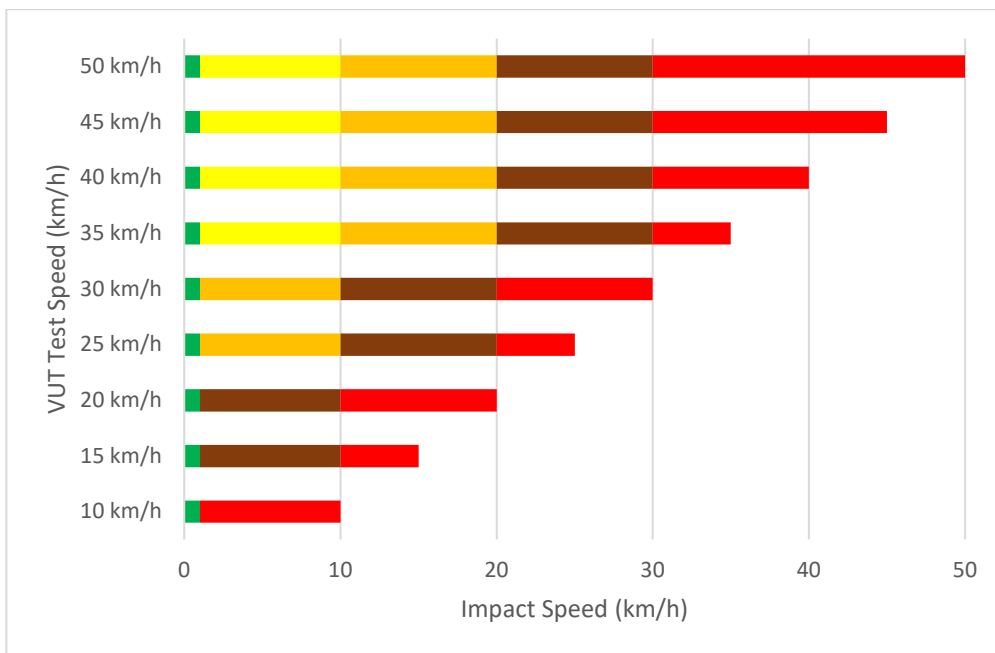


Figure 5-1 HPFA-50, HPNA-25, HPNA-75 and HBNA-50 predicted performance

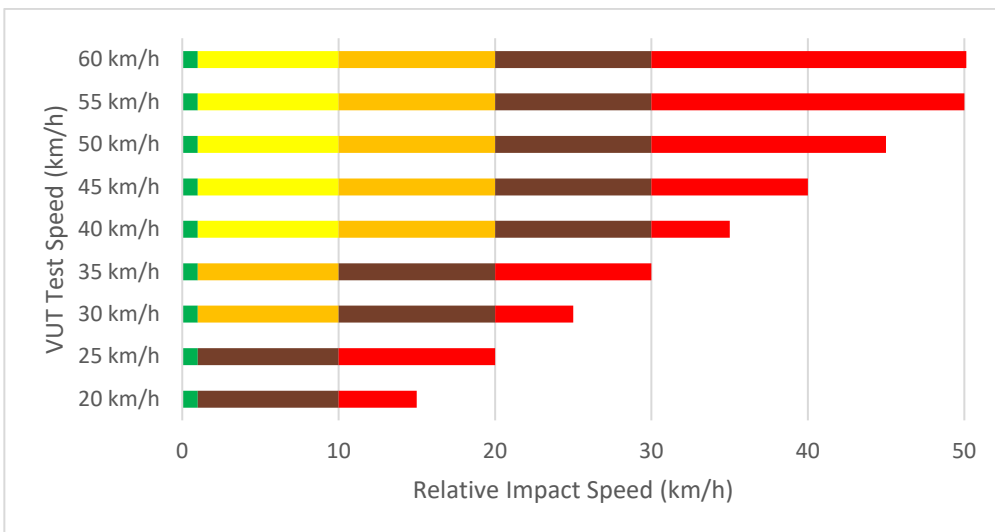


Figure 5-2 HPLA-25 and HPLA-50 predicted performance

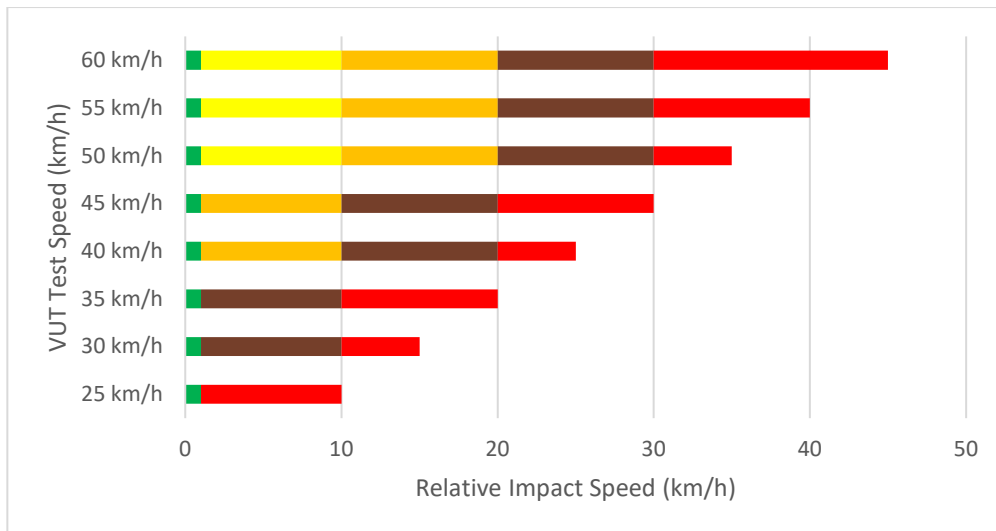


Figure 5-3 HBLA-25 and HBLA-50 predicted performance

Data should also be provided illustrating the anticipated FCW timing for HPLA-25 and HBLA-25.

### 5.1.1 Bicyclist Near Side Turn

For HBNtap data should be provided for each trajectory and impact position combination illustrating the anticipated outcome in terms of:

VUT collision with VRU

- Avoided (green)
- Mitigated to reduced impact speed (orange)
- No pre-collision speed reduction (red)

In case of collision, post-collision response

- Overrun avoided (green)
- No post-collision speed reduction (red)

## 6 TEST CONDITIONS

### 6.1 Test Track

#### 6.1.1 Paved Surface

Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a maximum slope of 1 % in the longitudinal direction, < 2 % for half a lane width either side of the centreline and < 3 % for the outer half of the test lane in lateral direction.

The test surface shall have a minimal peak braking coefficient (PBC) of 0.9, must be paved and may not contain any irregularities (e.g. large dips or cracks, manhole covers or reflective studs) within a lateral distance of 3.0 m to either side of the centre of the test lane and with a longitudinal distance of 30 m ahead of the VUT from the point after the test is complete.

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 5.0 m either side. Lines or markings may cross the test path but may not be present in the area where AEB activation is expected.

