Transport for London

LONDON BUS SERVICES LIMITED

Specification for new buses: Attachments

Version 1.1

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MAYOR OF LONDON

TRANSPORT FOR LONDON

EVERY JOURNEY MATTERS

1 Preface

This protocol covers the assessments to be carried out for safety features fitted to TFL buses.

Where a vehicle manufacturer perceives that a particular feature should be changed, this should be raised by the manufacturer 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 assessment facility.

Vehicle manufacturers 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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Table of Contents

Attachment 1: London Bus Cycle

1 Introduction

The LBC supersedes the former Transport for London MLTB procedure and encompasses a number of additions to more accurately refect real-world driving conditions. TfL in conjunction with the LowCVP have harmonised both the former MLTB and LUB cycles, enhanced test procedures & setup conditions so that the real-world operating conditions are better reflected during the test process. This has enabled LowCVP and TfL to combine both test cycles into one bus test cycle called the “UK Bus Cycle” or UKBC.

The following preconditions, vehicle setup, in-test procedures and emission standards must be met in order for a TfL designated testing authority to issue LBC certification.

2 Normative References

United Nations Economic Commission for Europe (UNECE) Regulation 101: Uniform provisions concerning the approval of passenger cars powered by an internal combustion engine only, or powered by a hybrid electric power train with regard to the measurement of the emission of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range, and of categories M1 and N1 vehicles powered by an electric power train only with regard to the measurement of electric energy consumption and electric range

3 Definitions

- **Test Authority:** The test authority is an organisation designated by TfL to ensure comparative standards and quality of testing is achieved. Only an accredited testing authority can be used, a list of approved authorities is available on request to TfL
- **Test Bus:** is the vehicle being assessed for its emissions performance
- Kerb Weight:
- **ULW**: Unladen weight of the bus when all fluid levels are filled to recommended levels but no driver, passengers or luggage are on board.
- **GVW:** Gross Vehicle Weight is the maximum weight of the vehicle permitted by law or defined by the vehicle manufacturer, whichever is the lower.
- **Payload capacity:** is the GVW minus the Kerbweight.
- **Test weight:** Is the total mass of the vehicle at which testing shall be undertaken and is equal to the kerbweight plus the passenger load
- **Passenger load**: The passenger load is a mass equal to the number of passengers multiplied by 68 kg plus 75kg to represent the driver.

ECU: Electronic Control Unit

4 Vehicle Preparation

4.1 Testing shall in principle follow UNECE Regulation 101, whole vehicle testing procedure for passenger cars.

4.2 The Test Bus shall be provided either by the manufacturer or by TfL. It shall be specified in accordance with the full applicable requirements of the London bus specification.

4.3 The testing authority should request a vehicle specification sheet detailing the bus model, registration plate, ULW,GVW, passenger capacity: both seated and standing, engine start process).

4.4 Manufacturers and / or bus operators are permitted to be present during preparation and testing but are not permitted to interfere with or adjust the bus engine calibration/ after treatment/ propulsion / energy recovery system without full agreement of the testing authority and TfL. A software ID and serial number will be noted by the test authority and recorded on the test certificate issued. Any adjustments will be noted by the testing authority. Laptops must not be connected during certification runs. ECU flash file must be as used in London operation. Certification runs must be in the same condition and consecutive.

4.5 The test bus shall be weighed by the testing authority to obtain the kerb weight and compared to the ULW as certified on the side of the bus. The kerb weight as measured by the testing authority shall be used for the purposes of the test.

4.6 The test Vehicle shall be loaded with a ballast mass equivalent to the passenger load, which shall be calculated as follows:.

4.6.1 If the seated passenger capacity multiplied by 68 kg per passenger is a mass of half of the payload capacity or more, then the passenger load shall be defined based a passenger number equal to half of the seated capacity.

4.6.2 If the seated passenger capacity multiplied by 68 kg per passenger is a mass of less than half of the payload capacity, then the passenger load shall be defined based a passenger number equal to a quarter of the total passenger capacity (seated + standing).

4.7 Wheels and tyres shall meet the manufacturers specifications. Tyre pressures shall be set to the bus manufacturer's recommendation and shall be the same for both track coastdown and dyno tests.

4.8 The exhaust system shall be checked to ensure it is free from significant leaks. The wheels and tyres used for track coastdown must be to manufacturer specification. Track coastdown and dyno tyre pressure must be the same.

4.9 If a coastdown is required, the test bus must be delivered to the Test Authority ahead of the scheduled test date.

4.10 The Test Bus must be in a safe on-road condition for testing. No warning lights shall be present on instrument panel (except if present due to a modification to allow vehicle to drive on a chassis dynamometer) and power steering MUST be active

5 Test Procedure & Limit Values

5.1 All Buses

5.1.1 The bus is linked to a chassis dynamometer in a test chamber for emissions testing. The test chamber is held at a temperature of 10°C +/- 2°C and vehicle tracking fans are positioned to simulate actual road speed in the test chamber.

5.1.2 All power operated passenger doors shall be opened and closed on every designated bus stop, except during a warmup phase. Doors shall not be opened at any other time during the test.

5.1.3 All bus ancillaries must be turned on including; all interior lighting, exterior sidelights and dipped beam headlamps.

5.1.4 Drivers cab demisters shall be turned on to full.

5.1.5 50% of available opening saloon windows shall be open on upper & lower saloon, evenly distributed and every other window each side.

5.1.6 Interior heating shall be set at 17°C ± 2 □C (if not auto for diesel & diesel-electric hybrid vehicles, 15°C for battery & fuel cell electric vehicles with a ± 1 □C variation during test permitted. Heating shall be switched on at the start of the warm up phase of the test procedure. Doors shall remain closed throughout the warm up phase.

5.1.7 The Test Authority shall monitor the temperature in the centre isle. The combined average saloon temperature per test run shall be recorded on the test certificate. The positions at which temperatures shall be monitored are defined as:

5.1.8 Lower Saloon, 1m above the saloon floor

5.1.8.1.1 centre front of bus (0.5m from windscreen).

a) centre of middle aisle

b) centre rear (0.5m from back of bus).

c) next to front windscreen demister vent

5.1.8.2 Upper Saloon, 1m above saloon floor:

a) centre front of bus (0.5m from windscreen).

b) centre of middle aisle

c) centre rear (0.5m from back of bus).

5.1.9 None of the above temperature readings should fall outside of the permitted range at any time. Temperature variation outside of permitted limits may result in a failed test, subject to review by TfL

5.2 Conventional Diesel and Diesel Electric Hybrid Buses

5.2.1 The UKBC is made up of the following phases based on the original LUB and MLTB cycles but in a revised order.

a) Outer Urban Phase

b) Inner Urban Phase

c) Rural Phase

5.2.2 The Precertification warm up run shall use only the Outer Urban Phase.

5.2.3 Note: In the previous LBSL emission procedure, warm-ups used the full MLTB cycle.

5.2.4 The data from all three phases from the new UKBC is combined to give an average emission performance and is used for certification by LowCVP.

5.2.5 Data from the LBC, i.e. the Outer Urban and Inner Urban phases, is combined to give an average emission performance and is used for certification by TfL. This must be extracted from a full UKBC run. To reflect the changes in procedure and harmonisation with LowCVP into a single UK bus test the Outer and Inner Urban phases extract from UKBC will called London Bus Cycle, LBC.

5.2.6 To clarify;

a) UKBC = Outer + Inner + rural phases

b) LBC = Outer and Inner phases (Previously MLTB)

c) The LBC shall not be tested in isolation. It must be extracted from a full UKBC test. The rural phase of tests must be carried out on every vehicle

d) Pre-test cycle warmup shall be an Outer Urban Phase, and shall be performed prior to each test run.

5.2.7 The buses must arrive at the test site with a full tank of fuel, including Ad-Blue. A one litre fuel sample shall be taken and retained for analysis if required.

5.2.8 Well-to-wheel emissions factors will be taken from the most recently published UK Government's (currently DBEIS) annual average carbon conversion factors for UK fuels e.g. Pump diesel inclusive of biofuel content.

5.2.9 The bus will be run over three validated UKBC cycles of the above test to produce an average result in the report from the extracted Outer and Inner Urban phases (LBC). Cycles must be consecutive unless net energy change (NEC) exceeds +/- 5% in which case another test shall be required.

5.2.10 NEC shall be calculated as per the revised LBC procedure, document available on request to TfL.

5.2.11 Bag analysis of the following emissions is reported for each test. Emissions are reported on each of the three phases (outer, inner, rural) and a combined overall test average, in grammes per kilometre for each pollutant.

a) Engine NOx, NO, NO2, HC, CO, CO2 at 1 Hz

b) Tailpipe NOx, NO, NO2, HC, CO, CO2 at 1 Hz

c) FTIR at tailpipe (NO, NO2, N2O, methane (CH4), NH3)

d) Particle number to PMP method

e) Three dilute ‘bags’ collected and analysed for NOx, CO, HC & CO2

f) PM is measured over the combined Outer and Inner urban phases on one filter, per test cycle. The Rural phase shall be collected on a single filter, per test cycle. The weighted average mass of the Outer/Inner and the Rural phase shall be calculated for the UKBC.

g) Fuel Consumption is calculated using Carbon Balance Method, reported in Litres / 100km

5.2.12 An emission test summary sheet showing all ‘bag’ data shall be provided to TfL showing all ‘legislated’ pollutants along with a TfL emissions summary certificate indicating CO2e.

5.2.13 A “hybrid” bus is defined as a bus that has on board energy storage which is then used to provide vehicle traction.

