LONDON BUS SERVICES LIMITED

Specification for new buses: Attachments

Version 2.1

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1 Preface

This protocol covers the assessments to be carried out for safety features fitted to Transport for London (TfL) buses.

Where an Original Equipment Manufacturer (OEM) perceives that a particular feature should be changed, this should be raised by the OEM with the competent authority (TfL) assessor present at the assessment, or in writing to the competent authority (TfL) Nominated Officer in the absence of an assessor. The competent authority (TfL) will assess the problem based on their judgment and provide instruction to the relevant Test Service/s.

OEMs are barred from directly or indirectly interfering with the assessment and prohibited from altering any characteristics that may impact the assessment, including but not restricted to vehicle setting, laboratory environment, etc.

2 Disclaimer & Copyright

TfL has taken all appropriate caution to guarantee that the information contained in this protocol is correct and demonstrates the prevailing technical decisions taken by the organisation. In the occasion that a mistake or inaccuracy is identified, TfL retains the right to make amendments and decide on the assessment and future outcome of the affected requirement(s).

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Attachment 15: Advanced Emergency Braking (AEB) Assessment Protocol

1 Introduction

Advanced Emergency Braking (AEB) is a system that uses forward looking sensors such as Lidar, Radar, and/or Cameras to identify a risk of an imminent collision.

This document presents an assessment protocol and the underlying test procedures for objectively measuring the performance of Advanced Emergency Braking (AEB).

For full understanding of this Attachment it should be read in conjunction with the Attachment 16: Advanced Emergency Braking (AEB) Guidance Notes and New Bus Specification, Section 4.3.2.

2 Scope

This protocol applies to all new buses intended for service under contract to TfL that are passenger vehicles with a maximum mass exceeding 5 tonnes and a capacity exceeding 22 passengers. The passenger vehicles will be capable of carrying seated but unrestrained occupants and standing occupants. Such vehicles are categorised the Consolidated Resolution on the Construction of Vehicles (R.E.3) as M_3; Class I.

3 Purpose

The purpose of the assessment is to test the ability of an AEB system fitted to a bus to avoid or mitigate collisions with other road users while minimising risks to occupants of the bus from unnecessary brake interventions. It is intended that the assessment generates objective data from a controlled and repeatable test to measure casualty reduction potential in the following collision types and where the bus is moving at a speed between 10 and 60 km/h:

- Frontal collisions with the rear of a stationary vehicle ahead
- Frontal collisions with a pedestrian crossing the road
- Frontal collisions with the rear of pedal cycles travelling in the same direction

The assessment also tests for false positive activation in a manoeuvre where the impact can easily be avoided by steering. Premature activation in situations where a pedestrian about to cross on a collision course with the vehicle, suddenly stops before entering the vehicles path is also assessed.

However, it should be noted that tests for true, false and premature positive activations represent only a small proportion of the real-world events that the systems will encounter in service. For example, it is expected that systems will react in collisions with the rear of any normal road vehicle in the lane ahead but only collisions with cars and bicycles are assessed. Similarly, the false and premature activation tests represent just two of thousands of real world scenarios that might challenge AEB systems. This protocol promotes the functionality that TfL see as reasonably feasible and of most benefit to their objectives but, in isolation, it is insufficient to guarantee excellent system performance at all times in real world service. OEMs should always design systems to perform well in real world service and not only to do well in this test.

This test and assessment protocol may be applied in collaboration with an OEM as a validation of data they provide, or independently as part of a market surveillance activity or any other reason as defined by the Approval Authority.

4 Normative references

The following normative documents, in whole or in part, are referenced in this document and are indispensable for its correct application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 4.3.2
- For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Attachment 16 AEB Test Guidance Notes
- Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- Regulation (EU) 2018/858 of the European Parliament and of the Council of 30th May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC
- UNECE Regulation 107 Uniform provisions concerning the approval of category M_2 or M_3 vehicles with regard to their general construction
- Euro NCAP Test Protocol AEB VRU Systems Version 2.0.1 August 2017
- Euro NCAP Test Protocol AEB Systems Version 1.1 June 2015
- Euro NCAP Test Protocol AEB Systems Version 2.0.1 November 2017
- Articulated Pedestrian Target Specification document version 1.0.
- Bicyclist Target Specification document version 1.0.
- Euro NCAP Technical Bulletin TB025 – Global Vehicle Target Specification for Euro NCAP
- ISO 15037-2 Road vehicles – Vehicle Dynamics Test Methods – Part 2: General conditions for heavy vehicles and buses

5 Definitions

For the purpose of this Protocol:

- **AEB: Advanced Emergency Braking** – Any system that is active at speeds of 10 km/h or more and uses information from sensors to detect an imminent collision and, if the driver fails to take appropriate avoidance action, automatically applies sufficient braking to avoid the collision or at least reduce the collision speed. Different sub-categories of AEB are currently considered:

  AEB bus front to vehicle rear – An AEB system that detects and responds to imminent collisions where the front of the equipped vehicle would collide with the rear of another vehicle directly ahead of it.

  AEB Pedestrian – An AEB system that detects and responds to imminent collisions with pedestrians.

  AEB Cyclist – An AEB system that detects and responds to imminent collisions with pedal cycles and their riders.

- **Approval Authority:** The Approval Authority is the body within TfL that certifies that a bus is approved for use in the TfL fleet and assigns its score under the bus safety standard for use in procurement processes.

- **FCW: Forward Collision Warning** – An audiovisual warning that is provided automatically by the vehicle in response to the detection of a likely collision to alert the driver.

- **OEM: Original Equipment Manufacturer** - The business responsible for the manufacture of the bus being assessed.

- **PBC: Peak Braking Coefficient** – 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.

- **Test Path:** For the bus stop test, the test path is defined by the co-ordinates specified in Appendix A. For all other tests, the test path is a virtual straight-line path equivalent to the centreline of the lane in which the collision occurs.

- **Test Scenario:** An arrangement and movement of vehicles and test equipment that is intended to represent a particular collision type. A range of different test scenarios are referred to in this protocol:

  Bus-to-Car Rear Stationary (BCRS) – A collision in which a bus travels forwards towards another stationary vehicle and the frontal structure of the bus strikes the rear structure of the other vehicle.

  Bus-to-Pedestrian Farside Adult 50% (BPFA-50) – A test scenario representing a collision in which a bus travels forwards towards an adult pedestrian crossing its path running from the farside and the frontal structure of the bus strikes the pedestrian at 50% of the width of the bus when no braking action is applied.

  Bus-to-Pedestrian Nearside Adult 25% (BPNA-25) – A test scenario representing a collision in which a bus travels forwards towards an adult pedestrian crossing its path walking from the nearside and the frontal structure of the bus strikes the pedestrian when it has crossed 25% of the width of the bus when no braking action is applied.

Bus-to-Pedestrian Nearside Adult 75% (BPNA-75) – A test scenario representing a collision in which a bus travels forwards towards an adult pedestrian crossing its path walking from the nearside and the frontal structure of the bus strikes the pedestrian when it has crossed 75% of the width of the bus when no braking action is applied.

Bus-to-Pedestrian Nearside Child 50% (BPNC-50) – A test scenario representing a collision in which a bus travels forwards towards a child pedestrian crossing its path running from behind and obstruction from the nearside and the frontal structure of the bus strikes the pedestrian when it has crossed 50% of the width of the bus when no braking action is applied.

Bus-to-Bicyclist Longitudinal Adult 25% (BBLA-25) – A collision in which a bus travels forwards towards a bicyclist cycling in the same direction in front of the bus where the bus would strike the cyclist at 25% of the width of the bus assuming that no braking or steering is applied in response to any FCW issued.

Bus-to-Bicyclist Longitudinal Adult 50% (BBLA-50) – A collision in which a bus travels forwards towards a bicyclist cycling in the same direction in front of the bus where the bus would strike the cyclist at 50% of the width of the bus when no braking or steering action is applied.

Aborted Crossing Test - A scenario in which a bus travels forwards towards a child pedestrian on a crossing trajectory, walking from the nearside and, prior to the child pedestrian actually entering the path of the bus, the child pedestrian stops.

Bus Stop Test – A scenario in which a bus follows a defined curved path first left then right such that the nearside front corner of the bus passes a stationary adult pedestrian.

- **Test Service**: The organisation undertaking the testing and certifying the results to the Approval Authority.
- **Test Target (TT)**: An item of test equipment accurately representing the characteristics of the relevant road user, as seen by the relevant sensing technologies used by AEB. A range of specific test targets are defined[1]:

EBT: Euro NCAP Bicyclist and Bike Target – Means the bicyclist and bike target as specified in the Euro NCAP Bicyclist Target Specification document version 1.0.

EPTa: Euro NCAP Pedestrian Target – Means the adult pedestrian target with articulating legs as specified in the Euro NCAP Articulated Pedestrian Target Specification document version 1.0.

[1] ISO standards for these test targets are under development and once published should replace the references to the equivalent Euro NCAP standards

EPTc: Euro NCAP Child Target – Means the child pedestrian target as specified in the Euro NCAP Articulated Pedestrian Target Specification document version 1.0.

EVT: Euro NCAP Vehicle Target – Means the car target defined in Annex A of the Euro NCAP AEB Systems test protocol (2015).

GVT: Global Vehicle Target – Means the car target defined in the Euro NCAP Technical Bulletin TB 025.

- **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.
- **Vehicle Under Test (VUT)**: Means the vehicle assessed according to this protocol.

6 Reference system

6.1 Local co-ordinates

A local co-ordinate system (x,y,z) for the VUT shall be defined such that the x-axis points toward the front of the bus, the y-axis towards the left and the z-axis upwards, as shown in Figure 15_1, below.