#### 6.1.2 Junction and Lane Markings

HBNTap scenarios described in this document require the use of a junction, where this is the case the scenario description will illustrate the scenario on a junction as in Figure 6-1. The main approach lane where the VUT path starts, (horizontal lanes in Figure 6-1) will have a width of 3.5m. The side lane (vertical lanes in Figure 6-1) will have a width of 3.25 to 3.5 m. The lane markings on these lanes need to conform to one of the lane markings as defined in UNECE Regulation 130:

- Dashed line starting at the same point where the radius transitions into a straight line with a width between 0.10 and 0.15 m
- Solid line with a width between 0.10 and 0.25 m
- Junction without any central markings

Note that all dimensions reference the centre of the lane markings.

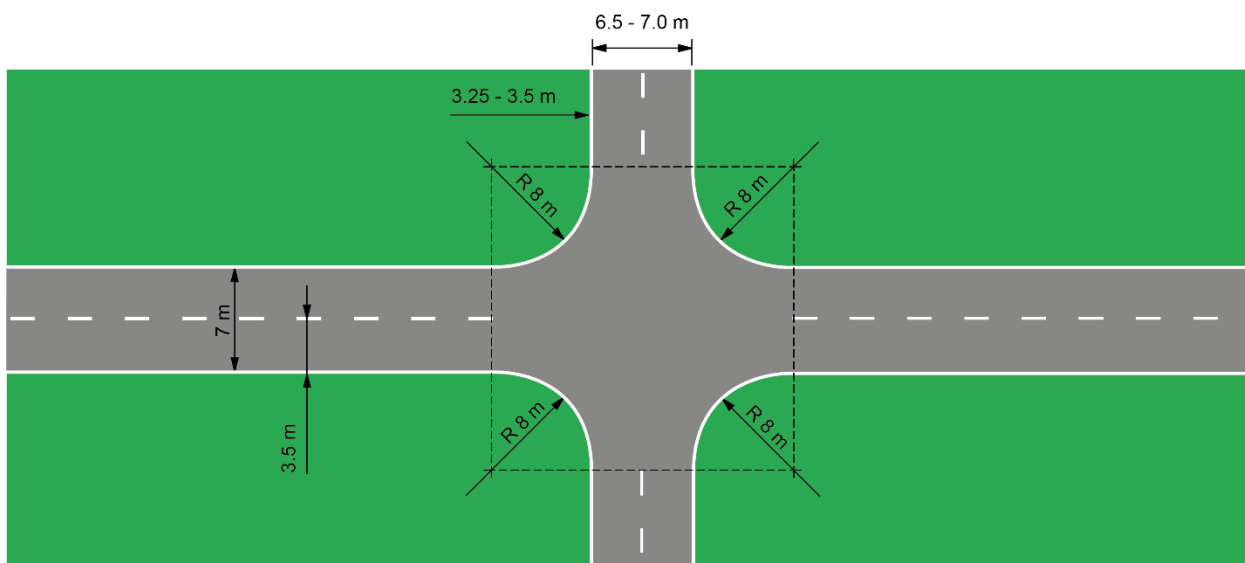


Figure 6-1 Layout of junction and the connecting lanes

### 6.1.3 Weather Conditions

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

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

Natural ambient illumination must be homogenous in the test area and in excess of 2,000 lux for daylight testing with no strong shadows cast across the test area other than those caused by the VUT or GVT. Ensure testing is not performed driving towards, or away from the sun when there is direct sunlight.

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

- Ambient temperature in °C
- Track Temperature in °C
- Wind speed in m/s
- Wind direction in azimuth ° and/or compass point direction (monitoring)
- Ambient illumination in Lux

### 6.1.4 Surroundings

Conduct testing such that there are no other vehicles, highway infrastructure, obstructions (except where detailed in the test scenario), other objects or persons protruding above the test surface, that may give rise to abnormal sensor measurements within:

- 5 m either side of the VUT test path during the full duration of the test and within a longitudinal distance 20 m ahead of the VUT when the test ends,
- a circle of 2 m radius around the VRU target, and
- the visual axis between the geometric centre of the VUT and the circle surrounding the VRU target as illustrated in Figure 6-2.

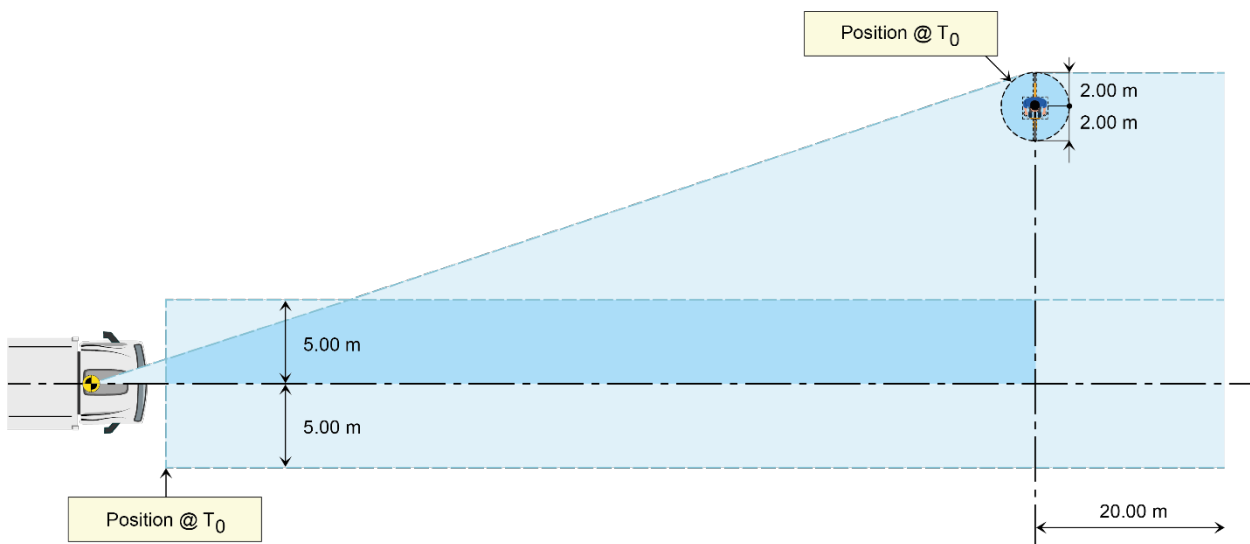


Figure 6-2 Free space requirements



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

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.

## 6.2 VUT Preparation

### 6.2.1 System Settings

Set any driver configurable elements of the system to the middle setting or midpoint and then next latest setting similar to the examples shown in Figure 6-3.