5.2.14 For hybrid buses that have the ability to operate in electric mode for more than 1km, the effect of the transition from electric to diesel on SCR efficiency will need to be demonstrated. For these vehicles, the test procedure must be agreed with TfL in advance of testing being conducted.

5.2.15 The emissions measured on average over the extracted LBC, shall not exceed the limit values defined below;

Emission	**Double Deck**		**Single Deck**	
	Standard Diesel	**Hybrid Diesel-Electric**	**Standard Diesel**	**Hybrid Diesel-Electric**
CO_2 g/Km	1250	980	900	750
NO_x g/Km	0.5			
PM g/Km	0.01			
PN/Km	6E+11			
$CO_{2\text{-}e}$ g/Km	<5% $CO_{2\text{-}Tot}$			
NH_3	10ppm (average) 25 ppm (peak)			

5.2.16 TfL reserves the right to review emissions test limits at anytime, however limits are not subject to an annualised update on publication of DBEIS annual UK average carbon conversion factors

5.3 Battery Electric Buses

5.3.1 Buses powered by battery electrical energy storage shall be tested over the complete UKBC procedure. It shall be assumed that they are charged using average UK grid-sourced electricity.

5.3.2 Energy consumption over the LBC will be extracted from the full UKBC via the use of current clamps connected to the high voltage (HV) battery.

5.3.3 The vehicle shall be driven over a minimum of 4 consecutive repeats of the UKBC with minimal breaks between the cycles. No prior warm up cycle before test run is required (A short warm up may be performed by the test house, at their discretion).

5.3.4 As no warm-up run is required, the saloon temperature limit of 15 ± 1°C will not apply to the first test of the four consecutive test runs of a battery EV. The correct saloon temperature shall be achieved on all other subsequent runs.

5.3.5 The vehicle shall be fully charged in a set location, less than 500m from the chassis dynamometer. The vehicle should be electrically fully charged using the manufacturers recommended equipment and process. Manufacturers must liaise with the test house to ensure the correct charging equipment is provided for vehicle charging.

5.3.6 If necessary the vehicle shall be moved to the test cell by driving or otherwise, but aiming to use as little energy as possible. This is to save potential costs for facility utilisation whilst charging.

5.3.7 The testing shall commence as soon as possible after the vehicle is removed from charge and within 6 hours as a maximum.

5.3.8 For the purpose of creating a dynamometer set of coefficients, the test house is allowed to use the dynamometer to motor the driven axle up and then allow it to coastdown as controlled by the dynamometer. Otherwise rotation of the wheels should be kept to a minimum.

5.3.9 The distance travelled shall be recorded by the dynamometer. If the vehicle warns the driver to stop and recharge or can not achieve 20km/h then the test shall be aborted.

5.3.10 The manufacturer will provide the ability for the test house to read the traction battery State Of Charge (SOC). This will be recorded by the test house at the start and end of each phase of the LBC.

5.3.11 The manufacturer shall declare the minimum SOC that the vehicle will operate normally at, as well as the maximum available onboard energy that can be used for vehicle operation in kWh.

5.3.12 The vehicle shall be moved, if required, using minimal energy, to be recharged using the same equipment prior to testing not more than 1 hour after the completion of the 4th cycle.

5.3.13 The vehicle shall be fully recharged during which the energy drawn from the mains by the charger shall be measured on a continuous basis as required in Regulation 101, and recorded.

5.3.14 The energy consumption shall be calculated as the total energy consumed by the mains charger (including energy lost during charge process) divided by the recorded distance travelled over the 4 UKBC tests. This shall be expressed as kWh/km.

5.3.15 The overall vehicle emissions factors in g/km will be derived using the consumption calculated in item 37 above in kWh/km and the national grid average emissions as stated by the latest UK Government National averages for UK Grid electricity, as stated in point 21.

5.3.16 From the SOC and distance travelled data this shall be linearly extrapolated to equate to an estimated range distance based on the declared minimum SOC recommended in service to maintain battery warranty.

5.4 Plug-in & Opportunity Charging Hybrid Buses

5.4.1 Manufacturers should discuss the operating characteristic for their plug-in vehicles with TfL and the test house to ensure the optimum test process is adopted.

5.4.2 Please contact TfL directly if you have a technology not considered here or wish to gain further clarity on the test process detail.

5.5 Fuel Cell Buses

5.5.1 The evaluation process is currently under development.

Attachment 2: Noise Test Procedure and Limit Values

1 Introduction

This procedure is intended to provide objective measurement of both exterior and interior noise associated with the bus

2 Normative References

- ISO 10844:2014 – Acoustics: Specification of test tracks for measuring noise emitted by road vehicles and their tyres.
- IEC 61672-1:2013 – Electroacoustics – Sound level meters – Part 1: Specifications
- IEC 60942;2017 – Electroacoustics - Sound Calbrators
- ISO 362:2007 – measurement of noise emitted by accelerating road vehicles – engineering method – part 1: M and N categories
- United Nations Economic Commission for Europe (UNECE) Regulation 51: Uniform Provisions Concerning the Approval of Motor vehicles having at least 4 wheels with regard to their sound emissions - 03 Series of amendments.
- ANSI S3.5-1969, “Methods for Calculation of the Spech Intelligibility Index”

3 Definitions

- **Sound Intensity** is defined as the power carried by sound waves per unit area in a direction perpendicular to that area. Its standard unit is the watt per square metre. Clearly this is a complex measurement involving multiple units and the range of sound intensity can be very large. Thus, sound intensity is usually measured in Decibels (dB).
- **Decibels (dB)** are effectively a logarithmic ratio of sound intensity relative to a threshold level of 0 dB. Zero dB is the quietest sound audible to a healthy human ear. From there, every increase of 3dB represents a doubling of the sound intensity.
- **Sound pressure level (SPL)** is strongly related to sound intensity and is the difference between ambient air pressure and the peak pressure caused by the sound wave and is measured in units of Pascal. However, sound pressure levels are also often expressed in Decibels. Hearing is directly sensitive to sound pressure.
- **Maximum SPL** is the peak value of SPL recorded during any given measurement peridod.
- **L_{EQ}** is the Equivalent Sound Level and is defined as the constant sound level that would produce the same cumulative sound intensity as a sound whose level varies over a defined recording period

- **A-weighting:** Sound intensity is spread out across a wide range of frequencies. However, the human ear is not as good at hearing very high or very low frequencies as it is those in the mid range. The standard decibel scale treats all frequencies equally and is referred to variously as flat, linear or Z weighted. An A-weighted decibel scale dB(A) has been developed that weights sound intensities at lower and higher frequencies differently so it more closely represents a human response to sound at relatively low levels.
- **Articulation Index (AI)** is a quantitative measure of the intelligibility of speech; the percentage of speech items correctly perceived and recorded. An articulation index of 100% means that all speech can be understood, 0% means that no speech can be understood.

4 Test Site

4.1 The surface of the test track and the dimensions of the test site shall be in accordance with ISO 10844:2014.

4.2 The site should allow for free-field propagation of sound, therefore there shall be no obstacles (inclusive of any observers) which could affect the sound field within the vicinity of the microphone.

5 Environmental Conditions

5.1 Ambient air temperature must be within a temperature range of 5°C to 40°C.

5.2 Wind speed, including gusts, must not exceed 5 ms^{-1}.

6 Instrumentation

6.1 Class 1 sound level meters, in accordance with IEC 61672, must be used for exterior and interior measurements.

6.2 Calibration of the sound level meters must be done at the start of every measurement session, using a precision sound calibrator (Class 1 or better, in accordance with IEC 60942).

7 Test Vehicle

7.1 The test vehicle shall be representative of an in-service vehicle, fitted with all London specific devices, and complete with regards to base vehicle build.

7.2 The tyre tread depths shall be a minimum of 1.6 mm and tyre pressures are to be declared by the manufacturer.

7.3 All auxiliary systems must be fully functioning. It is required of the manufacturer to provide a mechanism to enable the cooling fans to operate at maximum speed.

7.4 Any non-conformance must be declared prior to testing, and testing can be continued following the discretion of TfL. It is the manufacturer’s responsibility to ensure that in the event of missing devices, base vehicle components, etc. appropriate ballast is declared.

7.5 The peak power engine speed must be declared prior to test.

8 Dynamic tests

8.1 General

8.1.1 Measurement locations shall be as specified in accordance with ISO 362:2007 (as per ECE R51-03).

8.1.2 If a measurement is not able to be completed, then explanation is required.

8.1.3 All sound measurements shall be A-weighted, fast response.

8.1.4 Maximum or LEQ sound pressure levels (SPL) values to be recorded, dependent on test.

8.1.5 A minimum of 4 results to be recorded (within 2 dB).

8.2 Exterior

8.2.1 Vehicles with Internal Combustion Engines

8.2.1.1 Tests shall be undertaken as defined in UNECE R51-03

8.2.1.2 When the reference point passes line BB, the test vehicle speed must be 35 ± 5 kmh-1 and with an engine speed between 85 and 89% of the peak power engine speed.

8.2.1.3 If the test vehicle speed or engine speed is not met from the above point, then consult ECE R51-3 Annex 3 Para. 3.1.2.2.1.2., and conduct further tests as declared.

8.2.1.4 Between lines AA and BB, stable acceleration shall be ensured.

8.2.1.5 The tests shall be completed with cooling fans disabled.

8.2.1.6 The maximum sound pressure level, or arithmetic average as per ECE R51-3 Annex 3 Para. 3.1.3.2. (if further test speeds were required), shall be declared

8.2.2 Vehicles with Hybrid (Parallel and Series) Powertrains

8.2.3 Tests shall be undertaken as defined in section 8.2.1, but separate tests shall be undertaken with internal combustion engines operational and non-operational.