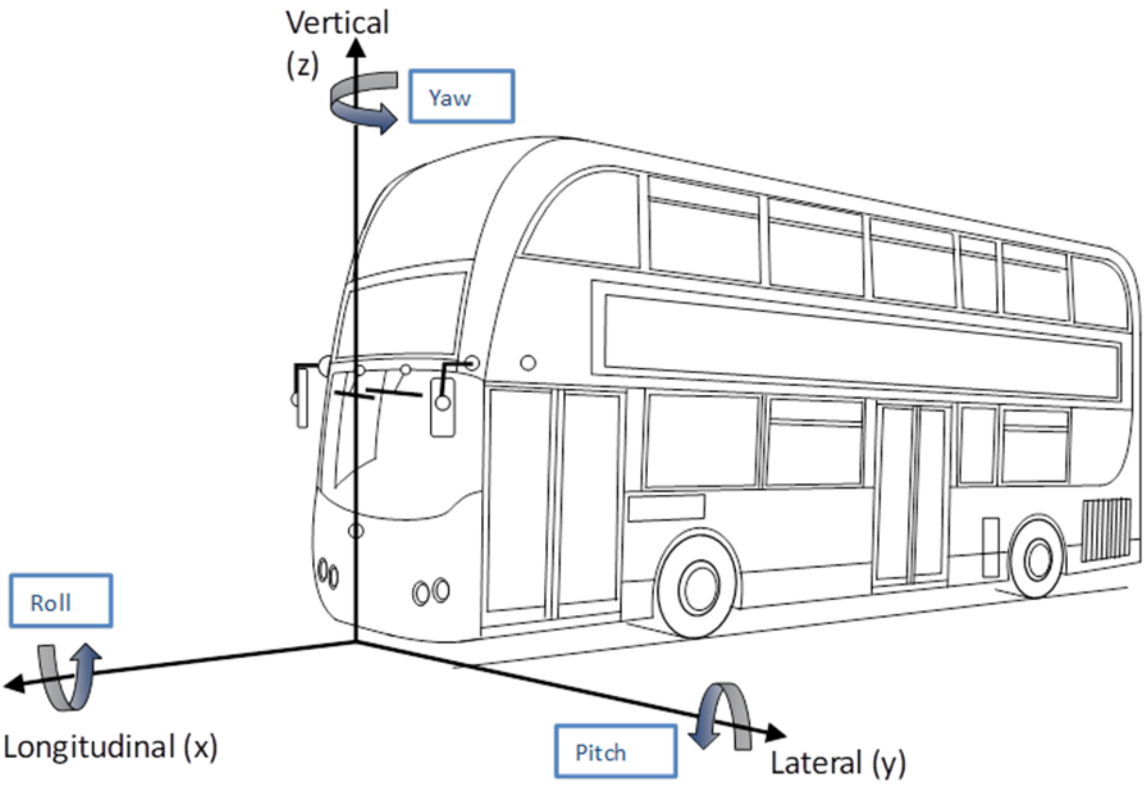


Figure 15_1: Local co-ordinate system and notation

The origin of the co-ordinate system shall lie on the ground plane, on the lateral centre line of the bus at its foremost point (ignoring the rear-view mirrors and windscreen wipers).

6.2 Global co-ordinates

A global co-ordinate system (X, Y, Z) fixed relative to the Earth shall be defined such that the global X-axis is coincident with the local X-axis of the vehicle in its initial starting position. Thus, a VRU travelling perpendicular to the initial direction of the test vehicle would be travelling along the global Y-axis.

7 Measurements and variables

7.1 Variables to be measured

Table 15_1 and Table 15_2 show the variables which must be measured, along with the minimum operating ranges and measurement accuracy required.

Table 15_1: Variables to be measured continuously during each test with minimum operating ranges and measurement accuracy

Variable	Operating range (at least)	Measurement accuracy
Time	24 Hours	GPS Time
Position (global co-ordinates) of the VUT (X_{VUT}, Y_{VUT})	400m in X and 100m in Y	±0.03m
Position (global co-ordinates) of the TT (X_{TT}, Y_{TT})	400m in X and 100m in Y	±0.05m
Speed of the VUT (V_{VUT})	0 km/h to 80 km/h	0.1 km/h
Speed of the TT (V_{TT})	0 km/h to 30 km/h	0.1 km/h
Heading (yaw) angle (Ψ) relative to global X-axis (Ψ_{VUT}, Ψ_{TT})	0˚ to 360˚	0.1˚
Yaw velocity of the VUT (Ψ'_{VUT})	± 50 ˚/s	0.1 ˚/s
Steering wheel velocity of the VUT (Ω'_{VUT})	± 1000 ˚/s	1.0 ˚/s
Pitch angle of the VUT (θ_{VUT})	±45˚	0.1˚
Roll angle of the VUT (ω_{VUT})	±45˚	0.1˚
Acceleration of VUT in local x-axis (A_{VUTx})	± 15 m/s^2	0.1 m/s^2
Acceleration of VUT in local y-axis (A_{VUTy})	± 15 m/s^2	0.1 m/s^2

Acceleration of TT in global y-axis (A_{TTY})	± 15 m/s^2	0.1 m/s^2
FCW Activation (FCW_A)	True/False	N/A

Table 15_2: Variables to be measured before each test with minimum operating ranges and measurement accuracy

Variable	Operating range (at least)	Measurement accuracy
Ambient Temperature	-5˚C to +50˚C	±1˚C
Track Temperature	-5˚C to +50˚C	±1˚C
Wind Speed	0 m/s to 20 m/s	± 0.2m/s
Ambient Illumination	0 lx to 150,000 lx	±10%

7.2 Measuring equipment

Details of the sensors used to measure the required variables shall be recorded in the test report together with the position in which they are installed within the VUT (measured relative to the local co-ordinate system for the test vehicle).

The default equipment to be used shall be a high quality inertial navigation system in combination with differential GPS. Data shall be recorded at a sample rate of 100 Hz. With such equipment, post-sampling digital filtering shall be as follows:

a) Position and speed require no additional digital filtering after data capture;

b) Acceleration and yaw rate shall be filtered with a phaseless digital filter complying with the requirements of ISO 15037-2:2002.

Alternatively, any measuring equipment that can be demonstrated to be compliant with the requirements of ISO 15037-2:2002 is permitted.

In addition to the data recording described above, the VUT shall be equipped with one or more video cameras positioned such that for each and every test, the TT can be clearly seen at the moment of impact, at impact points ranging from 1% to 99% of the vehicle width. A means of accurately synchronising the video feed with the data recordings shall be provided. This camera footage is intended for engineering use only in order to provide a visual reference to allow cross-checking of post-processed data. Camera mounting position, lens type etc. are not considered important for this purpose provided impact position or timing of avoidance can clearly be seen in the resulting footage.

7.3 Variables to be derived from the measurements

7.3.1 General

The variables that shall be calculated from the measured data are defined in Table 15_3.

Table 15_3: Variables to be derived from the measured data

Variable	Description	Definition/Derivation Method
A_{VUT_Long}	VUT Longitudinal Acceleration	The component of A_{VUTx} acting in the horizontal plane, or A_{VUTx} corrected for pitch angle
$A_{PEAK\_VUT\_Long}$	Peak Longitudinal Acceleration of VUT	The largest value of A_{VUT_Long} that occurs between the time T_{AEB} and the end of test
A_{VUT_Lat}	VUT Lateral Acceleration	The component of A_{VUTy} acting in the horizontal plane, or A_{VUTy} corrected for roll angle
T_0	The start of the test	Derived by recording the time T when the measured TTC first drops below 4s
TTC	Time To Collision	For every data point a calculation of the time taken for the VUT to reach the point of impact with the TT based on the current position of each and an assumption that the velocity of each (in the direction of travel of the VUT) remains constant
T_{AEB}	The time at which AEB activates	Find the first data point when the filtered A_{VUT_Long} is -1m/s^2 or larger, then move backwards in time to find the data point where the acceleration first crossed -0.3 m/s^2. The time at this point is T_{AEB}.
T_{FCW}	The time at which FCW activates	The time recorded at the first data point where FCW_A=True, based on recognition of the audible component of the warning. The means of recognition may need to vary depending on the exact system but may, for example, be achieved using a microphone in close proximity to the warning speaker where the signal is filtered with a pass band of 50Hz either side of the measured tone and dB(A) fast weighting applied, and noting the time when the weighted signal exceeds 50dB(A)
T_{Impact}	The time at which the VUT collides with the TT	See section 5.3.2.

Variable	Description	Definition/Derivation Method
V_{Test_VUT}	Nominal initial velocity of VUT before braking applied	Defined by specific test condition
$V_{Test\_VUT\_Act}$	Actual initial velocity of VUT before braking applied	Average of V_{VUT} over the 1 second immediately before T_{AEB}
V_{Rel_Test}	The initial speed of the VUT relative to the initial speed of the TT	Subtract the component of V_{Test_TT} acting in the same direction as the V_{VUT} from. $V_{Test\_VUT\_Act}$
V_{Test_TT}	The initial speed of the TT	Average of V_{TT} between T_0 and T_{AEB}
V_{Impact_VUT}	VUT velocity at the moment that it collides with the Test Target	See section 5.3.2
V_{Impact_TT}	Test Target velocity at the moment that it collides with the VUT	See section 5.3.2
V_{AEB_Red}	The reduction in VUT velocity achieved before impact as a consequence of AEB action	$(V_{Test\_VUT} – V_{Rel\_Impact})/V_{Test\_VUT}$
V_{Rel_Impact}	The relative impact speed between VUT and TT at the moment of impact	Subtract the component of V_{Impact_TT} acting in the same direction as the V_{VUT} from. V_{Impact_VUT}
Y_{Impact_Nom}	Nominal Impact Position on VUT if no braking occurred and V_{TT} remains constant	Locate T_{AEB} in the data file. Move forward in time in the data by the number of data points equivalent to the TTC recorded at the data point corresponding to T_{AEB}. Y_{Impact_Nom} is equal to the value Y_{TT} at this data point (actual for true positive tests, calculated for aborted crossing test).
Y_{Impact_Act}	Actual Impact Position on VUT	If no impact occurred this shall be recorded as not applicable. Where impact was deemed to occur, $Y_{Impact\_Act} = Y_{TT}$ when that impact first occurred.
Y_{VUT_Error}	Lateral path error of	Distance in y-axis between the centreline of

Variable	Description	Definition/Derivation Method
	the VUT	the vehicle at the foremost point of the VUT at the point of impact, and the same point if the VUT had followed its intended straight path.