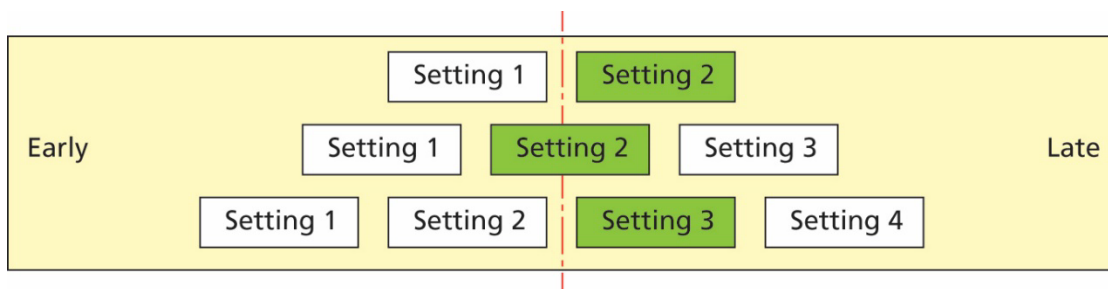


Figure 6-3 System setting for testing

### 6.2.2 Deployable Pedestrian/VRU Protection Systems

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

### 6.2.3 Drawing Vehicles

Where the VUT is designed as a prime mover intended for drawing a trailer, complete testing with the VUT coupled to an appropriate trailer of the following specification:

- Of length approaching but not exceeding maximum permitted
- Of adequate gross trailer mass to fulfil the gross train mass of the VUT
- Box or curtain side body
- Equipped with disc brakes, category A Antilock Braking System (ABS) and an Electronic Braking System (EBS)

### 6.2.4 Tyres

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 the manufacturer's instructions for the appropriate loading 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.

### 6.2.5 Running Order

Confirm that all VUT safety and operational systems are functioning correctly with no warning messages or indicators displayed to the driver. Rectify any faults before commencing testing.

Set any configurable driving controls to their automatic setting e.g. ride height setting. If an automatic setting is not available, set to a middle setting.

When driven on the test track with the steering control centrally aligned, ensure the VUT exhibits good straight line driving order. In case of unsatisfactory driving order, the test laboratory should undertake remedial work to return the geometry to within the OEM tolerances and confirm good driving order.

### 6.2.6 Loading and Vehicle Preparation

Complete testing with the VUT half laden to represent typical category N vehicle operation, with 'as tested' mass as follows:

$$\text{As tested mass} = \text{Unladen kerb mass} + ((\text{GVW} - \text{Unladen kerb mass})/2)$$

The procedure to prepare the VUT load requirement for testing is:

- Maintain adequate fuel in the vehicle to perform the testing
- Check the levels of all fluids and top up to their maximum levels if necessary
- Ensure that the VUT has all its bodywork and spare wheel on board, if fitted, along with any equipment or tools supplied. Nothing else should be in the VUT
- Ensure that all tyres are inflated according to the manufacturer's instructions for the appropriate loading condition
- Measure the VUT axle masses and determine the total mass. The total mass is the 'unladen kerb mass' of the VUT. Record this mass in the test details
- Calculate the load mass required to achieve the 'as tested mass'. Note the 'as tested mass' will also account for nominal half fuelling where the fuel source affects the vehicle mass
- Apply the load mass to the vehicle comprising of the driver, test equipment (i.e. on-board test equipment and instrumentation, associated cables, cabling boxes and power sources) and ballast, with a tolerance of the lesser of [5% of the GVW or 1000kg]. Locate the centre of mass of the ballast centrally within the cargo space (longitudinally and laterally) as far as is as practically possible. Ballast must be securely attached to the VUT. If water is used as ballast, it should be used in full containers to prevent the movement under acceleration
- Measure the VUT axle masses with the driver, test equipment and ballast on board and determine the 'as tested mass', confirming that individual axle weights do not exceed their permitted maximums

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

## 7 TEST PROCEDURE

### 7.1 VUT Pre-test Conditioning

#### 7.1.1 General

A new vehicle is used as delivered to the test laboratory, however a vehicle may have been used for other Euro NCAP active safety tests.

If requested by the vehicle manufacturer and where not already performed for other tests, drive a maximum of 100 km 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

Condition the vehicle's brakes in the following manner (if it has not been done before for another test or in case the laboratory has not performed 100 km of driving) to ensure they are neither brand new nor corroded. Before commencing the next brake conditioning run, confirm the temperature of the hottest brake rotor is less than [400] °C, or wait [120] seconds between runs to prevent brake overheating.

- Perform ten stops from a speed of 56 km/h with an average deceleration of approximately [0.2 to 0.3 g]
- Immediately following the series of 56 km/h stops, perform three additional stops from a speed of 72 km/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 72 km/h stops, drive the vehicle at a speed of approximately 72 km/h for five minutes to cool the brakes

#### 7.1.3 Tyres

Condition the vehicle's tyres in the following manner (if it has not been done before for another test or in case the laboratory has not performed 100 km of driving) to remove the mould sheen.

- Drive around a circle of [30 m] in diameter at a speed sufficient to generate a lateral acceleration of approximately [0.1 to 0.2 g] for three clockwise laps followed by three anticlockwise laps
- Immediately following the circular driving, drive four passes at 56 km/h, performing ten cycles of a sinusoidal steering input in each pass at a frequency of 1 Hz and amplitude sufficient to generate a peak lateral acceleration of approximately [0.1 to 0.2 g]
- Make the steering wheel amplitude of the final cycle of the final pass double that of the previous inputs

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 System Check

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 General

The performance of the AEB VRU system is assessed in a range of pedestrian and bicyclist crossing and longitudinal scenarios and VUT near side turning scenarios.

For all testing scenarios except HBNTap, 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.

See 7.2.6 for HBNTap and trajectory coordinates illustrated in ANNEX B.

In case of the maximum vehicle speed being less than 90 km/h, the laboratory must test up to the maximum vehicle speed with a tolerance of -2 km/h.

### 7.2.2 Pedestrian Crossing and Longitudinal

For AEB Pedestrian the scenarios HPFA-50, HPNA-25, HPNA-75, HPNCO-50 and HPLA are considered as shown in Figure 7-1, Figure 7-2, Figure 7-3 and Figure 7-4 respectively.