8.2.4 It is expected that the manufacturer will provide suitable advice or mechanisms to enable full control over the internal combustion engine, else low speed mileage accumulation will be completed to decrease the state of charge of the high-voltage batteries to force the internal combustion engine to operate.

8.2.5 **Stationary Vehicle Sound Emissions and Compressed Air Noise**

8.2.5.1 Tests shall be undertaken in accordance with UNECE R51-03 Annex 3 Para. 3.2. and Annex 5.

8.2.6 **ECE R51-03 Improved**

8.2.6.1 The tests described in section 8.2 shall be repeated but with cooling fans at maximum operational speed.

8.3 Interior

8.3.1 All interior sound measurements shall be completed at the following microphone positions. The microphone shall be positioned 1.0 m vertically above the seat squab in all cases:

a) Driver, right-hand ear position.

b) Forward most seated position, closest to centreline of test vehicle.

c) Directly above rear axle, closest to centreline of test vehicle.

d) Rear 5-way, centre seat.

8.3.2 If upper saloon (i.e. double deck bus), then additional measurements at:

a) Forward-most, closest to centreline of test vehicle.

b) Rear 5-way, centre seat.

8.3.3 Test conditions and measurements shall be:

a) Constant speed, 16 kmh-1, HVAC system off: LEQ SPL, 5 second measurements.

b) Constant speed, 40 kmh-1, HVAC system off: LEQ SPL, 5 second measurements.

c) Acceleration speed, 16 - 40 kmh-1, HVAC system off: Maximum SPL.

9 Static tests

9.1 General

9.1.1 If a measurement is not able to be completed, then explanation shall be required.

9.1.2 All measurements shall be A-weighted, fast response.

9.1.3 Maximum or LEQ sound pressure levels (SPL) values shall be recorded, dependent on test.

9.1.4 A minimum of 4 results shall be recorded (within 2 dB(A)).

9.1.5 Arithmetic average to be declared.

9.2 Exterior

9.2.1 Door Warning Device(s)

9.2.1.1 Microphone position shall be 1 m from outermost face of door aperture (away from centreline of test vehicle), bisection across door width, and 1.2 m high.

9.2.1.2 Maximum SPL shall be declared.

9.2.1.3 Requirements are applicable to each door.

9.2.2 Ramp Warning Device(s)

9.2.2.1 Microphone position shall be 1 m from outermost edge of ramp (away from centreline of test vehicle), bisection across ramp width, and 1.2 m high.

9.2.2.2 Maximum SPL shall be declared.

9.2.2.3 Applicable to each ramp fitted.

9.2.3 Interior

9.2.3.1 Interior measurements for 9.2.6 and 9.2.7 to be completed at the following microphone positions, all are 1.0 m high from seat squab:

a) Driver, right-hand ear position.

b) Forward most seated position, closest to centreline of test vehicle.

c) Directly above rear axle, closest to centreline of test vehicle.

d) Rear 5-way, centre seat.

9.2.3.2 If upper saloon (i.e. double deck bus), then additional measurements at:

a) Forward-most, closest to centreline of test vehicle.

b) Rear 5-way, centre seat.

9.2.4 Door Warning Device(s)

9.2.4.1 Microphone position to be 0.5 m from innermost face of door aperture (towards centreline of test vehicle), bisection across door width, and 1.2 m high.

9.2.4.2 Maximum SPL shall be declared

9.2.4.3 Requirements are applicable to each door.

9.2.5 Ramp Warning Device(s)

9.2.5.1 Microphone position to be 0.5 m from outermost edge of ramp (towards centreline of test vehicle), bisection across door width, and 1.2 m high.

9.2.5.2 Maximum SPL shall be declared.

9.2.5.3 Applicable to each ramp fitted.

9.2.6 **Engine Idle, HVAC system off**

9.2.6.1 The sound pressure level (LEQ) measured over 5 seconds shall be declared

9.2.7 **Engine Idle, HVAC system on**

9.2.7.1 Tests shall be undertaken at maximum fan speed.
9.2.7.2 The sound pressure level (LEQ) measured over 5 seconds shall be declared

10 Articulation Index (AI)

10.1 Further analysis shall be done on measured data using ANSI S3.5-1969, “Methods for Calculation of the Spech Intelligibility Index”.

10.2 Individual AI values to be declared for each measurement location and discrete test.

10.3 Average of AI values to be declared.

11 Sound Pressure Level Limits

Table 11-1. Limits for diesel buses.

Single/ Double	Test Element	Limit, dB(A)	AI, %
Both	8.2.1 ECE R51-03 “Motion”, Exterior	76/78/80[1]	N/A
Both	8.2.1 ECE R51-03 “Static” , Exterior	N/A	N/A
Both	8.2.5 ECE R51-03 “Compressed Air” , Exterior	72	N/A
Both	8.2.6 ECE R51-03 Improved, Exterior	75/77/79[2]	N/A
Single	8.3 Constant Speed, 16 kmh^{-1}, HVAC off, Interior	60	
Single	8.3 Constant Speed, 40 kmh^{-1}, HVAC off, Interior	67	
Single	8.3. Acceleration, 16 - 40 kmh^{-1}, HVAC off, Interior	68	
Double	8.3. Constant Speed, 16 kmh^{-1}, HVAC off, Interior	62/65[3] 52/54[4]	
Double	8.3 Constant Speed, 40 kmh^{-1}, HVAC off, Interior	69/70[5] 62/62[6]	
Double	8.3 Acceleration, 16 - 40 kmh^{-1}, HVAC off, Interior	70/72[7] 60/61[8]	
Both	9.2.1 Door Warning Device, Exterior		N/A
Both	9.2.2 Ramp Warning Device, Exterior	75	N/A
Both	9.2.4 Door Warning Device, Interior	75	N/A
Both	9.2.5 Ramp Warning Device, Interior		N/A
Both	9.2.9 Engine Idle, HVAC off, Interior		
Both	9.2.10 Engine Idle, HVAC on, Interior		

Table 11-2. Limits for hybrid buses

[1] Dependent on engine power output (in kW).
[2] Dependent on engine power output (in kW), -1 dB(A) from ECE R51-03 Para. 6.2.2.
[3] Lower deck Front/Rear positions.
[4] Upper deck Front/Rear positions.
[5] Lower deck Front/Rear positions.
[6] Upper deck Front/Rear positions.
[7] Lower deck Front/Rear positions.
[8] Upper deck Front/Rear positions.

Single/ Double	Test Element	Limit, dB(A)	AI, %
Both	8.2.2 ECE R51-03 “Motion”, Exterior	76/78/80[9]	N/A
Both	8.2.2 ECE R51-03 “Static” , Exterior	N/A	N/A
Both	8.2.5 ECE R51-03 “Compressed Air” , Exterior	72	N/A
Both	8.2.6 ECE R51-03 Improved, Exterior	75/77/79[10]	N/A
Single	8.3 Constant Speed, 16 kmh^{-1}, HVAC off, Interior	59	
Single	8.3 Constant Speed, 40 kmh^{-1}, HVAC off, Interior	66	
Single	8.3. Acceleration, 16 - 40 kmh^{-1}, HVAC off, Interior	67	
Double	8.3. Constant Speed, 16 kmh^{-1}, HVAC off, Interior	62/65[11] 52/54[12]	
Double	8.3 Constant Speed, 40 kmh^{-1}, HVAC off, Interior	69/70[13] 62/62[14]	
Double	8.3 Acceleration, 16 - 40 kmh^{-1}, HVAC off, Interior	70/72[15] 60/61[16]	
Both	9.2.1 Door Warning Device, Exterior		N/A
Both	9.2.2 Ramp Warning Device, Exterior	75	N/A
Both	9.2.4 Door Warning Device, Interior	75	N/A
Both	9.2.5 Ramp Warning Device, Interior		N/A
Both	9.2.9 Engine Idle, HVAC off, Interior		
Both	9.2.10 Engine Idle, HVAC on, Interior		

[9] Dependent on engine power output (in kW).
[10] Dependent on engine power output (in kW), -1 dB(A) from ECE R51-03 Para. 6.2.2.
[11] Lower deck Front/Rear positions.
[12] Upper deck Front/Rear positions.
[13] Lower deck Front/Rear positions.
[14] Upper deck Front/Rear positions.
[15] Lower deck Front/Rear positions.
[16] Upper deck Front/Rear positions.

Transport for London

Attachment 3: Fleet Management Systems (FMS)

(To follow)

Attachment 4: Installation Specification for Fleet Management Systems (FMS)

1 Introduction

This attachment provides requirements relating to the installation of the fleet management systems.

2 Definitions

- **Cable:** this is a generic term used for a wire or lom and an Ethernet cable.
- **Channel:** a channel is an unrestricted free space through which a cable can be easily drawn. It can be specifically designed for the purpose or make use of the existing design.
- **Fixing,** a point to which a cable can be secured.
- **Roof space,** this is the entire void between the inner and outer roof and coving skins.
- **Void:** an enclosed space.

Note: The terms 'channel' and 'void' largely overlap. Channels will normally make use of voids, but the importance is that a channel will offer an unrestricted cable passage from end to end.

3 General Principles for Cabling Access

3.1 Designated cable channels should be provided within the voids between the vehicle body inner and outer skins such that cables can easily be drawn between all equipment compartments and any other part of the vehicle in which equipment may need to be installed.