7.3.2 Determination of impact

Determining whether impact has occurred and, if so, at what time and speed, is undertaken using a virtual method. A virtual profile is defined around the VUT and each TT and related to the point on the VUT/TT that relates to the recording of its position (X_{VUT}, Y_{VUT}, X_{TT}, Y_{TT}). The first data point at which the recorded positions are such that the virtual profile of VUT and TT intersect is defined as the moment of collision. T_{Impact}, V_{Impact_VUT}, and V_{Impact_TT} are defined as the relevant time and speeds recorded at the moment of collision. This is illustrated in Figure 15_2.:

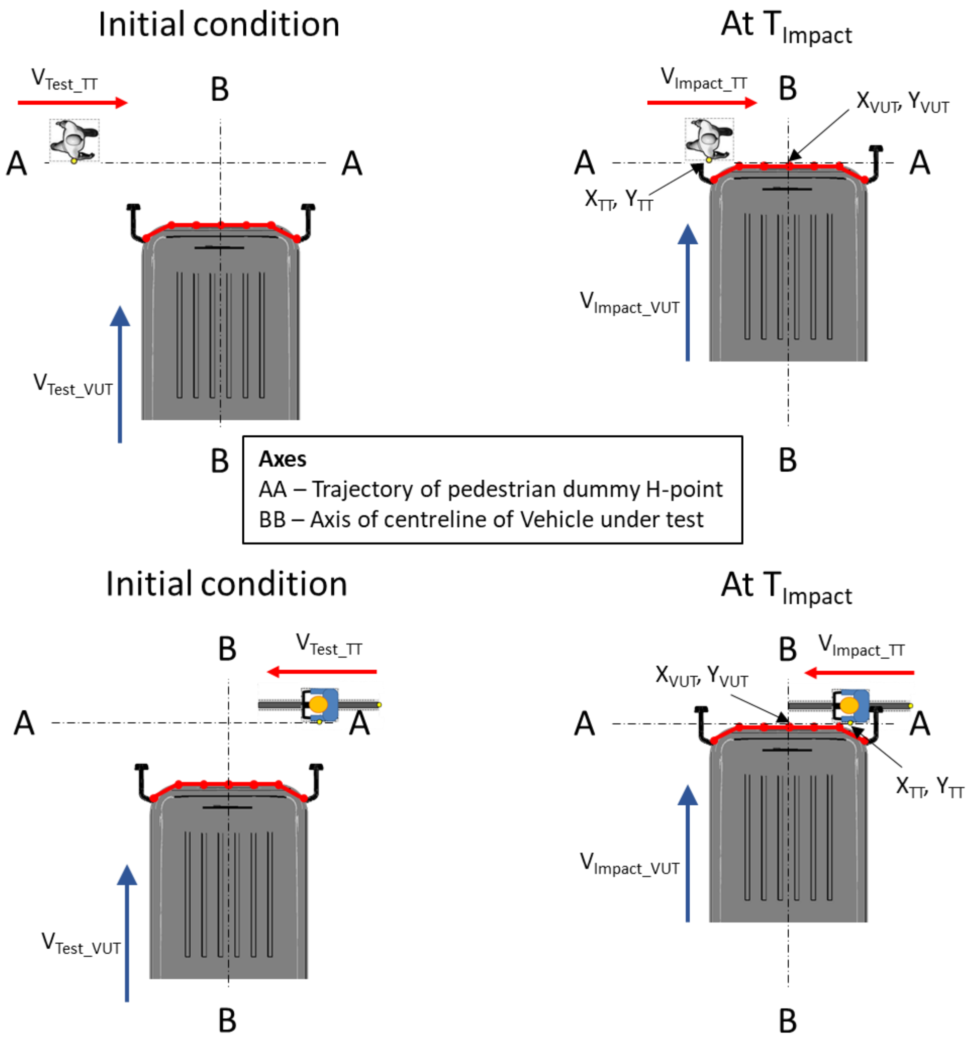


Figure 15_2: Illustration of the definition of the moment of impact (Pedestrian (top), Cyclist (bottom))

For the VUT, the virtual profile is defined around the front end of the vehicle by straight lines connecting seven points that are equally distributed over the vehicle width minus 50 mm on each side as shown in Figure 15_3. The x,y coordinates of each point shall be provided by the OEM and checked by the organisation undertaking the tests.

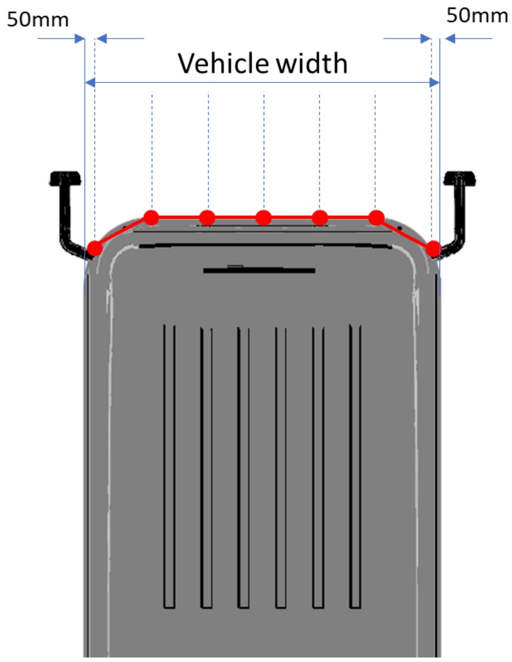


Figure 15_3: Virtual profile for determining impact for VUT

For the vehicle targets, EVT and GVT, they are considered essentially rectangular and should have a local X-axis completely aligned (within defined tolerances) with the local X-axis of the VUT[2]. Thus, a single X position is defined representing the rear of the vehicle target. Impact occurs when the foremost point of the virtual profile for VUT crosses the X position at the rear of the vehicle target.

For the pedestrian targets (EPT) a virtual box is defined around the target with dimensions as shown in Figure 15_4. For crossing scenarios, the reference point is the X,Y position of the hip and for longitudinal scenarios, it is a virtual point positioned where the centreline of the target meets the rear of the virtual box.

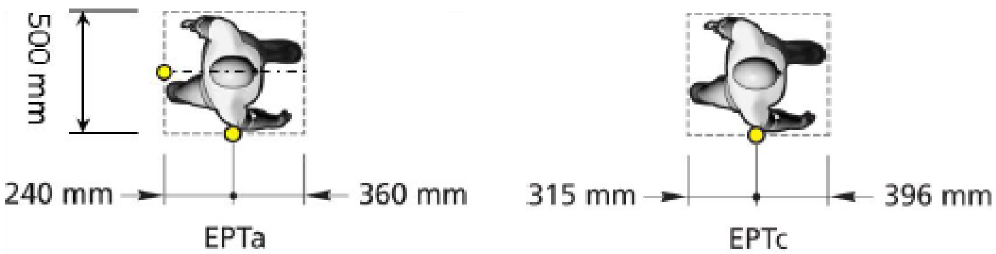


Figure 15_4: Virtual box around EPT

[2] Note that the GVT does in fact have a slightly curved rear profile but this does not affect the moment of impact determination in full overlap conditions as prescribed by this protocol, only in partial overlap conditions.

For the cyclist targets (EBT), the dimensions of the virtual box are shown in Figure 15_5. For crossing scenarios, the reference point of the EBT is the centre of the bottom bracket (crank shaft, indicated by a dashed line in Figure 15_5) and for the longitudinal scenario the most rearward point on the rear wheel is used.

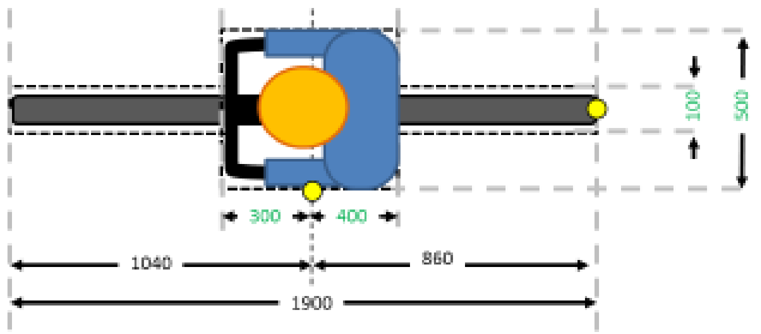


Figure 15_5: Virtual box around EBT

6 Test conditions

6.1 Test track

Tests shall be conducted 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 in the region where data is recorded.

The test zone surface shall be paved and shall not contain any irregularities (e.g. large dips or cracks, manhole covers or reflective studs) that may give rise to abnormal sensor measurements.

The test zone shall extend to a lateral distance of 3.0m either side of the test path and to a longitudinal distance of 30m ahead of the VUT when the test ends.

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

6.2 Weather and lighting conditions

Tests shall be conducted 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 1km.

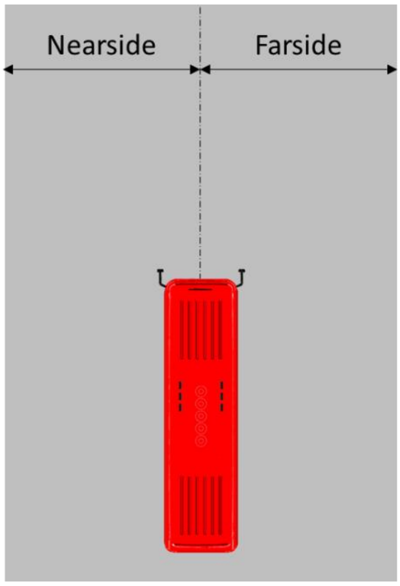
Wind speeds shall be below 10m/s to minimise EPT, EBT and VUT disturbance. The Test Service may, at their discretion repeat tests if unexpected results are observed at a time when wind speed exceeds 5 m/s.

For daytime testing, natural ambient illumination shall 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, EPT or EBT. Testing shall not be performed driving towards, or away from the sun when there is direct sunlight.

Testing at low ambient lighting conditions are defined herein as night-time tests. The conditions for those tests shall be as defined by ANNEX B of the Euro NCAP AEB VRU test protocol (2018).

6.2.1 Surroundings

Tests shall be conducted in clear surroundings such that there are no other vehicles, highway infrastructure (except lighting columns during the low ambient lighting condition tests), obstructions, other objects or persons protruding above the test surface that may give rise to abnormal sensor measurements. The clear zone shall be defined for the VUT test path as per Figure 15_6, with a longitudinal distance of 30m ahead of the VUT when the test ends and The clear zone for the EPT and EBT shall extend on all sides by 1.0m



Scenario	Nearside	Farside
BCRS	3m	3m
BPFA-50	4m	6m
BPNA-25	4m	4m
BPNA-75	4m	4m
BPNC-50	4m	4m
BBLA-25	6m	6m
BBLA-75	6m	6m
Max	**6m**	**6m**

Figure 15_6: Free surroundings

Test areas where the VUT would need 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 shall not comprise any highly reflective surfaces or contain any vehicle-like silhouettes that may give rise to abnormal sensor measurements.

7 Vehicle preparation

7.1 Deployable protection systems

If the vehicle is equipped with any external deployable safety systems (for example, pedestrian airbag), then this should be disabled before testing commences.

7.2 Tyres

Perform the testing with new (>90% original tread depth across the tread width) original fitment tyres of the make, model, size, speed and load rating as specified by the OEM.

Replacement tyres are permitted and may be supplied by the manufacturer or acquired at an official dealer representing the manufacturer. Replacement tyres must be of identical make, model, size, speed and load rating to the original fitment.