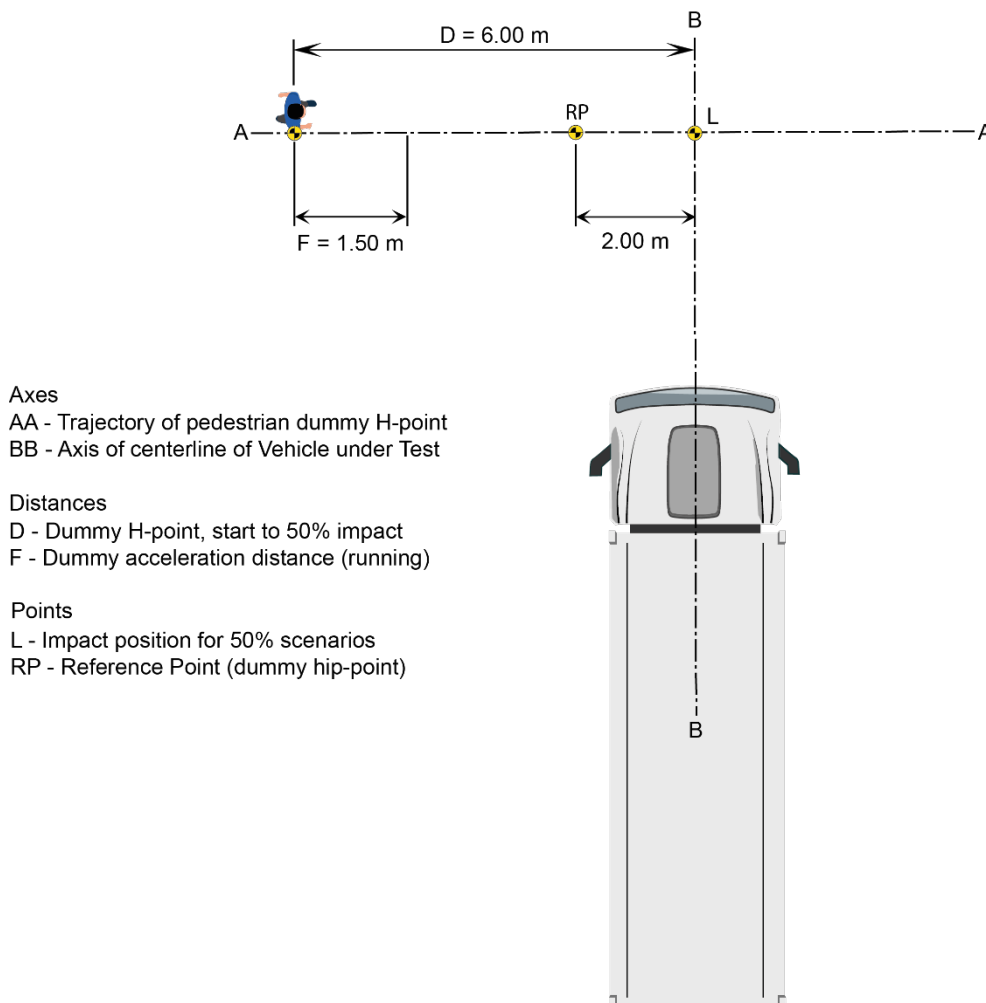


Figure 7-1 HPFA-50 scenario, running adult from far side

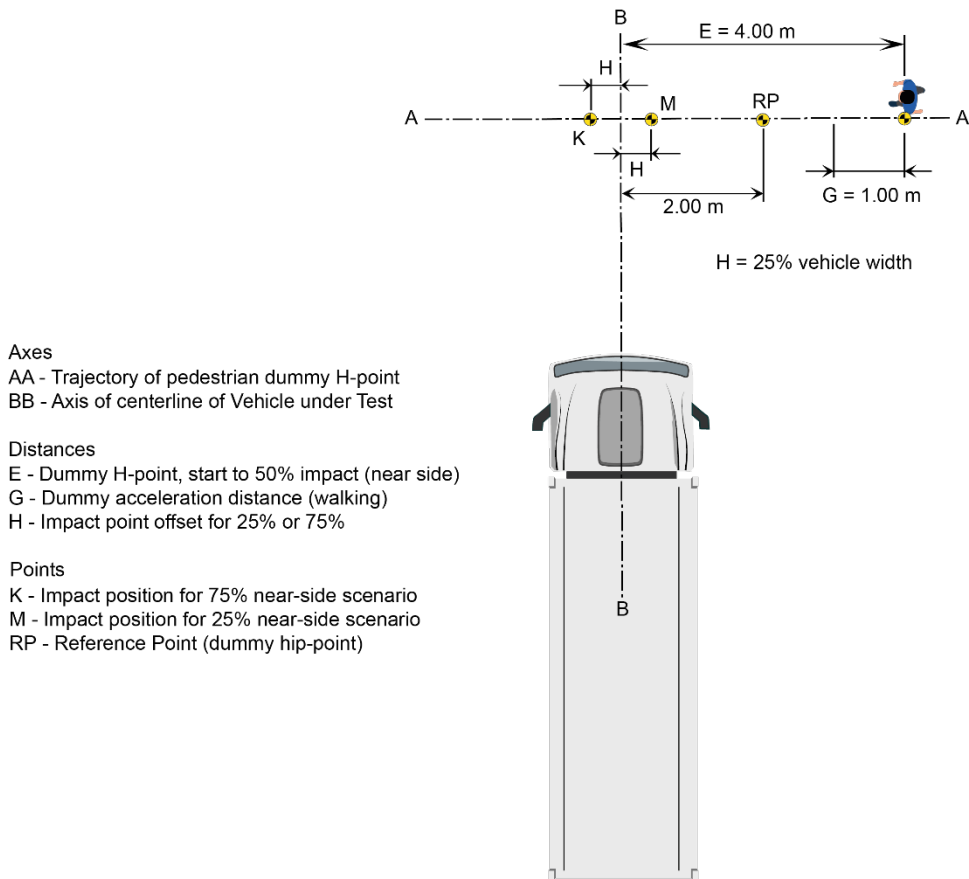


Figure 7-2 HPNA-25 & HPNA-75 scenarios, walking adult from near side

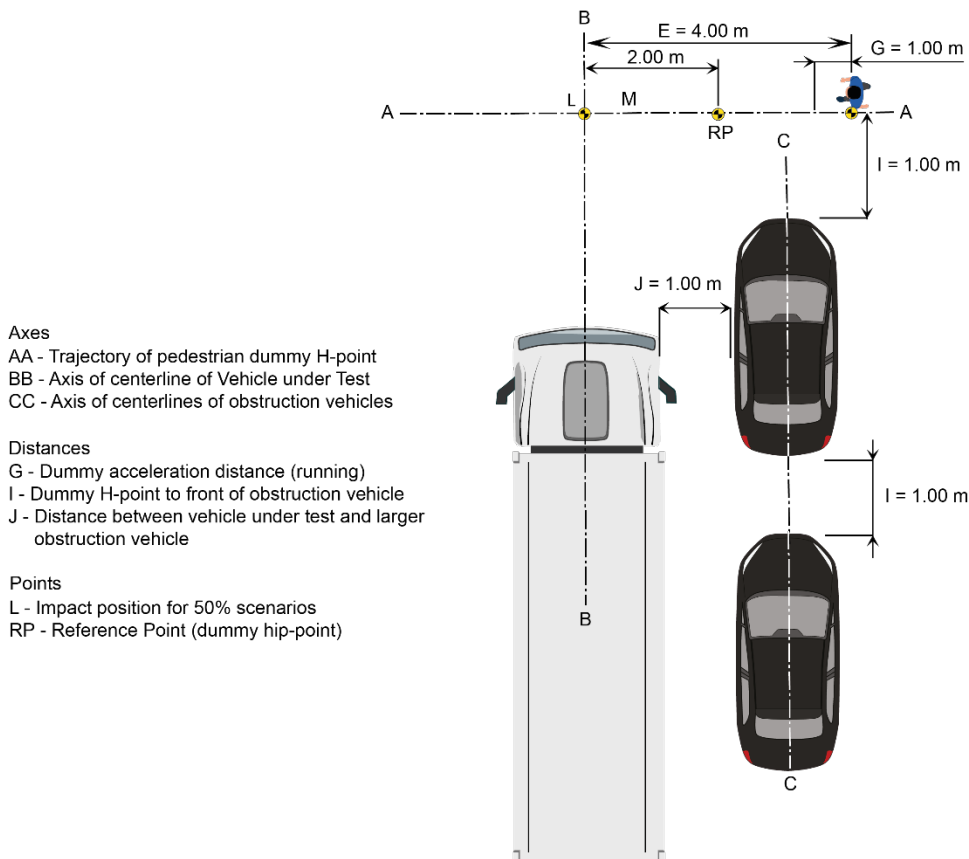


Figure 7-3 HPNCO-50 scenario, running child from near side from obstruction vehicles (see Annex A)