3.2 In particular,there shall be easy cable routes between equipment compartments and the following areas:

a) Cab dashboard, header panel, offside console and coving, rear bulkhead;
b) Offside and nearside covings, full length of both saloons;
c) Header panels, both saloons;
d) Staircase front, rear and side bulkheads, both saloons, and under stairs area;
e) All power door gear compartments;
f) Front, nearside and rear route/destination display equipment;
g) Engine compartment;
h) Antenna location (forward roof area);
i) Seat stanchions/grab poles;
j) Any further specific locations to be identified.

3.3 It shall be possible to feed and draw cables to and between these areas without the need for extensive dismantling of the coachwork, and definitely without the need for any cutting, drilling or other invasive surgery. This shall be achieved by ensuring that all voids/channels are contiguous and can be accessed easily by the provision of appropriate access points.

3.4 Access points shall be provided at all junctions and changes of direction.

3.5 Where a cable is secured to a fixing point the fixing point must be accessible such that the method used to secure the cable can be easily removed freeing the cable.

3.6 Cables for all the operator equipment fitted shall be separate and clearly identifiable.

3.7 Cables shall be installed so that when being removed they do not snag existing cables or equipment.

3.8 The upper and lower deck coving voids shall have channels on the left and right hand side so that it is possible to freely run cables the full length of the roof. Access shall be provided at regular intervals to facilitate this.

3.9 The channels in the roof space in the upper and lower deck shall be connected by channels running across the bus from left to right. These cross bus channels shall be at the front and rear of the bus. Access shall be provided at regular intervals to facilitate the use of these.

3.10 There shall be fixing points to fix the cables throughout the length of all channels. The fixing points shall be spaced at distances of approx. 200mm.

3.11 It shall be possible to run cables from the equipment enclosure to the lower deck roof space on the left and right hand side. It will be acceptable for the cables to follow the same route to the roof space and then one cable can use the cross bus channelling to access the other side. Access shall be provided at regular intervals to facilitate the use of these.

3.12 It shall be possible to run cables from the equipment enclosure to the upper deck roof space on the left and right hand side. If practical the cables may follow the same route to the roof space and then one cable can use the cross bus channelling to access the other side. Access shall be provided at regular intervals to facilitate the use of these.

3.13 All access panels used to facilitate the above shall have fastenings designed for the purpose of being removed and refitted by authorised personnel. At other times the panel shall remain securely in position.

3.14 All access panel fastenings shall be captive.

3.15 In the event access is restricted in areas such as the bodywork to the side of the upper deck front screen and the stairwell, conduit should be provided.

3.16 Where conduit is required at the upper deck front screen 2 pieces of conduit shall be provided, one will branch and run towards the front screen the other will run towards the rear of the bus.

3.17 Where conduit is required and the path is convoluted with tight bends conduit shall be used in multiple straight lengths.

3.18 All cable routes, channels and ducts shall have access points at regular intervals, and at all junctions and changes of direction, to facilitate the insertion and removal of cables.

3.19 Where it is not possible to have intermediate access points the minimum bend radius of the conduit shall be as advised by the supplier of the conduit.

3.20 All conduit used shall have a smooth internal wall allowing cables to be pushed easily through.

3.21 Where conduit is used it shall be a sufficiently long to be accessible at each end to allow easy access

3.22 The conduit used shall be a bright colour to allow it to stand out from the conduit used for the bus systems.

3.23 If there is a restriction to the dimensions of the conduit due to for instance the body work then the largest dimensions possible shall be used. As an absolute minimum this shall allow an un-terminated Ethernet cable to be drawn through when all cables using the conduit are present.

3.24 Where a cable goes through a bulkhead the cable should be secured in such a way that the integrity of the bulkhead in maintained. The method used should allow for additional cables to be fitted.

4 Enclosure Specification

4.1 An enclosure with a minimum size of at 50dm3 (1/20 m3) approx. 370mm x 370mm x 370mm shall be provided.

4.2 Access to the enclosure shall be provided via secure panels or doors.

4.3 The access doors or panels shall be situated to allow ease of access to installation and maintenance personnel.

Transport for London

Attachment 5: TfL Approved Bus Layouts

MAYOR OF LONDON

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EVERY JOURNEY MATTERS

Attachment 6: Standard for the Fire Retardant Properties of Materials

1 Introduction

This attachment specifies additional standards for materials with respects to their fire retardant capability, over and above those required by Regulation.

2 Normative References

United Nations Economic Commission for Europe (UNECE) Regulation No 118 Uniform technical prescriptions concerning the burning behaviour and/or the capability to repel fuel or lubricant of materials used in the construction of certain categories of motor vehicles

BS476: Fire tests on building materials and structures

UL94: Tests for flammability of plastic materials for parts in devices and appliances

BS5852: Methods of test for assessment of the ignitability of upholstered seating by smouldering and flaming ignition sources.

3 Requirements

3.1 The following schedule of component materials Fire Retardant Standards must by verified by each manufacturer and may be subject to independent assessment during or after submission.

3.2 All internal components in the bus that are not specified below must meet the applicable specification in EC Regulations 118.

3.3 The current minimum LBSL Materials Fire Retardancy Standards for each type of material used on a vehicle are: -

3.4 All materials forming a fire barrier between the engine bay and passenger saloons shall comply with BS476 Class 1, on engine-facing surfaces. This overrides other points below.

3.5 All GRP materials utilized as part of the interior or exterior of the bus shall comply with BS476 Class 3 front surface or BS476 Class 2 back surface, as applicable.

3.6 Melamine Laminates (side or roof panels) shall comply with BS476 Class 2

3.7 All completed flooring (plywood or alternative, including floor covering) shall comply with BS476 Class 2 on upper surface, BS476 Class 3 on lower surface.

3.8 Seat frames (ABS or Polycarbonate) shall comply with UL94V0

3.9 Seat assemblies shall comply with BS5852 Crib 7

3.10 Body Insulation shall comply with BS 476 Class 2

3.11 All internal ABS products (capping and finishing trims) shall comply with UL94V0

3.12 Body and Floor insulation shall comply with BS476 Class 2

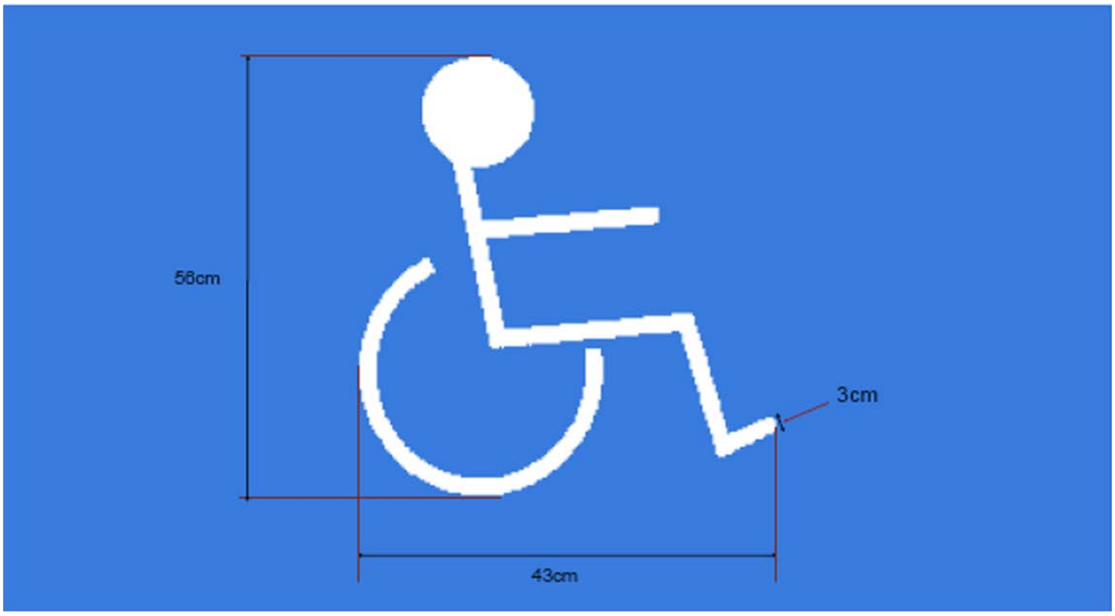
3.13 The above materials, or any treatment used to achieve the standard, must be capable of achieving the required standard when suitably cleaned or maintained over the operational life of the bus.

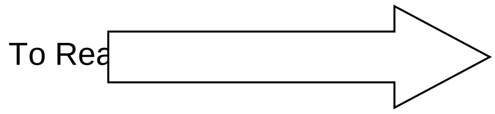
3.14 Replacement components and their associated material must achieve the same minimum standard as the original.

Attachment 7: Wheelchair Floor Logo

1 Whelchair Floor Logo

1.1 The wheelchair floor logo shall be of identical style and approximately identical dimensions as shown below





1.2 The floor covering used across the whole Wheelchair bay, as shown by manufacturers drawings (Attachment 7), shall be coloured in Blue Ref PMS 300 (the same blue as the wheelchair notice). The wheelchair logo shall be coloured in plain White. Mild fleck in the base colours may be added to increase durability of the floor covering.