Tyres shall be inflated to the manufacturers recommended pressure. They shall be set when the tyres are cold and re-checked at the start of every test day.

7.3 Wheel alignment measurement

The vehicle shall be subject to a vehicle (in-line) geometry check to record the wheel alignment in test condition.

Wheel alignment measurement shall be done with the vehicle at kerb weight.

7.4 Vehicle mass

The AEB shall be operative at all states of load.

VUT shall be tested and assessed unladen with only the driver and test equipment on board.

Each axle of the vehicle shall be weighed in the condition as tested and the measurements recorded in the test report.

At the discretion of the Approval Authority, additional tests may be undertaken in full or partial load conditions to assess the extent of any performance degradation compared to unladen.

7.5 AEB/FCW system check

As part of vehicle preparation, it is permitted to perform a maximum of 10 runs at the lowest test speed at which the system is expected to work to ensure proper functioning of the system before formal testing begins. This check may be performed using static targets without instrumentation or driving control or within a fully equipped test scenario, as deemed appropriate by the Test Service and agreed with the OEM.

7.6 Measuring front end geometry

The X-Y co-ordinates for the virtual front-end vehicle contour given by the OEM shall be verified.

When the co-ordinates specified are within 10mm of those measured by the Test Service, the co-ordinates as provided by the OEM will be used.

When the co-ordinates measured by the Test Service are not within 10mm of those supplied, or where the OEM has not provided the required data, the co-ordinates as measured by the Test Service shall be used.

8 Test procedure

8.1 VUT pre-test conditioning

8.1.1 Sensor calibration

If requested by the OEM, the Test Service shall drive a maximum of 100km on a mixture of urban roads with other traffic and roadside furniture to 'calibrate' the sensor system. Harsh acceleration and braking shall be avoided.

8.1.2 Brake conditioning

It shall be ensured that the brake assemblies are suitably run-in (also referred to as bedded in) and brake surfaces are neither brand new nor corroded.

8.1.3 Tyre conditioning

Tyres shall have been used in normal driving for at least a distance of 150km.

At the start of each sequence of testing, tyres shall be warmed up by driving for 1 km repeatedly steering left and right with a lateral acceleration of approximately 3 m/s^2.

8.1.4 Alignment checks

Before testing is undertaken and if any unexpected performance is observed during the tests, the Test Service shall consider checking the test equipment is correctly reproducing the intended test scenario.

For BCRS tests, this shall involve a static alignment test where the VUT is positioned on the test path while just touching the rear of the TT. The vehicles shall be manually measured to ensure that the centreline of the VUT and TT are aligned. The co-ordinates that the inertial measuring system report for the VUT at that time shall be recorded and retained for reference during analysis.

For VRU tests involving crossing scenarios static and dynamic tests shall be considered.

For static tests, position the VUT on the test path with the foremost point of the vehicle positioned on the X-axis at the point where impact with the TT would be expected. Move the TT to the Y-position expected to correspond to the intended impact point (25%, 50%, 75%). Measure the distance from the TT reference point to the edge of the bus in the Y-axis and calculate the actual impact point (%). Check that error complies with requirement.

For dynamic tests, run the desired test scenario without a TT in position such that AEB does not activate. Analyse the data to identify Y_{Impact_Act} and check that it complies with the requirements for that scenario.

8.2 Car tests

8.2.1 Test scenario

The performance of the VUT AEB system in the BCRS scenario is assessed in relation to a stationary target only. FCW is not assessed.

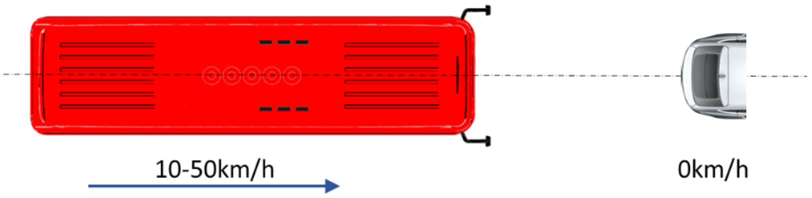


Figure 15_7: BCRs Scenario

The default TT is the EVT. However, the GVT may be used if requested by the OEM.

8.2.2 Sequence and number of test runs

Testing shall be commenced at the lowest test speed (V_{TEST_VUT} = 10 km/h). Whether to do the next test and, if so, at which test speed depends on the result of the preceding test:

a) If the result of the test is complete avoidance at that speed, then the next test speed (V_{TEST_VUT}) shall be incremented upwards by 10 km/h;

b) If the result of the test is contact at a speed at least 5 km/h less than the test speed ($V_{TEST\_VUT} - V_{IMPACT\_VUT} \geq$ 5km/h), and the test speed (V_{TEST_VUT}) was equal to 10 km/h, then the test speed shall be incremented upwards by 5 km/h;

c) If the result of the test is contact at a speed at least 5 km/h less than the test speed ($V_{TEST\_VUT} - V_{IMPACT\_VUT} \geq$ 5km/h), and the test speed (V_{TEST_VUT}) was greater than 10 km/h, the test speed shall be reduced by 5 km/h and then subsequent tests at increased speeds incremented at 5 km/h; or

d) If the result of the test was a speed reduction of less than 5 km/h ($V_{TEST\_VUT} - V_{IMPACT\_VUT} <$ 5km/h), or if the OEM states that they expect no performance at the next speed, then testing shall cease.

Tests shall not be undertaken at speeds in excess of 50 km/h. Only one valid test is required at each speed and the result from the first valid test shall be the result officially recorded.

Additional tests may be undertaken in order to investigate unexpected results at the discretion of the OEM, Test Service or Approval Authority. If so, the Test Service shall provide all data from repeat runs to the Approval Authority for their consideration.

8.2.3 Test execution

a) If requested by the OEM, an initialisation process shall be completed before the first, or every, test run.

The initialisation shall involve driving the vehicle on a circular path of radius ≤ 30m for a distance of 190m, half of which involves a left turn and half a right turn. At the request of the OEM this may also involve driving past a small number of parked vehicles. The initialisation process shall be completed before the tyre warm up.

b) The first test shall be commenced a minimum of 90 seconds and a maximum of 10 minutes after completion of the tyre warmup. Subsequent tests shall be completed within this same time window.

If the time between tests exceeds 10 minutes, then repeat the tyre warmup procedure.

c) Select the normal Drive mode of the vehicle/gearbox.

d) Accelerate the VUT to the test speed, position it on the test path and achieve steady state conditions before T_0 (TTC=4s).

e) If the VUT instigates AEB, then the accelerator pedal shall be released. No other driving controls (e.g. clutch or brake) shall be operated during the test.

f) The test is considered complete when one of the following has occurred:

   i. V_{VUT} = 0 km/h

   ii. VUT has made contact with the TT.

8.2.4 Validity of tests

Post-processing of data shall be undertaken to demonstrate the validity of tests. Tests are considered valid when all of the following criteria are met at all times between T_0 and T_{AEB}:

a) V_{VUT} ≥ Test Speed and V_{VUT} ≤ Test Speed + 0.5 km/h

b) Lateral deviation from VUT Test Path (Y_{VUT_Error}) = 0 ± 0.05m

c) VUT Yaw Velocity (Ψ'_{VUT}) = 0 ± 1.0 °/s

d) Steering wheel velocity (Ω'_{VUT}) = 0 ± 15.0 °/s

e) Centreline of the Test Target is within ± 0.05m of the Test path and parallel to the Test path within ±5°

To consistently meet these tolerances, electro mechanical control systems shall be used to apply the driving controls.

If a test is found to be non-compliant then it shall be repeated until a compliant result is achieved.

8.3 VRU crossing tests

8.3.1 Test scenarios

The performance of the system shall be assessed in the four scenarios BPFA-50, BPNA-25, BPNA-75 and BPNC-50 and these are illustrated in Figure 15_8 to Figure 15_10 . FCW is not assessed.

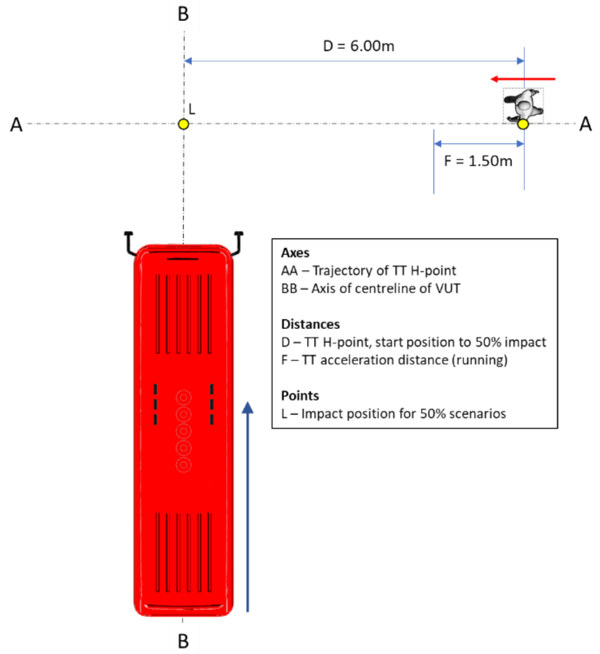


Figure 15_8: BPFA-50 scenario, adult running from the farside of the road

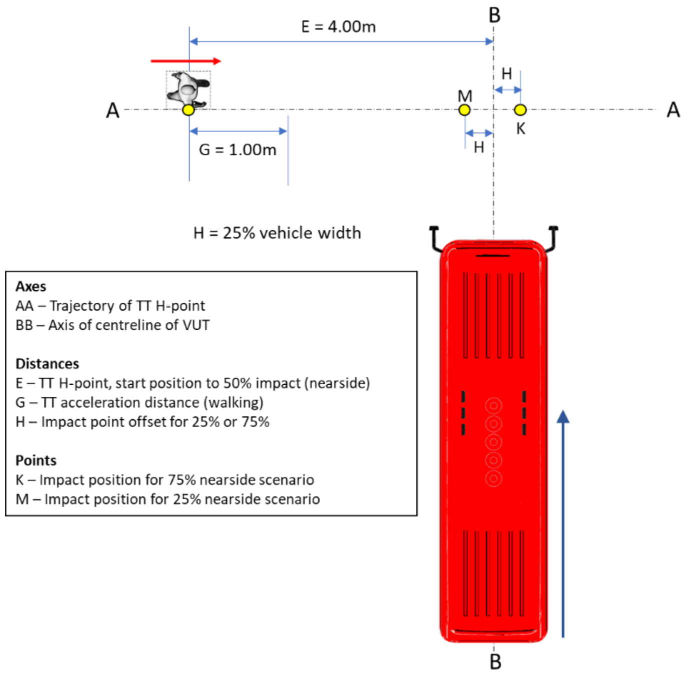


Figure 15_9: BPNA-25 & BPNA-75 scenario, adult walking from the nearside of the road