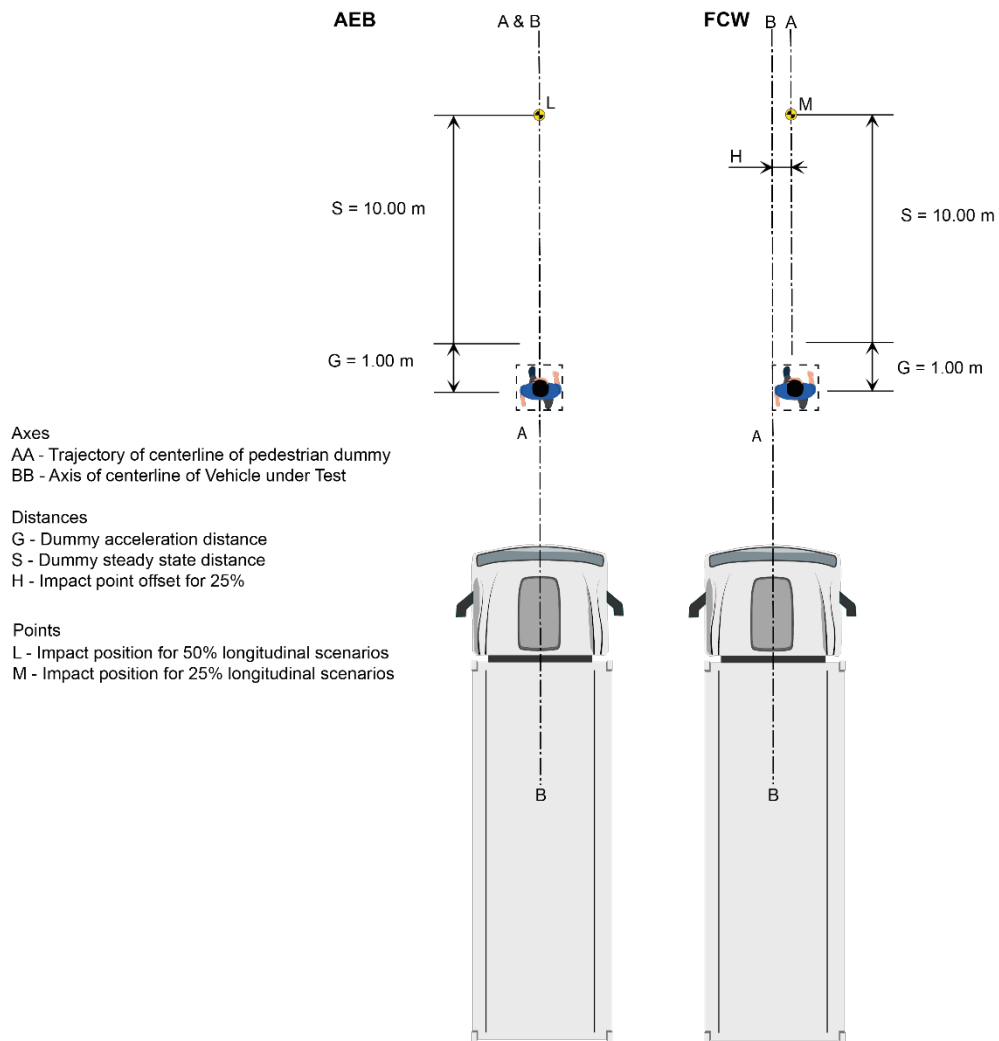


Figure 7-4 HPLA scenario, longitudinal walking adult (HPLA-50 AEB left and HPLA-25 AEB & FCW right)

All tests will be performed with 5 km/h incremental steps within the speed ranges as summarised in Table 7-1.

HGV AEB Pedestrian								
	HPFA-50	HPNA-25	HPNA-75	HPNCO-50	HPLA-25	HPLA-50	HPLA-25	
<b>Type of test</b>	AEB						FCW	
<b>VUT speed</b>	10-50 km/h			20-60 km/h			50-90 km/h	
<b>Target speed</b>	8 km/h			5 km/h				
<b>Impact location</b>	50 %	25 %	75 %	50 %	25 %	50 %	25 %	
<b>Lighting condition</b>	Day							

Table 7-1 AEB pedestrian crossing and longitudinal test configurations

In case of the maximum vehicle speed being less than 90 km/h, the laboratory must test up to the maximum vehicle speed with a tolerance of -2 km/h.

For the HPNA-75 scenario the following additional tests are performed as part of the prerequisite verification:

- Test speed of 20km/h with an EPTa speed of 3 km/h
- Test speed of 10km/h (or minimum idle speed in 1st gear) with an EPTa speed of 5 km/h

### 7.2.3 Bicyclist Crossing and Longitudinal

For AEB Bicyclist the HBNA and HBLA scenarios are considered as shown in Figure 7-5 and Figure 7-6.