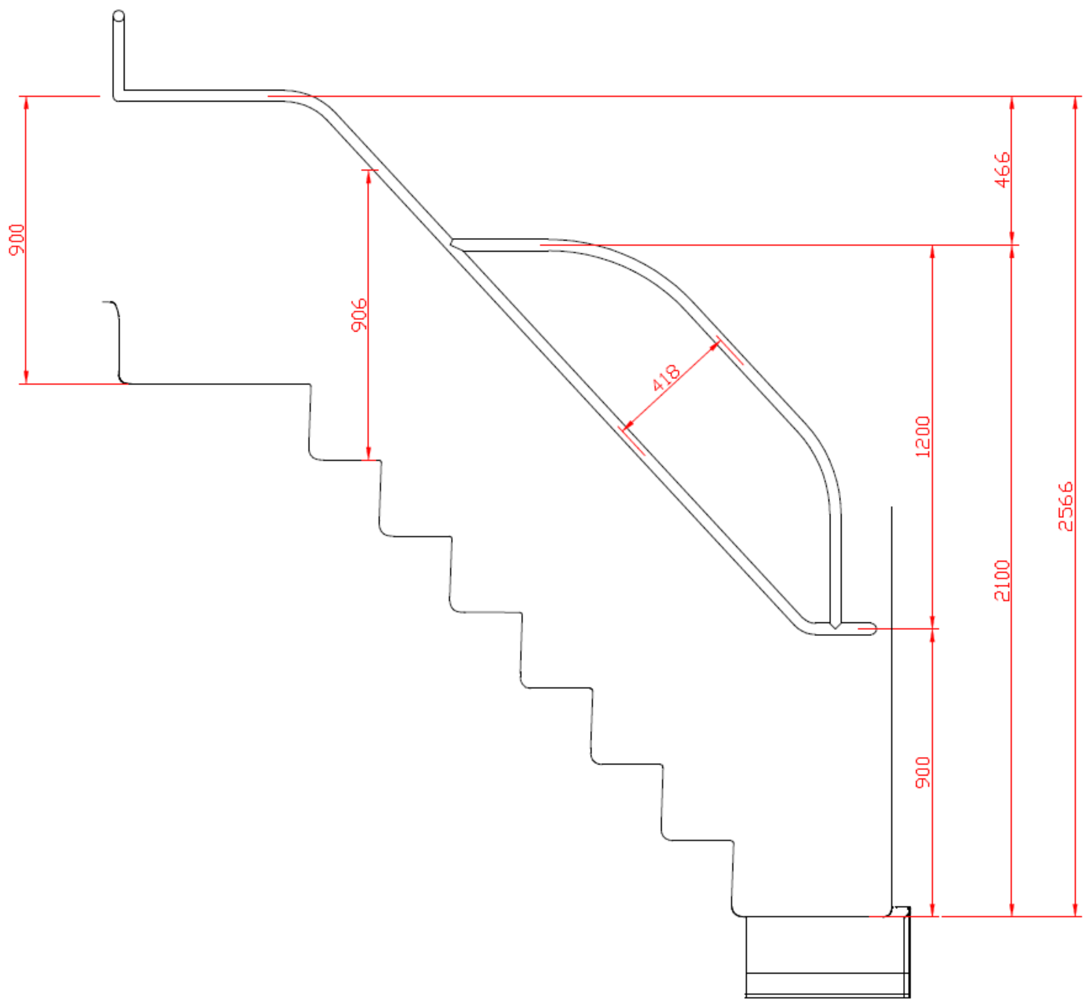
1.3 The logo in the wheelchair bay should always be positioned to demonstrate the actual position of the wheelchair.

1.4 The horizontal centre line of the logo should be on the centre line of the vertical wheelchair back board and be no more than 550mm from the front of the wheelchair board to the centreline of the logo.

Attachment 8: Staircase Handrail Layout

1 Body side staircase handrail

1.1 The size and layout of the staircase and handrail shall be as shown below.



1.2 A straight hand pole at first joint from top of staircase will also be acceptable

1.3 All handrails must be securely fixed to body structure

1.4 Open joints or butt / sharp ends to rails are not acceptable.

1.5 Continuous rails are the preferred arrangement

Attachment 9: Heating Ventilation and Air Conditioning (HVAC)

1 Introduction

This attachment provides specifications, test methods and limit values for the heating ventilation and air conditioning system as required by the main specification document.

1.1 General requirements

1.2 The heating and cooling system should keep the bus saloon at a comfortable temperature throughout the day and year. This specification sets out a controlled test; however we expect the heating system to work over a wider range of climate conditions to be capable of maintaining the bus saloon temperature at 15 degrees evenly throughout the vehicle. Whilst the heating system must be specified to meet the requirements set out in this specification, TfL may choose to set potentially less onerous requirements in service, particularly as we transition to zero tailpipe emission vehicles and range is an issue.

1.3 The objective of this testing is to validate the saloon heating performance of all vehicles and the cooling performance of the upper saloon air cooling systems for double deck vehicles. This test is carried out simultaneously with a test to validate the cooling performance in the driver's cab.

1.4 The bus for testing provided either by the manufacturer or TfL from an operator shall be to the London specification and fitted with all equipment necessary for operation in London.

1.5 The testing authority is designated by TfL to ensure comparative standards and quality of testing is achieved.

1.6 Manufacturers and / or bus operator are permitted to be present during testing but are not permitted to interfere with or adjust the bus setting without full agreement of the testing authority and TfL. All adjustments will be noted by the testing authority.

1.7 The testing authority shall temporarily fit four thermocouples to single deck vehicles or seven to double deck vehicles, three on the lower deck, three on the upper deck and one in the driver's cab.

1.8 Thermocouples on the lower deck are to be fitted in the front, middle and rear centre line, 1.2 metres above floor level.

1.9 The upper deck thermocouples will be located 1.2 metres above the floor of the upper saloon, along the longitudinal centreline of the bus (mid-gangway). The forward / rearward position of the three thermocouples should be as follows;

a) Thermocouple 1 (front) should be located at a position aligning with the middle of the seat base of a seat at the very front of the upper saloon on the nearside.

b) Thermocouple 2 (middle) should be located at a position aligning with the middle of the seat base of a seat on the 7th row (from front) of the upper saloon on the nearside.

c) Thermocouple 3 (rear) should be located at a position aligning with the middle of the seat base of a seat at the very back of the upper saloon on the nearside.

1.10 The driver's cab thermocouple will be located 1.2 metres above the floor for the driver's feet, on the centreline of the driver's seat base when the driver's seat is set to a mid-position on its forward / rearward slider.

1.11 The thermocouples are connected to a data logger capable of recording the temperature at each point at a maximum of 1 minute intervals. The results from the data logger shall be the only results utilised to evaluate the test procedure.

2 Heating Test

2.1 The heating test is to be undertaken in a climatic chamber with the temperature set at zero degrees Celsius. In order to simulate the heating effect from passenger loading, 14 x 130 W heaters are to evenly distributed across the front, middle and rear seats (to include upper deck where applicable by applying 7 to the lower deck and 7 to the upper deck).

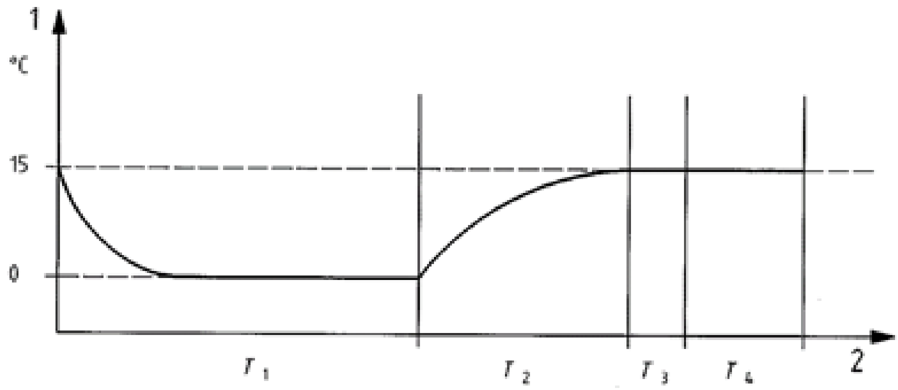
2.1.1 Heating (non zero emission buses)

2.1.1.1 The heating system shall be capable of raising the temperature from zero to 15˚C in 45 minutes, rising to and maintaining 17˚C within 90 minutes. The test should include both doors opening for 10 seconds at a time to simulate 15 bus stops evenly distributed in the first 25 minutes and 13 evenly distributed in the next 20 minutes. Maximum air vents velocity of 5 m/s.

2.1.2 Heating (zero emission buses)

2.1.2.1 Zero emission buses are required to have a pre-heat function. The vehicle is to be pre-heated from zero to 15˚C (T2) and maintained at 15˚C for 1 hour (T3). The zero emission bus should maintain a temperature of 15˚C whilst doors are cycled (T4). A +/- 1˚C degree test tolerance is to be applied. A current clamp will be connected to the HVAC unit to calculate power consumption. The test should include the opening of both doors for 10 seconds every two minutes for one hour. The maximum air vent velocity is 5 m/s.

2.1.3 The testing authority will produce a graph of the test showing the temperature recorded by each individual thermocouple – temperature against time. Ambient chamber temperature will also be included on each graph. A spreadsheet showing the results from each thermocouple and ambient chamber temperature will accompany the graphs.



Key

1 ambient temperature

2 time

T_1 is the cooling time ≥ 5 h;

T_2 is the heating time

T_3 is the stabilising time = 1 h (starts when internal temperature reaches 15 °C);

T_4 is the measuring time = 1 h to measure consumption of thermal energy.

3 Drivers Cab Air conditioning

3.1 Cab / Drivers Screen Demisting

3.1.1 Control should be by manual driver selection, capable of independent operation at all times and raising the temperature from zero to 20˚C within 25 minutes. The test should include both doors opening for 10 seconds at a time to simulate 15 bus stops in the first 25 minutes and 13 in the next 20 minutes. The maximum air vent velocity is 5 m/s.