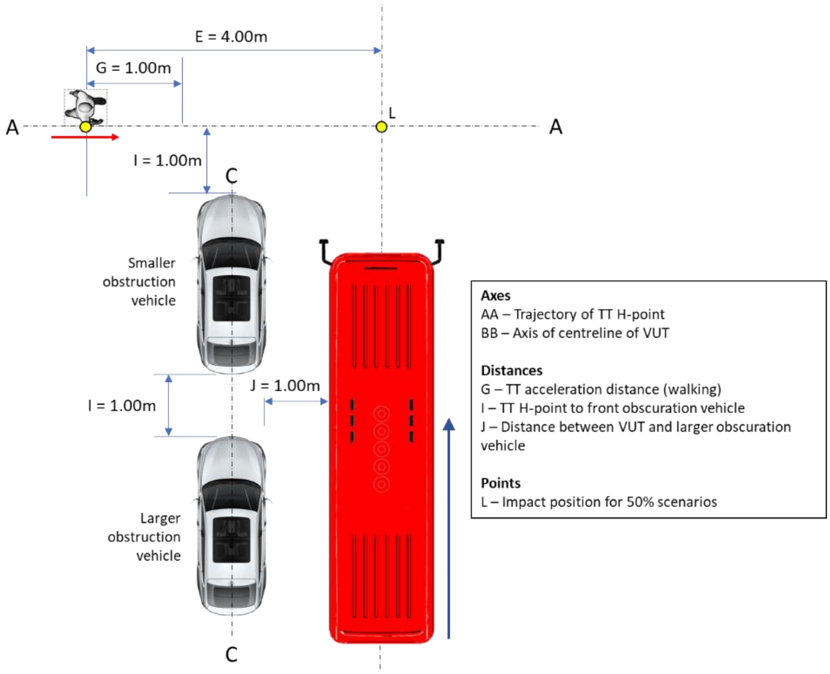


Figure 15_10: BPNC-50 scenario, child running from the nearside from behind obstructing vehicles

Figure 15_10 defines the relative position of the obstructing vehicles. The definition of the size and type of vehicles to be used is that specified in the Euro NCAP AEB VRU systems protocol (2018).

In all scenarios except BPNC-50, the TT to be used is the Euro NCAP Pedestrian Target adult dummy (EPTa). For scenario BPNC-50, the test target shall be the Euro NCAP Pedestrian Target child dummy (EPTc).

The details of the tests are shown in Table 15_4.

Table 15_4: Test variables for the VRU crossing tests

	Test Scenario			
	BPFA-50	BPNA-25	BPNA-75	BPNC-50
VUT speed (V_{TEST_VUT})	20 – 45 km/h			
TT speed (V_{TEST_TT})	8 km/h	5 km/h		
Impact location (VUT)	50%	25%	75%	50%
Lighting conditions	Day	Day & Night		Day

In addition to the tests defined in Table 15_4, the BPNA-75 scenario shall be tested in daylight conditions with:

a) V_{TEST_VUT} = 20 km/h and V_{TEST_TT} = 3 km/h; and

b) V_{TEST_VUT} = 10 km/h and V_{TEST_TT} = 5 km/h.

8.3.2 Sequence and number of test runs

VUT tests speeds (V_{TEST_VUT}) shall be increased in increments of 5 km/h, until V_{TEST_VUT} = 40 km/h.

VUT tests speeds in excess of 40 km/h shall only be tested when:

a) OEM has provided data indicating an expected significant performance at the next speed increment; and

b) $V_{TEST_VUT} – V_{IMPACT_VUT} \geq 5$km/h where $V_{TEST_VUT} = 40$km/h

The number of test runs to be completed in each test condition and the process of determining the result to be recorded for that condition are the same as those defined in section 8.2.2.

8.3.3 Test execution

The process for executing each test shall be as defined in section 8.2.3. with the following exceptions.

T_0 is defined as being at a TTC of 6 seconds.

The test is considered complete when one of the following has occurred:

a) VVUT = 0 km/h

b) VUT has made contact with the TT

c) The TT has crossed the full width of the VUT and moved out of its path without making contact with it

8.3.4 Validity of tests

Post-processing of data shall be undertaken to demonstrate the validity of tests. Tests are considered valid when all of the following criteria are met at all times between T_0 and activation of AEB or the end of test, whichever comes first:

a) $V_{VUT} \geq$ Test Speed and $V_{VUT} \leq$ Test Speed + 0.5 km/h

b) Lateral deviation from VUT Test Path (Y_{VUT_Error}) = 0 ± 0.05m

c) Lateral deviation from TT path = 0 ± 0.05m

d) Lateral Velocity of deviation from the TT path = 0 ± 0.15m/s

e) VUT Yaw Velocity (Ψ'_{VUT}) = 0 ± 1.0 ˚/s

f) Steering wheel velocity (Ω'_{VUT}) = 0 ± 15.0 ˚/s

Once it has reached a steady state condition, the speed of the TT shall remain at the defined speed ±0.2 km/h. The steady state period shall commence no later than the point when the EPT has reached a lateral distance (Global Y-axis) of both:

a) 3.0m from the VUT centreline, in tests approached from the nearside

b) 4.5m from the VUT centreline in tests approached from the farside

In addition to this, Point L = Target value ± 3% of vehicle width

To consistently meet these tolerances, electro mechanical control systems shall be used to apply the driving controls.

If a test is found to be non-compliant then it shall be repeated until a compliant result is achieved.

8.4 VRU longitudinal tests

Test scenarios

The VUT shall be assessed in two longitudinal scenarios. Both AEB and FCW shall be assessed. The TT shall be the Euro NCAP Bicyclist and bike Target (EBT). The test scenario is outlined in Figure 15_11, below.

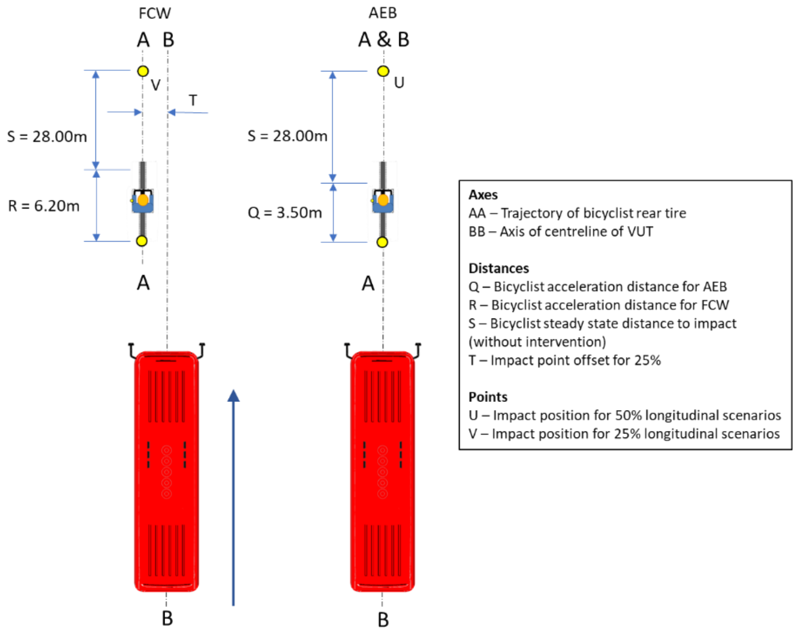


Figure 15_11: Longitudinal bicyclist scenarios; BBLA-25 (left) & BBLA-50 (right)

The tests to be undertaken are as defined in Table 15_5 .

Table 15_5: Test Variables: Longitudinal scenarios

	Test Scenario	
	BBLA-25	**BBLA-50**
Type of Test	AEB	FCW
VUT speed (V_{TEST_VUT})	50 km/h - 60 km/h	25 km/h – 60 km/h
TT speed (V_{TEST_TT})	20 km/h	15 km/h
Impact location (VUT)	25%	50%
Lighting conditions	Daylight	

8.4.1 Sequence and number of test runs

VUT tests speeds (V_{TEST_VUT}) shall be increased in increments of 5 km/h, until V_{TEST_VUT} = 40 km/h.

VUT tests speeds in excess of 40 km/h shall only be tested when:

a) an OEM has provided data indicating an expected significant performance at the next speed increment; and

b) $V_{TEST\_VUT} – V_{IMPACT\_VUT} \geq$ 5km/h where V_{TEST_VUT} = 40km/h.

The number of test runs to be completed in each test condition and the process of determining the result to be recorded for that condition shall be as defined in section 8.2.2.

8.4.2 Test execution

The test execution shall be as specified in section 8.2.3, except that steady state shall be achieved before the time T_0 – 1 seconds (that is, 1 second before T_0).

For scenario BBLA-25 only, the test may be aborted if no FCW has been issued when the TTC has reduced to ≤ 1.5 seconds.

8.4.3 Validity of tests

Post-processing of data shall be undertaken to demonstrate the validity of tests. Tests are considered valid when all of the following criteria are met at all times between the time T_0 – 1seconds and T_{AEB} or T_{FCW}:

a) $V_{VUT} \geq$ Test Speed and $V_{VUT} \leq$ Test Speed + 0.5 km/h

b) Lateral deviation from VUT Test Path (Y_{VUT_Error}) = 0 ± 0.05m

c) Lateral deviation from TT path = 0 ± 0.15m

d) Lateral Velocity of deviation from the TT path = 0 ± 0.15m/s

e) VUT Yaw Velocity (Ψ'_{VUT}) = 0 ± 1.0 ˚/s

f) Steering wheel velocity (Ω'_{VUT}) = 0 ± 15.0 ˚/s

Once it has reached a steady state condition, the speed of the TT shall remain at the defined speed ±0.2 km/h. The steady state period shall commence no later than the point when the TT is positioned 22m forward of the impact point on the VUT.

To consistently meet these tolerances, electro mechanical control systems shall be used to apply the driving controls.

If a test is found to be non-compliant then it shall be repeated until a compliant result is achieved.

8.5 Aborted crossing test

8.5.1 Test scenario

This test scenario has the same geometry as that described for BPNA-25 and illustrated in Figure 15_9 previously. However, the TT shall be the EPTc. As per BPNA-25, the movement of the TT shall be timed such that if the TT continued at its constant steady state speed (V_{TEST_TT} = 5 km/h) and the VUT maintained constant speed (without braking) and lateral position, an impact would occur 25% across the width of the VUT.