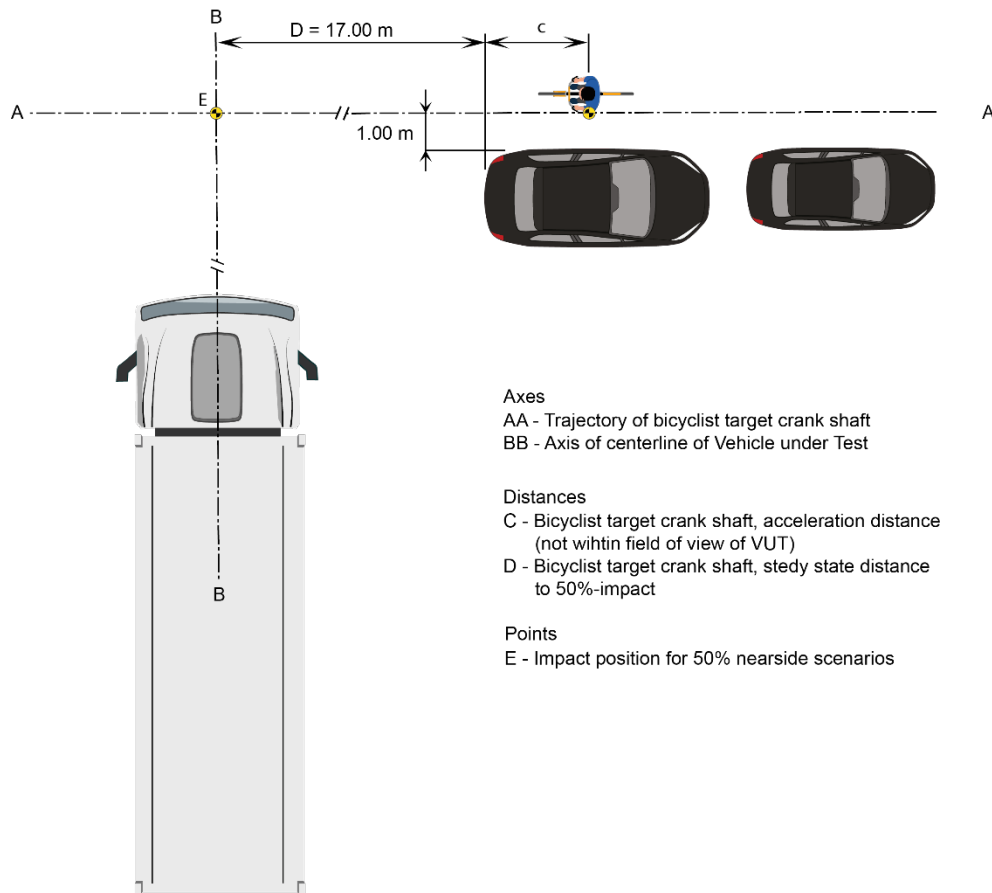


Figure 7-5 HBNA scenario, bicyclist from near side



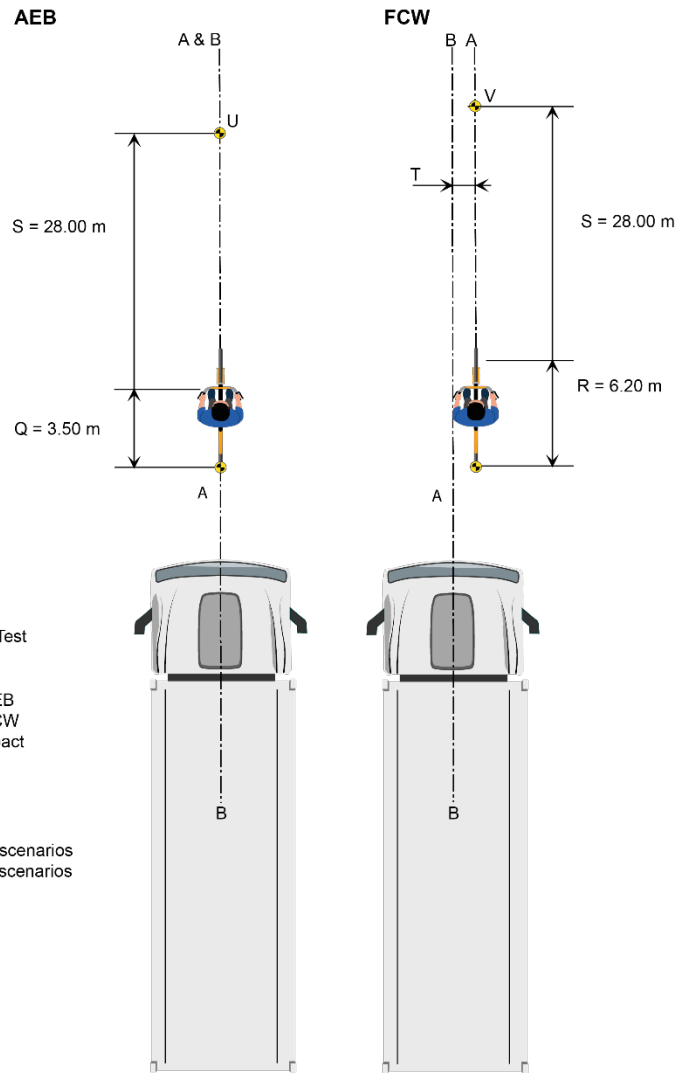


Figure 7-6 HBLA scenarios, longitudinal bicyclist (HBLA-50 AEB left and HBLA-25 AEB & FCW right)

All tests will be performed with 5 km/h incremental steps within the speed ranges as summarised in Table 7-2.

HGV AEB Bicyclist				
	HBNA-50	HBLA-25	HBLA-50	HBLA-25
<b>Type of test</b>	AEB		FCW	
<b>VUT speed</b>	10 to 50 km/h	25 to 60 km/h	50 to 90 km/h	
<b>Target speed</b>	15 km/h		20 km/h	
<b>Impact location</b>	50 %	25 %	50 %	25 %
<b>Lighting condition</b>	Day			

Table 7-2 AEB bicyclist crossing and longitudinal test configurations

### 7.2.4 Bicyclist Near Side Turn

For this scenario, the desired path and desired speed of the VUT are given as per trajectory “A”, “B”, “C” or “D”, detailed in Annex II. The bicycle dummy EBT shall be synchronized so that its’ reference point impacts the relevant impact point on the VUT.

	HGV AEB Bicyclist			
	HBNTap Borrow from source	HBNTap Large turn radius	HBNTap Short vehicle	HBNTap Borrow from destination
<b>Type of test</b>	AEB			
<b>VUT configuration</b>	With semitrailer, if relevant	With semitrailer, if relevant	Without semitrailer, if relevant	With semitrailer, if relevant
<b>VUT speed and path</b>	Trajectory “A” to be driven by centre of front axle	Trajectory “B” to be driven by centre of front axle	Trajectory “C” to be driven by centre of front axle	Trajectory “D” to be driven by centre of front axle
<b>Target speed</b>	15 km/h			
<b>Impact location</b>	0m and 3m (reference points “0m” and “3m”)			
<b><math>d_{lat}</math></b>	1.5 m			
<b>Lighting condition</b>	Day			

Table 7-3 AEB bicyclist crossing and longitudinal test configurations

The reference points on vehicle and dummy are shown in Figure 7-7, the test layout in Figure 7-8.