4 Upper deck Air Cooling Validation Test

4.1 If the drivers cab air conditioning is on, the upper deck air-cooling may function on a reduced setting to balance the cooling system. It must maintain capability of reducing the temperature from 30˚C to 25˚C within 20 minutes. Test should include both doors opening for 10 seconds at a time to simulate 15 bus stops in the first 25 minutes.

4.2 Air Cooling (Upper Deck Only)

4.3 Air cooling should be fully shut down, ‘Off’ <23˚C, ‘On’ >23˚C, gradual build up to maximum capacity output at 28˚C. A maximum cooling capacity capable of a reduction of 5˚C is required when interior saloon temperature is 30˚C over a 30 minute pull down test as described below. If Driver’s cab air conditioning is off, upper deck air-cooling will function

4.4 All bus models will be tested in a temperature controlled chamber at a temperature of 30˚C and must achieve the pull down procedure shown below to validate settings and efficiencies.

4.5 In order to simulate the heating effect from passenger loading, 14 x 130 W heaters are to evenly distributed across the front, middle and rear seats (to include upper deck where applicable by applying 7 to the lower deck and 7 to the upper deck).

4.6 The bus will be put in a closed climate control chamber set at a temperature controlled to hold 30°C (+/- 1°C). It is permissible to open the vehicle windows, doors or roof vents as considered necessary to speed up the soak time.

4.7 The soak condition is considered to be met when all four thermocouples record a steady state of 30°C for 15 minute duration (+/- 1°C) after a minimum soak time of 1 hour. A minimum of 15 minutes of data should be recorded to demonstrate a stable soaked temperature. During this time if the temperature of any sensor drops below 30°C the 15 minutes should be reset.

4.8 The bus should be powered on when the following preparations checks have been completed:

a) All windows, roof vents and doors are closed

b) The thermocouples are correctly positioned

c) The data recorder is running.

4.9 When the bus is switched on the upper saloon air cooling should come on automatically (as above 23°C). The driver's cab air conditioning should be turned on, set to maximum capacity, maximum fan speed and if there is a control to direct the airflow it should be directed to the driver position rather than the windscreen. If possible all dashboard vents, floor vents or ceiling vents in the driver's cab should be directed towards the sensor position as far as practical. If the cab air conditioning has a damper flap to select between fresh air and recirculated air then the recirculated air function should be selected. The drivers windscreen demist system should be turned off and any associated vents closed.

4.10 For the complete duration of the test, the bus should be powered on and should be run at the bus engine idle speed, where applicable. If any recirculation air supply is optional or variable the system should be set to maximum fresh air supply. Any demisting or other system that provides air to the upper saloon must be isolated to not interfere with the test results.

4.11 The data logger timer should then start.

4.12 The test will measure the temperature drop delivered by the system over a 30 minute period on a minute by minute basis.

4.13 All three upper saloon thermocouples should achieve the target reduction temperature of 25°C within the first 20 minute period and be capable of holding the temperature below the 25°C for the remaining 10 minutes. Averaging the results is not acceptable over time or between the sensors.

4.14 The testing authority will produce a graph of the Pull Down showing the temperature recorded by each individual thermocouple – temperature against time. Ambient chamber temperature will also be included on each graph. A spreadsheet showing the results from each thermocouple and ambient chamber temperature will accompany the graphs.

Attachment 10: Destination Display Output

Off Side Front

Ultimate Destination

1160mm x 330mm
Sight Size

Near Side Front

Route Number

450mm x 330mm
Sight Size

Near Side Route Number and Destination

Route Number Forward
270mm x 210mm
Sight Size

Side Destination Rearward
687mm x 210mm
Sight Size

Rear
Route Number

450mm x 330mm
Sight Size

Attachment 11: CCTV

(To follow)

Attachment 12: Exterior and Interior Notices

(To follow)

Attachment 13: Operator Codes and Fleet Number Identification

1 Operator Code Requirements

1.1 The following operator codes must be used on the roof identification on the first line followed by the operator's fleet number on the second line. The codes must be fitted at the rear of the roof panel in the white panel area as shown in the diagram below

Operator	Code
Abellio	ABL
Arriva	ARL
Go Ahead Group	GAG
CT Plus	CTP
Metroline	MTG
Quality Line	QUL
Stagecoach	STC
London United	LUB
London Sovereign	SOV
Sullivan Buses	SVB
Tower Transit	TTO
University Bus	UNO

Typical Operator Code and Fleet Number Arrangement

Rear of Vehicle

1.2 All Characters shall be in New Johnston Bold font

1.3 Characters shall be in Matt Black cut out vinyl

1.4 Characters shall be 350mm in height

Attachment 14: Free Issued Equipment

(To follow)

Attachment 15: Automated Emergency Braking (AEB) Assessment Protocol

1 Introduction

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

1.1 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, Class II.

1.2 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; and
- 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. Manufacturers 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 a vehicle manufacturer 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.

2 Normative references

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

- 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

3 Definitions

For the purpose of this Protocol:

3.1 **AEB: Automated 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:

a) 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.
b) AEB Pedestrian – an AEB system that detects and responds to imminent collisions with pedestrians.
c) AEB Cyclist – an AEB system that detects and responds to imminent collisions with pedal cycles and their riders.

3.2 **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.

3.3 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.

3.4 **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.

3.5 **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.

3.6 **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:

a) 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.
b) 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.
c) 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.
d) Bus-to-Pedestrian Nearside Adult 75% (BPNA-75) – a test scenario

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.

e) 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.

f) 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.

g) 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.

h) 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.

i) 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.

3.7 **Test Service**: The organisation undertaking the testing and certifying the results to the Approval Authority.

3.8 **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[17]:

a) 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.

b) 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.

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

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

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

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

3.9 **Vehicle Manufacturer:** the business responsible for the manufacture of the bus being assessed.

3.10 **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.

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

4 Reference system

4.1 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 1**, below.

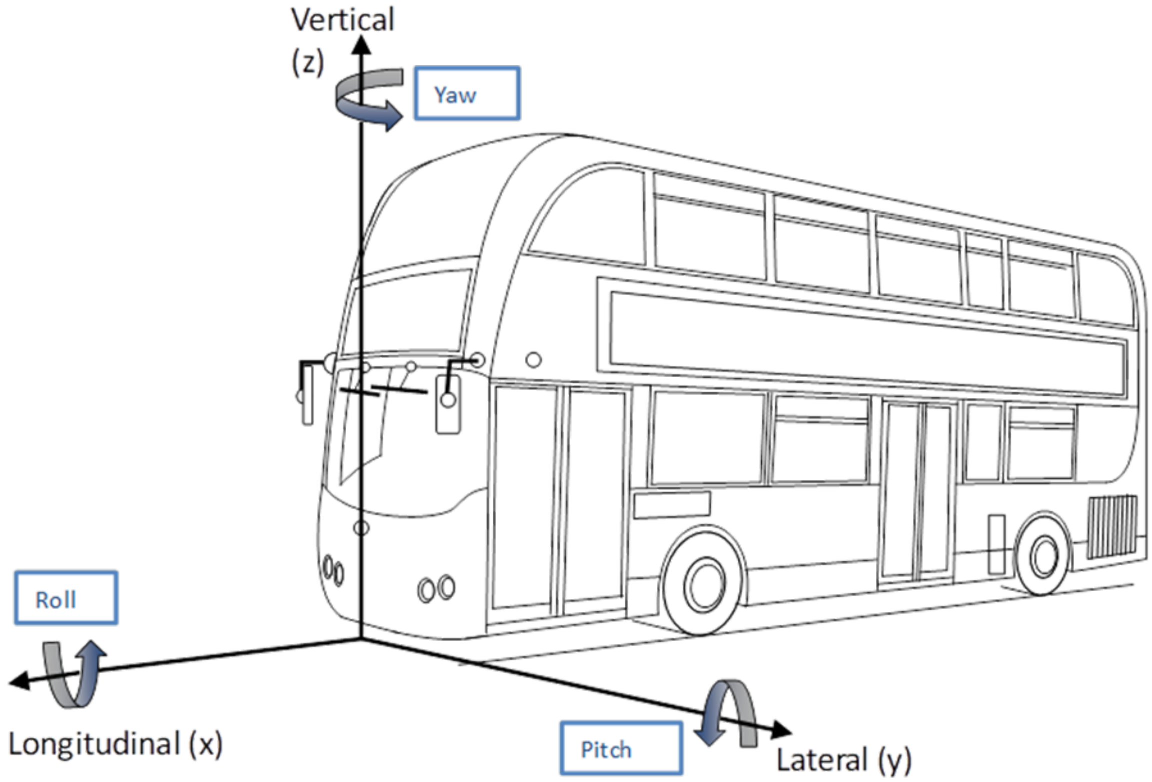


Figure 1: Local co-ordinate system and notation

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).

4.2 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.

5 Measurements and variables

5.1 Variables to be measured

Table 3 and Table 4 show the variables which must be measured, along with the minimum operating ranges and measurement accuracy required.

Table 3: Variables to be measured continuously during each and every 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 4: Variables to be measured periodically, ideally before each test but at least every 30 minutes, 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%

5.2 Measuring equipment

5.2.1 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).

5.2.2 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.

5.2.3 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.

5.3 Variables to be derived from the measurements

5.3.1 General

The variables that shall be calculated from the measured data are defined below:

Table 5: 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 0.
V_{Test_VUT}	Nominal initial velocity of VUT	Defined by specific test condition

Variable	Description	Definition/Derivation Method
	before braking applied	
$V_{Test\_VUT\_Act}$	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 0
V_{Impact_TT}	Test Target velocity at the moment that it collides with the VUT	See section 0.
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 the VUT	Distance in y-axis between the centreline of the vehicle at the foremost point of the VUT at the point of impact, and the same point if

Variable	Description	Definition/Derivation Method
		the VUT had followed its intended straight path.