Thus, the TT motion shall be initiated as for BPNA-25. However, instead of the TT continuing at 5 km/h until the end of the test, it shall be stopped with a mean deceleration of 3 m/s^2 at Point W, where distance N is the distance from the edge of the VUT path, as illustrated in Figure 15_12.

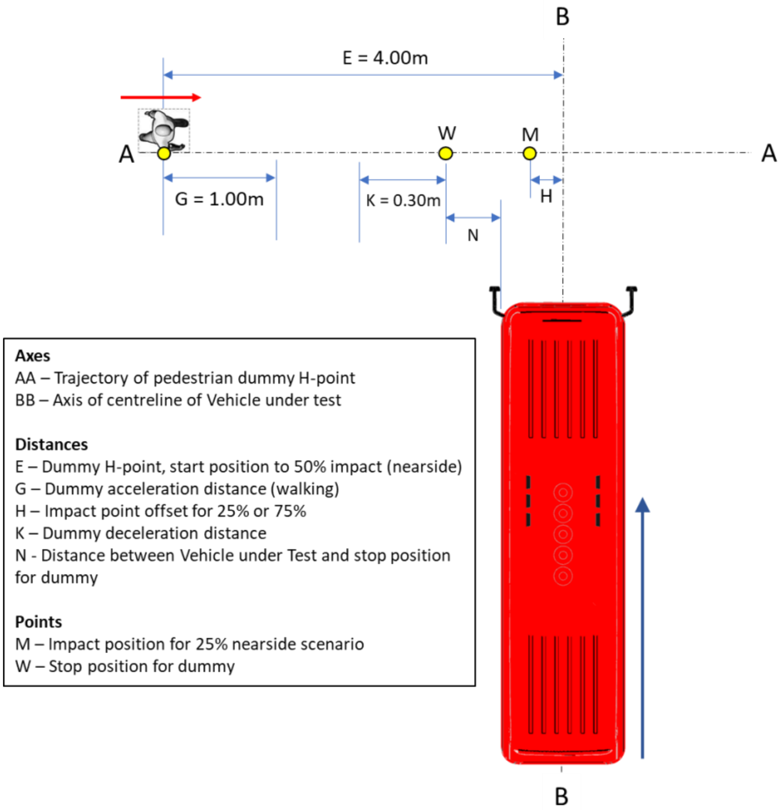


Figure 15_12: TT start and stop positions in aborted crossing test

Tests shall be undertaken at V_{TEST_VUT} = 30 km/h for values to N = 0.6m, 0.75m and 0.9m.

8.5.2 Sequence and number of test runs

The first tests shall be undertaken at N = 0.6m and 3 identical tests shall be completed.

Distance N shall be increased to the next increment if the AEB activates in any of the 3 tests.

If AEB is not activated in any tests then testing can be ceased and the system will be deemed not to have activated in any of the tests at greater values of N.

8.5.3 Test execution

Accelerate the VUT to the test speed (V_{TEST_VUT}), position it on the test path and achieve steady state conditions before T_0 (TTC=4s). For buses with automatic transmission, select Drive (D). For buses with a manual transmission, select the highest gear that results in an engine speed of at least 1,000 RPM at the test speed.

If the VUT instigates AEB, then the throttle pedal shall be released. No other driving controls (e.g. clutch or brake) shall be operated during the test.

The test is considered complete one second after the TT has come to rest (V_{TT}=0).

8.5.4 Validity of tests

Post-processing of data shall be undertaken to demonstrate the validity of tests. Tests are considered valid when all of the following criteria are met at all times between T_0 and activation of AEB or the end of test, whichever comes first:

a) V_{VUT} ≥ Test Speed and V_{VUT} ≤ Test Speed + 0.5 km/hLateral deviation from VUT Test Path = 0 ± 0.05m

b) Lateral deviation from TT path = 0 ± 0.05m

c) Lateral Velocity of deviation from the Test Target path = 0 ± 0.15m/s

d) VUT Yaw Velocity (Ψ'_{VUT}) = 0 ± 1.0˚/s

e) Steering wheel velocity (Ω'_{VUT}) = 0 ± 15.0˚/s

Once it has reached a steady state condition, the speed of the TT (V_{TT}) shall remain at the defined speed ±0.2 km/h until commencement of the deceleration phase.

The nominal impact point (Point M) shall be 25% ± 3% of vehicle width.

The deceleration phase shall commence at the time required to achieve the intended point W. The mean deceleration shall be within ±5% of the target value.

To consistently meet these tolerances, electro mechanical control systems shall be used to apply the driving controls.

If a test is found to be non-compliant then the non-compliant tests must be repeated until 3 compliant runs are achieved.

8.6 Bus stop test

8.6.1 VUT path geometry

The bus stop test involves the VUT steering a defined curved path first left then right of 125m radius such that the nearside front corner of the vehicle describes the path illustrated in Figure 15_13 and defined by the corridor specified in XY co-ordinates in Appendix A.

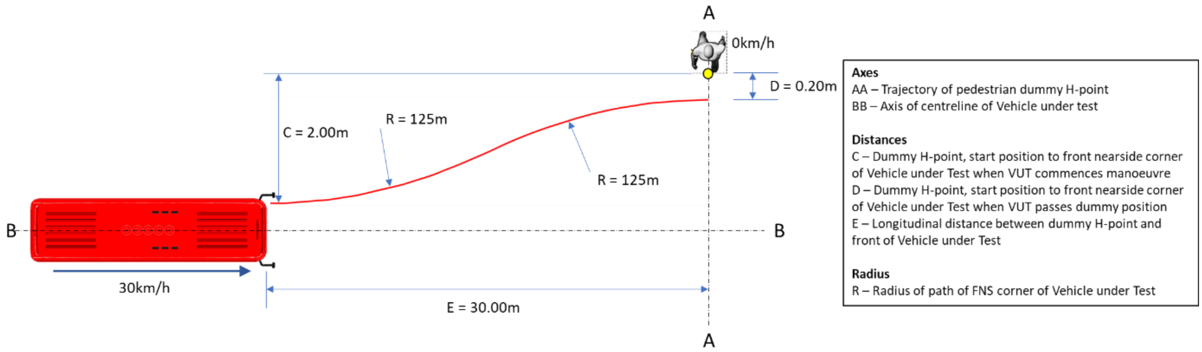


Figure 15_13: VUT Path and pedestrian position in false positive bus stop test

8.6.2 False positive test – TT Stationary

As shown described in Figure 15_12. The TT shall remain stationary at all times and shall be positioned such that the lateral separation (on global Y-axis), between the centre of the TT and the nearside front corner of the VUT, is initially 2m (Point C).

This distance shall reduce as the VUT approaches the TT until a distance of0.2m (Point D) at the moment the front nearside corner of the VUT is at the same position as the TT on the Global X-axis.

V_{VUT} shall be 30 km/h and shall remain constant throughout the test unless AEB is activated.

8.6.3 True positive test – TT non-stationary

As described in Figure 15_13. The TT shall initially be positioned such that the lateral separation (on global Y-axis), between the centre of the TT and the nearside front corner of the VUT, is initially 4.55m (Point C).The TT shall be accelerated to a speed of V_{TEST_TT} = 5 km/h at a time such that it is on a collision course with the front of the VUT where the nominal impact point (Point L) is 50%± 3% of bus width. V_{TEST_VUT} shall be 30 km/h.

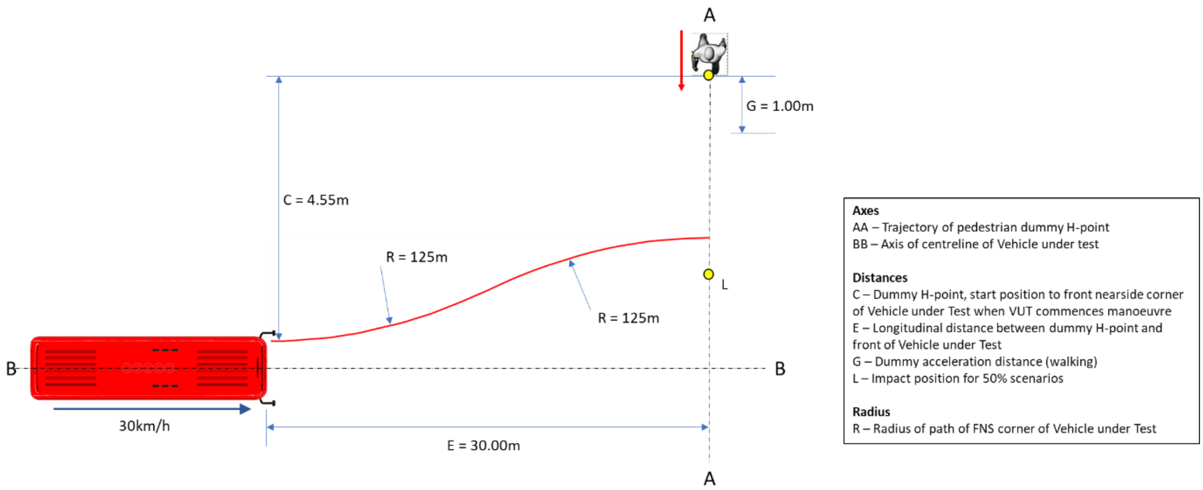


Figure 15_13: VUT path and TT position in true positive bus stop test

8.6.4 Sequence and number of test runs

Each test involves only one test configuration and will be completed only once.

8.6.5 Test execution

Accelerate the VUT to the test speed (V_{TEST_VUT}) in a straight line

Position the front nearside corner at a point that complies with the requirements for the first lateral position defined.

When the front of the VUT reaches a position of 30m from the TT in the global X-axis, steering is applied such that the front nearside corner stays within the corridor defined by Appendix A.

For buses with automatic transmission, select Drive (D). For buses with a manual transmission, select the highest gear that results in an engine speed of at least 1,000 RPM at the test speed.

If the VUT instigates AEB, then the throttle pedal shall be released. No other driving controls (e.g. clutch or brake) shall be operated during the test.

The test is considered complete when the foremost point of the VUT has passed the position of the TT in the global x-axis, or the VUT has come to rest, whichever occurs first.

8.6.6 Validity of tests

Post-processing of data shall be undertaken to demonstrate the validity of tests.

Tests are considered valid when all of the following criteria are met at all X_{VUT} positions between that representing entry to the corridor defined in Appendix A and activation of AEB or the end of test, whichever comes first:

a) $V_{VUT} \geq$ Test Speed and $V_{VUT} \leq$ Test Speed + 0.5 km/h

b) Front nearside corner remains in defined corridor

To consistently meet these tolerances, electro mechanical control systems shall be used to apply the driving controls.