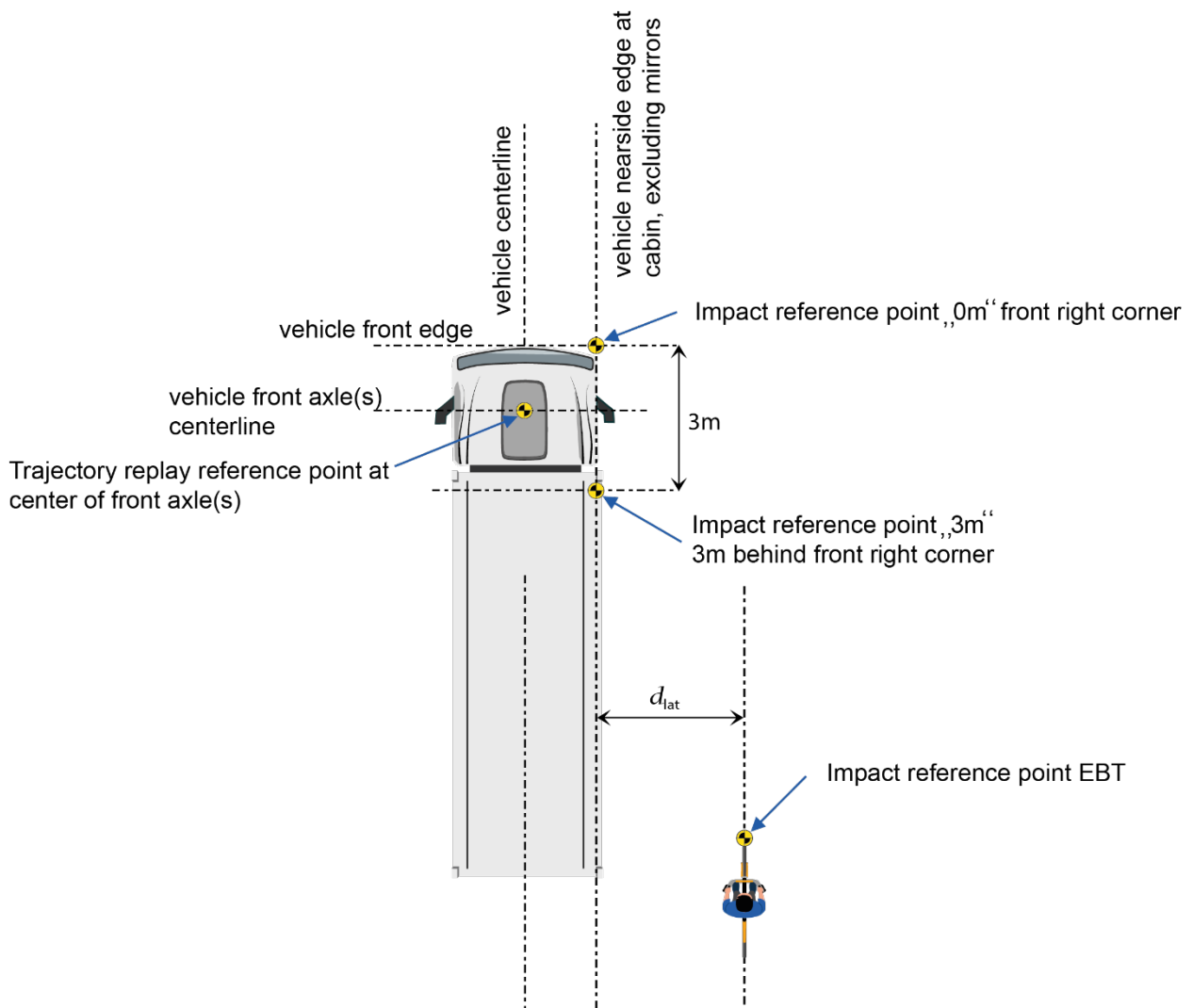


Figure 7-7 Reference points on vehicle under test VUT and bicycle dummy EBT

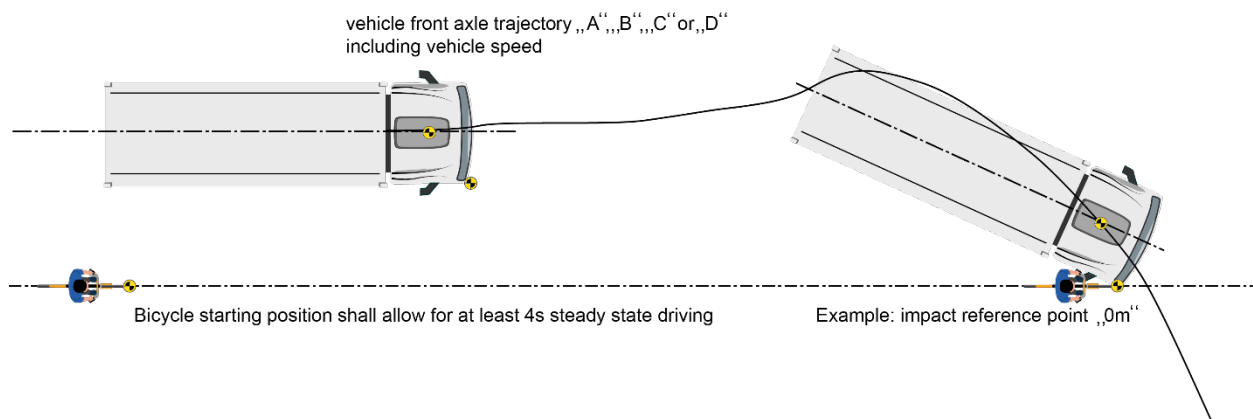


Figure 7-8 Test layout

## **7.3 Test Conduct**

### **7.3.1 General**

Before every test run, drive the VUT around a full circular path, 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.

Before commencing the next test run, confirm the temperature of the hottest brake rotor is less than 150 °C. It is acceptable to wait for brake cooling to occur between test runs. Forced cooling is permitted with ambient air only.

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

### **7.3.2 Pedestrian and Bicyclist Crossing and Longitudinal**

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 [1000] at the test speed. If fitted, a speed limiting device or cruise control may be used to maintain the VUT speed (not ACC), unless the vehicle manufacturer shows that there are interferences of these devices with the AEB system in the VUT. Apply only minor steering inputs as necessary to maintain the VUT tracking along the test path.

### **7.3.3 Bicyclist Near Side Turn**

For vehicles with an automatic transmission select D. For vehicles with a manual transmission shift through gears as necessary to maintain an RPM of at least [1000] throughout the trajectory speed profile. Apply steering, accelerator and brake inputs as necessary to follow the trajectory path and speed.

## 7.4 Test Execution

Accelerate the VUT and EPT or EBT to their respective test speeds on their appropriate test paths.

The test shall start at  $T_0$  (4 s TTC or start of trajectories for HBNtap) and is valid when all boundary conditions are met between  $T_0$  (for CPLA & CBLA-AEB  $T_0 - 1$  s) and  $T_{AEB}$  and/or  $T_{FCW}$ , or any other system intervention:

-	Speed of VUT (GPS-speed)	
	• Crossing and longitudinal scenarios	Test speed + 1.0 km/h
	• Near side turn scenario	Trajectory speed $\pm$ 3.0 km/h
-	Speed of EPT during steady state	$\pm$ 0.2 km/h
-	Speed of EBT during steady state	$\pm$ 0.5 km/h
-	Lateral deviation from test path for VUT	
	• Crossing and longitudinal scenarios	$0 \pm [0.10]$ m
	• Near side turn scenario	$0 \pm [0.50]$ m
-	Lateral deviation from EPT and EBT test path	
	• Crossing scenarios	$0 \pm 0.05$ m
	• Longitudinal scenarios	$0 \pm 0.15$ m
	• Lateral velocity	$0 \pm 0.15$ m/s
-	Yaw velocity of VUT	
	• Crossing and longitudinal scenarios	$0 \pm 1.0$ °/s
-	Steering wheel velocity	
	• Crossing and longitudinal scenarios	$0 \pm 15.0$ °/s
-	Start of steady state	
	• EPT near side	3.0 m from VUT centreline
	• EPT longitudinal	10.0m from VUT impact point
	• EBT near side	17.0 m from VUT centreline
	• EBT longitudinal	28.0 m from VUT impact point
	• HBNtap	18.0 m from VUT impact point