5.3.2 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 2, below:

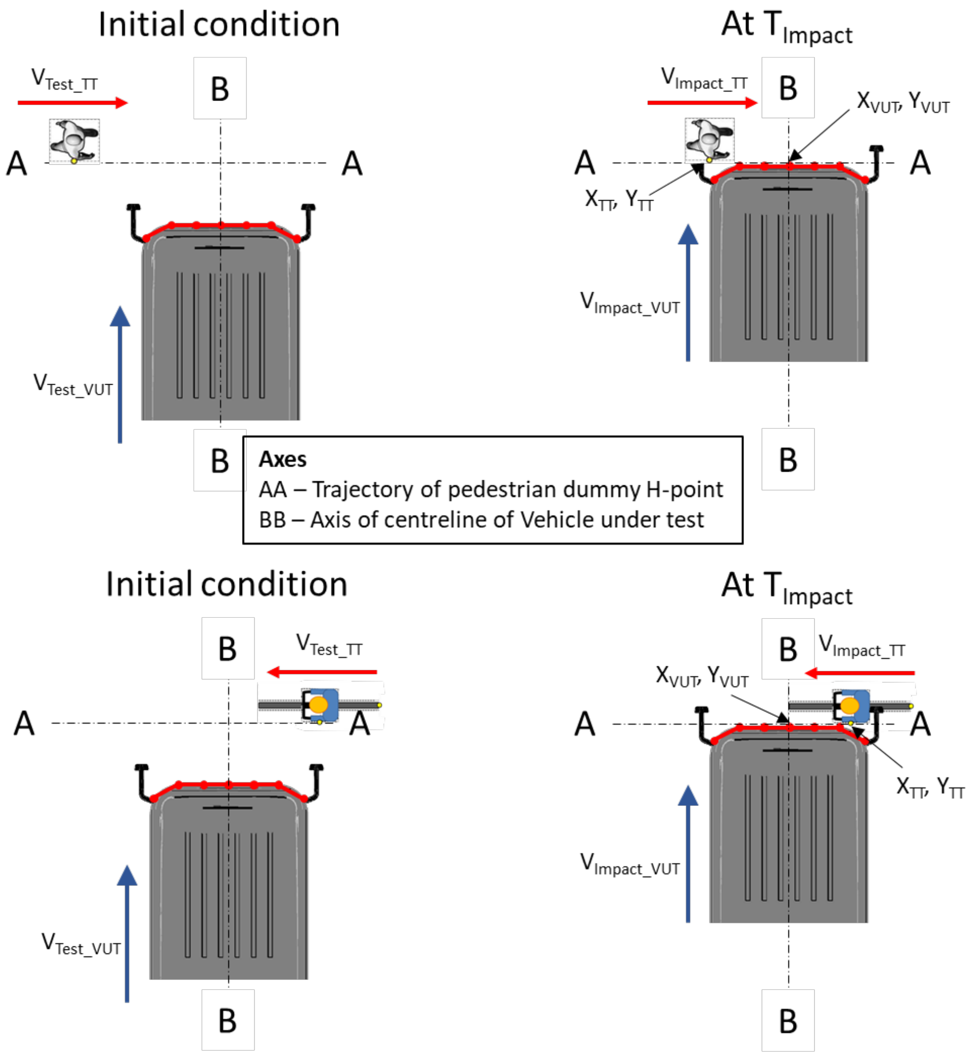


Figure 2: Illustration of the definition of the moment of impact (Pedestrian (top), Cyclist (bottom))

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. The x,y coordinates of each point shall be provided by the vehicle manufacturer and checked by the organisation undertaking the tests.

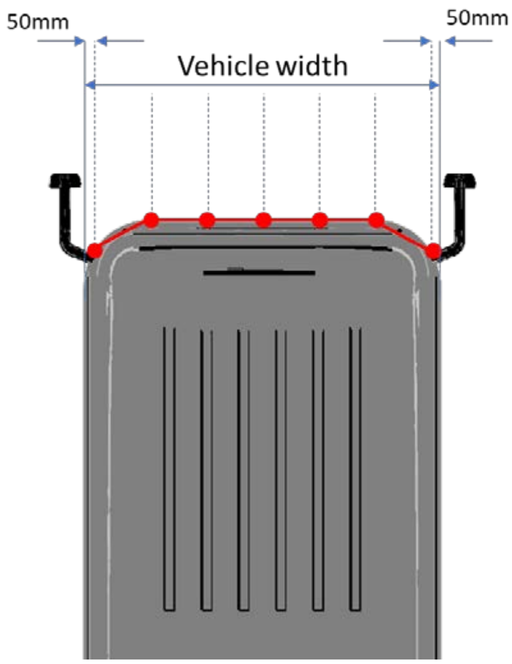


Figure 3: Virtual profile for determining impact for VUT

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[18]. Thus, a single x position is defined representing the rear of the VUT and impact occurs when the foremost point of the virtual profile for VUT crosses the x position at the rear of the EVT/GVT.

For the pedestrian targets (EPT) a virtual box is defined around the target with dimensions as shown in Figure 4, below. 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.

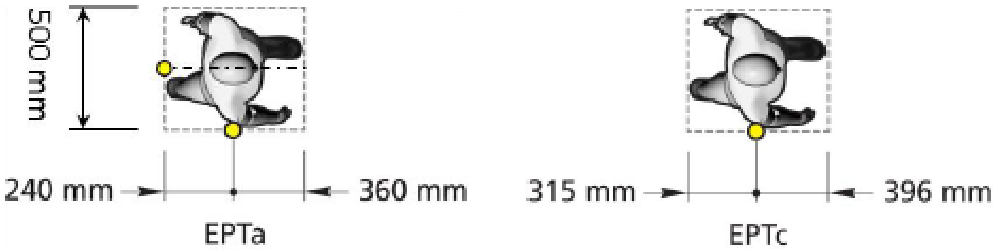


Figure 4: Virtual box around EPT

[18] 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 5, below. 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 5) and for the longitudinal scenario the most rearward point on the rear wheel is used.

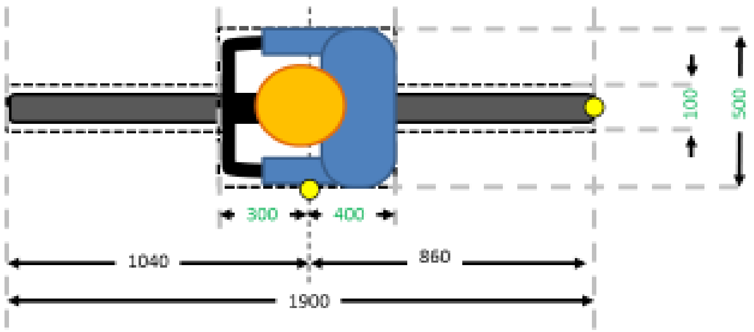


Figure 5: Virtual box around EBT

6 Test conditions

6.1 Test track

6.1.1 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.

6.1.2 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.

6.1.3 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 be 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

6.2.1 Tests shall be conducted in dry conditions with ambient temperature above 5°C and below 40°C.

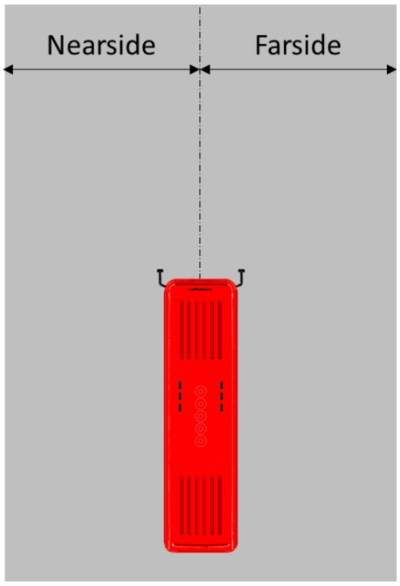
6.2.2 No precipitation shall be falling and horizontal visibility at ground level shall be greater than 1km. Wind speeds shall be below 10m/s to minimise EPT, EBT and VUT disturbance. The Test Service may, at their discretion repeat tests if unexpected results are observed at a time when wind speed exceeds 5 m/s.

6.2.3 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.

6.2.4 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).

6.3 Surroundings

6.3.1 Tests shall be conducted in 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 within a minimum lateral distance of the VUT test path as per table below, 1.0m around of the EPT and EBT and within a longitudinal distance of 30m ahead of the VUT when the test ends (**Figure 6**).



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 6: Free surroundings

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

6.3.3 The general view ahead and to either side of the test area shall comprise of a wholly plain man made or natural environment (e.g. further test surface, plain coloured fencing or hoardings, natural vegetation or sky etc.) and 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

7.1.1 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

7.2.1 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 vehicle manufacturer. 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

7.3.1 The vehicle shall be subject to a vehicle (in-line) geometry check to record the wheel alignment in test condition. This shall be done with the vehicle at kerb weight.

7.4 Vehicle mass

7.4.1 The AEB shall be operative at all states of load. However, it 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

7.5.1 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 Vehicle Manufacturer.

7.6 Measuring front end geometry

7.6.1 The x-y co-ordinates for the virtual front-end vehicle contour given by the Vehicle Manufacturer 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 Vehicle Manufacturer will be used. When the co-ordinates measured by the Test Service are not within 10mm of those supplied, or where the Vehicle Manufacturer 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

8.1.1.1 If requested by the Vehicle Manufacturer, 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

8.1.2.1 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 or corroded.