If a test is found to be non-compliant then the non-compliant test shall be repeated.

8.7 Validation of OEM supplied test data

The procedures as outlined above are intended to be applicable as an independent assessment of a bus equipped with AEB capable of standing alone. Where an OEM supplies a Test Service with a prediction of performance in each test condition in terms of both an expected impact speed (0km/h if it is expected that the system will avoid impact) and, where applicable, the peak deceleration applied to achieve that result, a reduced burden procedure can be undertaken. The Test Service will randomly select a sample of test conditions in which to verify the OEM’s result, ensuring a broad cross section of variables are covered which must include:

a) For car scenarios, a minimum 3 of 5 test conditions

b) For crossing scenarios, a minimum 16 of 32 test conditions

c) For longitudinal scenarios, a minimum 6 of 11 test conditions

d) Aborted crossing and bus stop tests shall always be completed in full.

9 Assessment of results

9.1 Assessment criteria

The true positive performance of AEB shall be assessed using the criteria (V_{AEB_Red}). This is defined as the difference between the test speed and the impact speed, expressed as a percentage of the test speed, where the impact speed is considered to be 0km/h when the impact is avoided.

For the longitudinal cyclist tests the test and impact speeds are defined as the relative speeds of the VUT and the TT. An example of this is shown in Table 15_6.

Table 15_6: Example V_{AEB_Red} for longitudinal cyclist tests

Condition	VUT	TT	Relative
Test Speed (km/h)	50	15	35
Impact Speed (km/h)	30	15	15
V_{AEB}_Red (km/h)			-20
V_{AEB}_Red (%)			57%

FCW shall be assessed on a binary basis, based upon the TTC at the moment the warning is issued (TFCW). When TFCW≥1.7seconds then the score shall be 100%. Where TFCW<1.7seconds, then the score shall be 0%.

9.2 Pre-conditions

The score awarded for AEB will be zero unless the following pre-conditions are met:

a) In test BPNA-75 with VTEST_TT= 3km/h and VTEST_VUT=20 km/h then VAEB_Red shall exceed 25% in both day & night conditions

b) In test BPNA-75 with VTEST_TT= 5km/h and VTEST_VUT=10 km/h then VAEB_Red shall exceed 25% in both day & night conditions

c) The AEB system shall default ON at the start of every journey. It shall not be possible for the driver to easily switch off the system. It shall be possible for technicians to enable a service mode that deactivates it for maintenance and test purposes (for example when placed on a rolling road/brake rollers).

d) AEB must not activate in the false positive bus stop test.

e) VAEB_Red shall be no less than 1 km/h in the true positive bus stop test.

9.3 Test scenario and crash type scores

Each individual test scenario comprises several individual tests at different initial test speeds. Weightings shall be applied to each individual test within each test scenario and crash type. The speed weightings are defined in the following sections.

9.3.1 Car tests

For scenario BCRS, the score for the test scenario shall be calculated from each individual test run as per the example given in to Table 15_7.

Table 15_7: Scoring and weighting applicable to scenario BCRS

Test Speed (km/h)	A	B	C = A*B
	V_{AEB_Red}	Speed Weighting	Weighted score
10	100.0%	5.0%	5.0%
15	100.0%	5.0%	5.0%
20	100.0%	20.0%	20.0%
25	100.0%	15.0%	15.0%
30	100.0%	15.0%	15.0%
35	100.0%	20.0%	20.0%
40	60.0%	10.0%	6.0%
45	20.0%	5.0%	1.0%
50	0.0%	5.0%	0.0%
		Total (Scenario Score)	**87.0%**

The total of the weighted scores for each test speed shall become the scenario score. The car tests only use one test scenario and therefore the scenario score is also the crash type score.

9.3.2 VRU crossing tests

For the VRU crossing tests the score shall be calculated for each individual test run as per the example given in Table 15_8.

Table 15_8: Scoring and weighting applicable to each VRU crossing scenario

Test Speed (km/h)	A	B	C = A*B
	V_{AEB_Red}	Speed Weighting	Weighted score
20	100.0%	20.0%	20.0%
25	100.0%	20.0%	20.0%
30	53.0%	20.0%	10.6%
35	40.0%	20.0%	8.0%
40	20.0%	10.0%	2.0%
45	0.0%	10.0%	0.0%
		Total (Scenario Score)	**60.6%**

The total of the weighted scores for each test speed shall become the scenario score. The process shall be repeated for each of the VRU crossing scenarios.

Each of the different VRU scenarios shall also be weighted according to casualty prevention potential to produce a crash type score for all VRU crossing scenarios. Table 15_9 provides an example of the scenario weighting and the calculation.

Table 15_9: Scoring and weighting to combine scenario scores to crash type score

Scenario	A	B	C = A*B
	Scenario Score	Scenario Weighting	Weighted score
BPFA-50 (Day)	60.6%	15.0%	9.1%
BPNA-25 (Day)	75.4%	26.0%	19.6%
BPNA-25 (Night)	60.7%	22.0%	13.4%
BPNA-75 (Day)	91.0%	18.0%	16.4%
BPNA-75 (Night)	80.0%	15.0%	12.0%
BPNC-50 (Day)	70.0%	4.0%	2.8%
		Total (Crash Type Score)	**73.2%**

9.3.3 VRU longitudinal tests

The VRU longitudinal tests assess both AEB and FCW. The principles for AEB are identical to the crossing scenarios. Forward collision warning shall be assessed according to TFCW. The scores shall be calculated for each individual test run as per the example given in Table 15_10

Table 15_10: Scoring and weighting for VRU longitudinal tests

Test Speed	BBLA-50 (AEB)			BBLA25-(FCW)		
	A	B	C = A*B	D	E	F=D if E≥1.7
	V_{AEB_Red}	Speed Weighting	Weighted score	Speed Weighting	T_{FCW}	Weighted score
25	100.0%	20.0%	20.0%			
30	100.0%	20.0%	20.0%			
35	80.0%	20.0%	16.0%			
40	40.0%	15.0%	6.0%			
45	0.0%	10.0%	0.0%			
50	0.0%	5.0%	0.0%	40.0%	1.8	40.0%
55	0.0%	5.0%	0.0%	30.0%	1.6	0.0%
60	0.0%	5.0%	0.0%	30.0%	1.5	0.0%
		Total (Scenario score)	**62.0%**	Total (Scenario score)		**40.0%**
		Scenario weighting	75.0%			25.0%
					Total (Crash type score)	**71.5%**

The total of the weighted scores for each test speed shall become the scenario score. Each scenario is weighted to then produce a combined score for the whole crash type.

9.3.4 False positive aborted crossing scenario

The results of the aborted crossing scenario shall be interpreted in terms of the peak acceleration (APEAK_VUT_Long) measured during any activation. Where the system does not activate APEAK_VUT_Long shall be deemed to be zero. Points shall be awarded for each individual test configuration on the following basis:

a) In tests where Y_{TTStop} = 0.6m

i. $A_{PEAK\_VUT\_Long} \leq -7m/s^2$: 0 Points

ii. $A_{PEAK\_VUT\_Long} > -7m/s^2$ AND $< 0m/s^2$: 2 Points

b) In tests where Y_{TTStop} > 0.6m

i. $A_{PEAK\_VUT\_Long} \leq -7m/s^2$: 0 Points

ii. $A_{PEAK\_VUT\_Long} > -7m/s^2$ AND $< 0m/s^2$: 1 Points

iii. $A_{PEAK\_VUT\_Long} = 0\ m/s^2$: 2 Points

The total score for each individual test configuration shall be summed and divided by the maximum possible score (18) and expressed as a percentage Scenario Score as per the example given in Table 15_11.

Table 15_11: Example scoring for false positive aborted crossing tests

Y_{TTStop}	Test 1	Test 2	Test 3	Total
0.6m	0	0	2	2
0.75m	1	2	1	4
0.9m	2	2	2	6
			Total	12
			Scenario Score	**66.7%**

9.4 Overall score

The scores by crash type shall be converted to an overall score for AEB according to weightings based on London bus collision data. A worked example is shown in Table 15_12.

Table 15_12: Scoring & Weighting to produce overall AEB result

Crash Type	A	B	C= A*B	D	E = C*D
	Crash type score	**Crash type weighting**	**Weighted score**	**Performance type weighting**	**Weighted performance score**
Car	87.0%	10.0%	8.7%	80%	59.6%
VRU crossing	73.2%	85.0%	62.2%		
VRU longitudinal	71.5%	5.0%	3.6%		
False positive: aborted crossing	66.7%	100.0%	66.7%	20%	13.3%
				Total (Overall AEB Score)	**72.9%**

10 Test report

The Test Service shall provide a comprehensive test report that will be made available to the Approval Authority. The test report shall consist of three distinct sections:

a) Performance data

b) Confirmation of protocol compliance

c) Reference information

The minimum performance data required is:

a) The value V_{Impact} and $A_{PEAK\_VUT\_Long}$ for each and every individual test run, with the number of tests reported based on the rules in, for example, section 8.2.2

b) For BBLA-25 the performance output is the TTC at T_{FCW}.

To confirm protocol compliance, the Test Service shall:

a) Make available the video recordings as specified in section 7.2

b) Include in the report processed data (e.g. graphs, tables etc.) that show that each test was compliant with its respective section on validity of tests

c) Provide data on environmental validity criteria, including temperature, weather and lighting measurements, demonstrating compliance with respective limit values

The reference information required includes as a minimum:

a) Vehicle make
b) Vehicle model
c) Vehicle model variant
d) AEB hardware version (e.g. sensor types, ECU references)
e) AEB software version
f) Tyre make/model/size/pressure
g) Test weight
h) Make, model, serial number of key control and measurement equipment
i) Details of the Test Service
j) Test date(s)

Appendix A - Co-ordinate corridor defining the path to be followed by the front nearside corner of the VUT

The co-ordinates defined below are based on the global co-ordinate system as defined in section 6.1, for use in section 8.6.1, assuming the vehicle width is 2.5m. For different vehicle widths all target Y values shall be adjusted by half the difference in width. However, the important element is not the initial offset in Y but the difference in Y between the TT and the VUT initial position and the difference between the VUT Y-position at any given X and its initial Y-Position at X=0.