The end of a test, where the AEB function is assessed, is considered when one of the following occurs:

- $V_{VUT} = 0$  km/h (crossing) or  $V_{VUT} = V_{EPT/EBT}$  (longitudinal)
- Contact between VUT and EPT or EBT plus [2] seconds to observe the post-collision VUT response ( $T_{impact} + 2.0$  s)
- EPT or EBT has left the VUT path or VUT has left the EPT or EBT path

For tests where the FCW function is assessed, the end of a test is considered when one of the following occurs:

- $V_{VUT} = 0$  km/h (crossing) or  $V_{VUT} = V_{EPT/EBT}$  (longitudinal)
- $T_{FCW} < 1.7$  s TTC, after which an evasive action can be started

For manual or automatic accelerator control, it needs to be assured that during automatic braking the accelerator pedal does not result in an override of the system. There shall be no operation of other driving controls during the test e.g. clutch or brake pedal.

#### **7.4.1 Pedestrian and Bicyclist Crossing and Longitudinal**

For AEB systems tests, when there is complete avoidance (if applicable, test results below 20 km/h may be ignored), the subsequent test speed for the next test is incremented with 10 km/h. When there is contact, first perform a test at a test speed 5 km/h less than the test speed where contact occurred. After this test continue to perform the remainder of the tests with speed increments of 5 km/h.

For tests above 20 km/h, stop testing when the manufacturer predicts no performance. In the tests above 40 km/h, stop testing when the speed reduction seen in the test is less than 5k m/h, or the relative impact speed is greater than 20 km/h for two consecutive test speeds.

For FCW systems tests, when the FCW is issued before 2.2 s TTC, the subsequent test speed for the next test is incremented with 10 km/h. When the FCW is issued after 2.2 s TTC, first perform a test at a test speed 5km/h less than the test speed where this occurred. After this test continue to perform the remainder of the tests with speed increments of 5 km/h.

Stop testing when the manufacturer predicts that the FCW is not issued before 1.7 s TTC.

Where the predicted speed reduction in the tests above 40 km/h is at least 20km/h (sufficient to score points), but the actual speed reduction measured in the test is between 15 and 20 km/h, the test shall be repeated a further two times and the middle value will be used in the assessment.

In case FCW triggers between 1.7 and 2.2 s TTC, the test shall be repeated a further two times and the middle value will be used in the assessment.

#### **7.4.2 Bicyclist Near Side Turn**

Test each trajectory and impact position combination except those marked red in the manufacturer system performance data.

## APPENDIX A OBSTRUCTION DIMENSIONS

### A.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

### A.2 Larger obstruction vehicle

The larger obstruction vehicle should be of the category Small Off-road 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

## APPENDIX B NEAR SIDE TURN TRAJECTORIES

The VUT trajectories used for HBNTap testing scenarios are recording of actual HGV test drives navigating the intersection. Raw data can be downloaded from [www.euroncap.com](http://www.euroncap.com). Note that trajectories are only relevant for  $x > -40$  m up to  $y < -20$  m and the origin lies at the centre of the Euro NCAP intersection layout.

The paths are shown in Figure B-1 and the speeds in Figure B-2

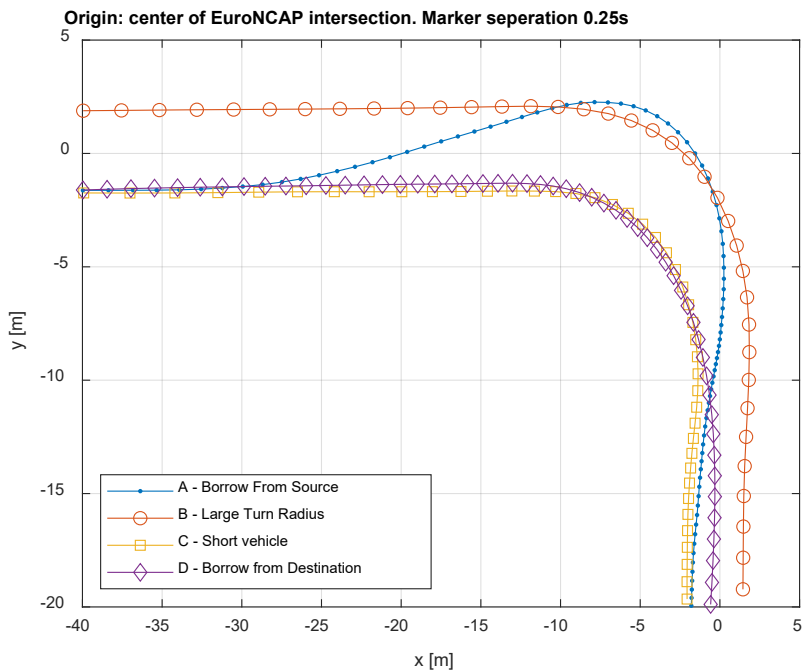


Figure B-1 HBNTap trajectory paths

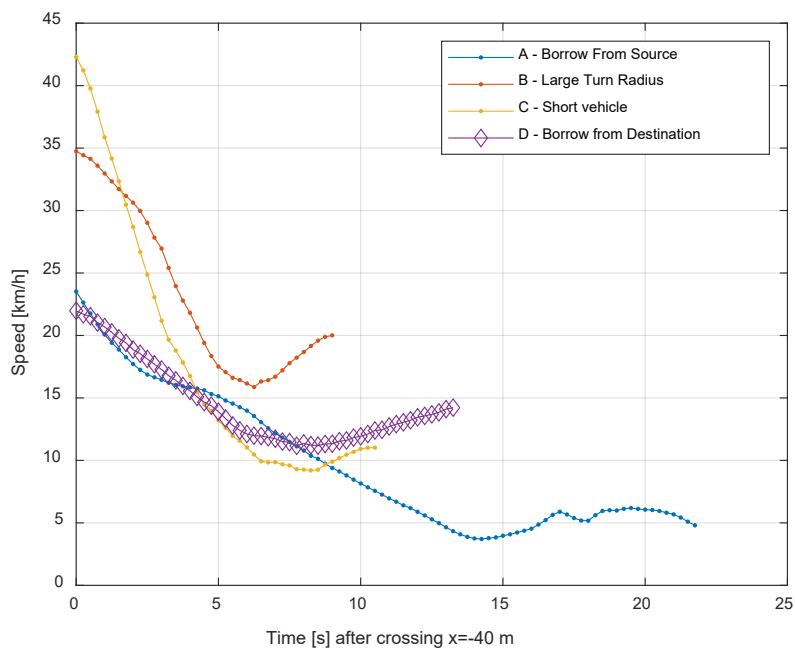


Figure B-2 HBNTap trajectory speeds