X	Target Y	Y Position Corridor which NSF of VUT must lie within	
0.00	1.25	1.20	1.30
1.00	1.25	1.20	1.30
2.00	1.27	1.22	1.32
3.00	1.29	1.24	1.34
4.00	1.31	1.26	1.36
5.00	1.35	1.30	1.40
6.00	1.39	1.34	1.44
7.00	1.45	1.40	1.50
8.00	1.51	1.46	1.56
9.00	1.57	1.52	1.62
10.00	1.65	1.60	1.70
11.00	1.73	1.68	1.78
12.00	1.83	1.78	1.88
13.00	1.93	1.88	1.98
14.00	2.04	1.99	2.09
15.00	2.15	2.10	2.20
16.00	2.27	2.22	2.32
17.00	2.38	2.33	2.43
18.00	2.48	2.43	2.53
19.00	2.57	2.52	2.62
20.00	2.65	2.60	2.70
21.00	2.73	2.68	2.78
22.00	2.80	2.75	2.85
23.00	2.86	2.81	2.91
24.00	2.91	2.86	2.96
25.00	2.95	2.90	3.00
26.00	2.99	2.94	3.04
27.00	3.01	2.96	3.06
28.00	3.03	2.98	3.08
29.00	3.04	2.99	3.09
30.00	3.05	3.00	3.10

Attachment 16: Advanced Emergency Braking (AEB) Guidance Notes

11 Introduction

Advanced Emergency Braking (AEB) is a system that uses forward looking sensors such as Lidar, Radar, and/or Cameras to identify a risk of an imminent collision. It will typically first warn the driver of the risk and, if the driver does not react, apply braking automatically to avoid the collision or to reduce the collision speed and therefore the potential for injury.

TfL intend to run a trial on some routes to determine whether AEB is effective when fitted to London buses.

This document sets out the guidance notes related to the fitment of AEB. These guidance notes are aimed at bus operators and OEMs as a practical guide for implementation of the Bus Safety Standard.

These notes are for guidance only and are not legally binding. In all circumstances, the guidance provided by an OEM or system supplier shall take precedence, and these guidance notes are only for use in the absence of other information. These are not intended to be exhaustive, but to point the operators toward practical advice and questions to raise with OEMs/suppliers.

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 4.3.2 and Attachment 15 – AEB Assessment Protocol

12 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

AEB shall be provided on all new build buses, within the AEB road trial. The road trial is being undertaken to increase understanding of system effects before full implementation.

It shall not be retrofitted unless sufficient evidence can be provided to TfL that systems can be implemented safely and robustly.

12.1 Compliance and warranty

As part of the acceptance procedure for new buses, they will be tested against TfL's Test and Assessment protocol for AEB, Attachment 15. In order to be accepted, new buses must attain a score greater than zero for AEB - the higher the score the better.

A bus operator should ask to see compliance certificates for UNECE Regulation 13 and warranty information for the brake system from the OEM and/or the AEB system supplier. The bus operator must be able to present certificates to TfL as evidence that the bus brake system will continue to operate safely.

An OEM should work with any brake or AEB system suppliers to ensure that UNECE Regulation 13 requirements are met, and that warranty on the brake system is maintained. The OEM must be able to present certificates to TfL as evidence that the bus brake system will continue to operate safely.

12.2 Normal Operation

A bus operator should ask to see evidence of how well the system performs when it is activating in the situations it is intended to activate in. This should include the results and scoring from the AEB solution test and assessment protocol document. This protocol includes a variety of physical tests designed to assess the ability of an AEB system fitted to a bus to avoid or mitigate collisions with other road users while minimising risks to occupants of the bus from unnecessary brake interventions.

12.3 False positive activations

All AEB systems carry a risk that the sensors ‘misjudge’ a particular traffic situation such that a warning function or even automated braking are applied in a situation where it would not be intended to act, otherwise known as a false positive activation.

It is important that an AEB system causes as few braking events resulting from false positive activations as possible. The OEM shall target zero false positive activations and will need to demonstrate evidence to TfL that the vehicle is capable of driving for at least 600,000km in mixed London traffic without any false positives.

A bus operator should ask to see the evidence from the OEM and/or AEB system suppliers that demonstrates that their vehicles have been rigorously tested and there is evidence to show the distance travelled during development of the AEB system without any false positive activations occurring. Such a test programme must cover an extensive range of environmental conditions, events and scenarios that are representative of those that could reasonably be expected to occur in service. This may involve documents showing how far has been driven in dense city environments for the base system used across different vehicles and specifically for the system as fitted to the specific bus in question and the number of false positive activations. The evidence can relate to the OEM’s tuning process, in which case it is permissible for the system to have suffered a false positive activation if there is evidence to show that the algorithm was tuned to eliminate that effect and that this was demonstrated to work in a computer simulation using the actual sensor inputs recorded by the system when the activation first occurred.

12.4 False negatives

It should be noted that systems are not guaranteed to successfully detect an imminent frontal collision in all circumstances. There are some circumstances in which it is not designed to activate. Even in situations it is designed to activate in, unusual permutations of conditions can come together to cause it to fail to detect the object. These instances are known as false negatives.

12.5 Balancing risks

The TfL requirements are open and flexible. Although certain minimum standards must be met or it will fail to meet the requirements of the bus vehicle specification, there is still very considerable room for industry to choose the level of system performance that they think will work best for their particular operation. For example, TfL will attempt to commercially incentivise systems that maximise the potential to avoid collisions. However, some OEMs may produce systems that apply only partial braking in an emergency or differ in terms of the vehicle speed that the system will be active at. Operators should aim to consult different OEMs to identify any such differences, explain the rationale and then decide which best suits their corporate aims, balancing any incentives with the effect on any internal objectives.

12.6 Monitoring

AEB is new to the bus market and London will be a pioneer in implementing it. Any brake activation, human or automated, has the potential to cause injury to bus occupants. The AEB system cannot apply braking that is any more severe than a skilled driver could. However, in a false positive brake activation this creates a risk that would not exist if the advanced braking system did not exist. TfL has, therefore, mandated that if an AEB system is fitted, it must make data available for recording via the CCTV system or some other suitable method.

It is very important that operators capture as much of this data as possible, monitor it closely and report it to TfL. Current practice with CCTV is that operators make a semi-permanent download of CCTV data every time there is an incident which the driver feels could result in a complaint or some form of claim. As a minimum, any observed activation of AEB should be considered as such an incident and result in data recording and retention and reporting to TfL

However, the above system is reliant on the driver. In false positive activations, a full brake stop should be relatively rare. Most will be a very short duration stab on the brakes, very quickly released again. Drivers may not realise that it was caused by AEB and hence not report appropriately. Similarly in true positive situations where genuine collision risk existed, there may be an incentive for drivers not to report AEB activation because they may feel it would highlight some shortcoming in their driving. It would, therefore be preferable if the data provided by the AEB could trigger an automatic record and alert to the operator. This would ensure a more accurate assessment of the operational success of the system or alternatively flag any emerging problems earlier.

13 Training

13.1 For test services

The AEB solution test and assessment protocol contains many similarities to the tests carried out on passenger cars by EuroNCAP and by regulatory authorities on HGVs. Therefore test houses accredited to undertake Euro NCAP tests or to undertake approval tests to UNECE Regulation 131 will be considered suitable to undertake performance tests. Test services without such accreditation will be required to demonstrate to TfL, at their own expense, that they can achieve the same standard of testing as an accredited organisation.

13.2 Bus drivers

An AEB system is only aimed at preventing rare occurrences where the driver has not already taken any/sufficient braking action in order to avoid an imminent collision. As such, the system should be entirely invisible to the drivers for the vast majority of their driving time.

In principle therefore, the drivers don’t necessarily need to be trained in exactly how the system works. However, it may be beneficial to inform them how the system will operate, e.g. the specific audible and/or visual warnings, how the system will apply the vehicle’s brakes, and any specific action(s), if any, required by the driver to return to normal driving following an activation. One key message for drivers is that this is a system of last resort, intended to work in situations that develop faster than they can reasonably react or where they have not been able to pay full attention to the risk for whatever reason. It does not replace any part of the driving task or their responsibility for safe operation of the vehicle and will not work in all circumstances, environments or weather conditions. Under no circumstances should they attempt to demonstrate its operation or rely on it to stop the vehicle in a situation they are capable of dealing with.

Unless automatic monitoring is implemented, drivers should be encouraged to report every activation of the system in whatever driving circumstance it occurs.

13.3 Shift Supervisors

Shift supervisors should be trained in how the system works and the monitoring and reporting requirements. In the event that the system develops a fault, then, unless the OEM advises differently, they should understand this as an ‘amber’ warning where the loss of capability is explained to the driver and the vehicle is taken out of service for repair as soon as possible. The system should fail safe in that it will simply stop providing the benefit rather than cause any new problems. As such it is not necessary to stop immediately (e.g. at the roadside) in the case of a warning light illuminating in the cab.

13.4 Bus maintenance engineers

The engineers carrying out general bus maintenance should be aware of the location and details of any sensors related to the AEB system. Training should be based on the OEMs' guidance. However, this is likely to include understanding the importance of ensuring the sensors are correctly aligned, undamaged and unobstructed since the performance of the AEB system is completely contingent on the sensors the system is connected to.

A bus operator should ask the OEM and/or AEB system supplier to provide guidelines in the event that the windscreen/grille area in front of sensor becomes damaged, or if the performance of the system has degraded.

14 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs. Each OEM will have a set of maintenance requirements for their systems. These can vary quite significantly between OEMs, and Operators should discuss these requirements with their suppliers to ensure that all of the implications are considered at the purchase stage and, thereafter, in routine operation. Most systems will require that the areas that sensors are installed in remain clean, undamaged and clear of any possible obstruction not part of the original design. In short, do not mount any ancillary equipment in the field of view of the sensors.

When damage occurs in the area of the sensor, it is possible that it may become misaligned and this can significantly impair AEB performance.

Some sensors can automatically self-align to some degree in order to compensate for minor disturbances. Others cannot and will require resetting after every disturbance. Once a sensor has been disturbed, most will require some form of reset and/or recalibration process. This process can vary substantially, from a simple software reset, through simple calibration processes easily undertaken in a workshop environment, to a need for very specialist equipment and/or large spaces to enable dynamic manoeuvres to be safely undertaken. This can have significant cost implications in the event of damage/disturbance. In particular, in the passenger car market it was found that some camera based systems required complex and expensive recalibrations after windscreen replacement whereas others did not require any intervention. Operators should check the specific requirements of the systems being offered by their suppliers with preference for self-aligning systems with low burden recalibration requirements.

15 Repair

If during system maintenance checks (14) any of the sensors are deemed to be faulty or failing they should be replaced as soon as possible. The AEB system's effectiveness and reliability is completely contingent on the performance of the sensors the system is connected to. However, unless the OEM advises to the contrary, the system should fail safe such that it is not necessary to stop the vehicle immediately, for example, at the side of the road.