8.1.3 Tyre conditioning

8.1.3.1 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.

8.2 Alignment checks

8.2.1 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.

8.2.2 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.

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

8.2.4 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.

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

8.3 Car tests

8.3.1 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.

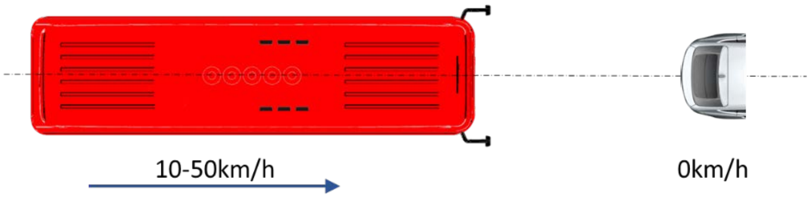


Figure 7: BCRs Scenario

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

8.3.2 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 ($V_{TEST_VUT} - V_{IMPACT_VUT} \geq 5$km/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 ($V_{TEST_VUT} - V_{IMPACT_VUT} \geq 5$km/h), and the test speed (V_{TEST_VUT}) was greater than 10 km/h, then first, 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 ($V_{TEST_VUT} - V_{IMPACT_VUT} < 5$km/h), or if the Vehicle Manufacturer 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 Vehicle Manufacturer, Test Service or Approval Authority. If so, the Test Service shall provide all data from repeat runs to the Approval Authority for their consideration.

8.3.3 Test execution

a) If requested by the Vehicle Manufacturer, 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 Vehicle Manufacturer 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. Accelerate the VUT to the test speed, position it on the test path and achieve steady state conditions before T_0 (TTC=4s).

d) 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.

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

f) V_{VUT} = 0 km/h; or

g) VUT has made contact with the TT.

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 T_{AEB}:

a) V_{VUT} ≥ Test Speed and ≤ 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; and

e) Centreline of the Test Target is within ± 5cm 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.

8.4 VRU crossing tests

8.4.1 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 8 to Figure 10, below. FCW is not assessed.

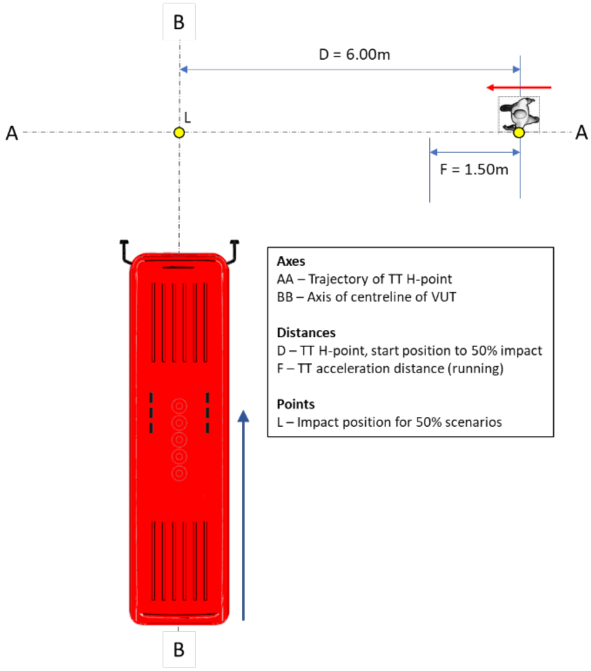


Figure 8: BPFA-50 scenario, adult running from the farside of the road

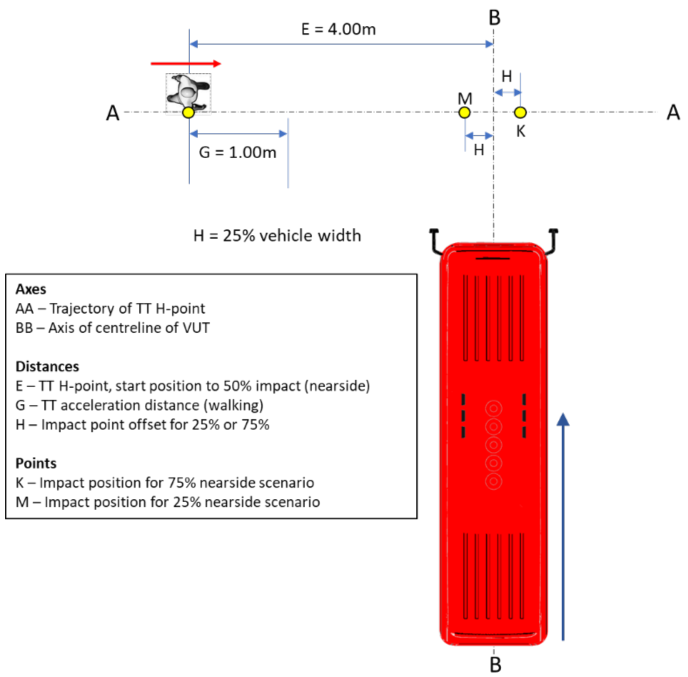


Figure 9: BPNA-25 & BPNA-75 scenario, adult walking from the nearside of the road

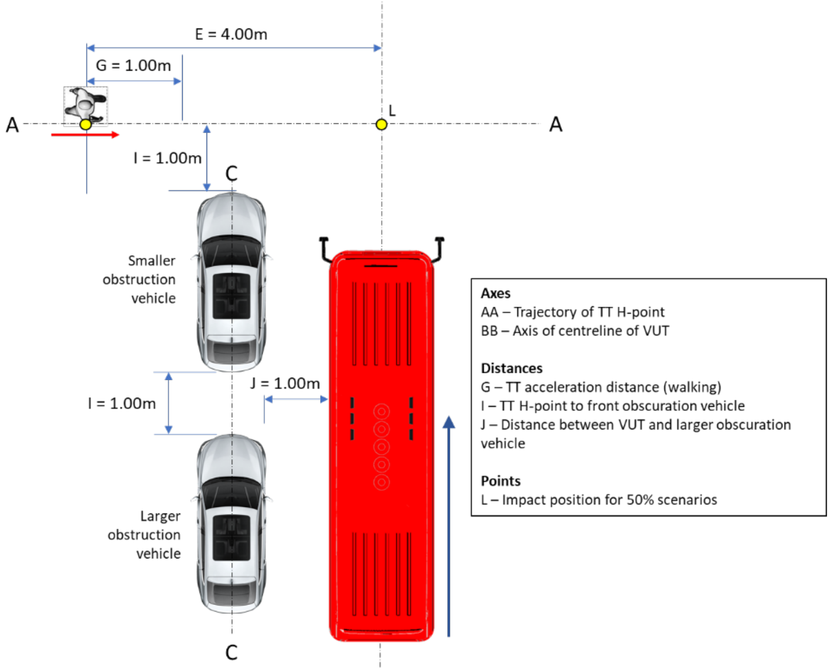


Figure 10: BPNC-50 scenario, child running from the nearside from behind obstructing vehicles

Figure 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 6**, below.

Table 6: 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 6**, then 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.

8.4.2 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) a Vehicle Manufacturer 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 shall be as defined in section 8.3.2.

8.4.3 Test execution

The process for executing each test shall be as defined in section 8.3.3. 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; or

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

8.4.4 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 ≤ 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; and

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:

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

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.

8.2 VRU longitudinal tests

8.4.5 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 11**, below.

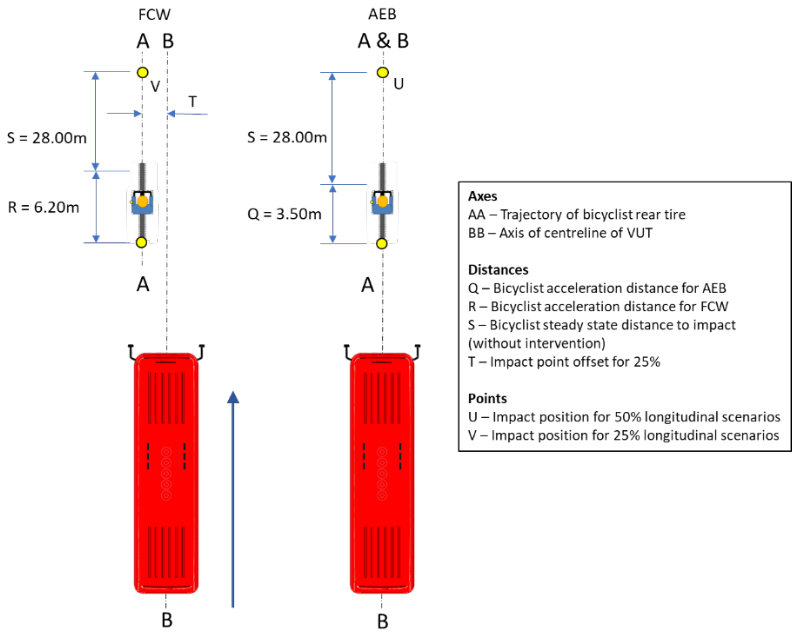


Figure 11: Longitudinal bicyclist scenarios; BBLA-25 (left) & BBLA-50 (right)

The tests to be undertaken are as defined in **Table 7**, below.

Table 7: 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	

8.4.6 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) a Vehicle Manufacturer 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 8.3.2.

8.4.7 Test execution

The test execution shall be as specified in section 8.3.3, 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.

8.4.8 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) Test Speed ≤ V_{VUT} ≤ 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 and

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 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 12, below.

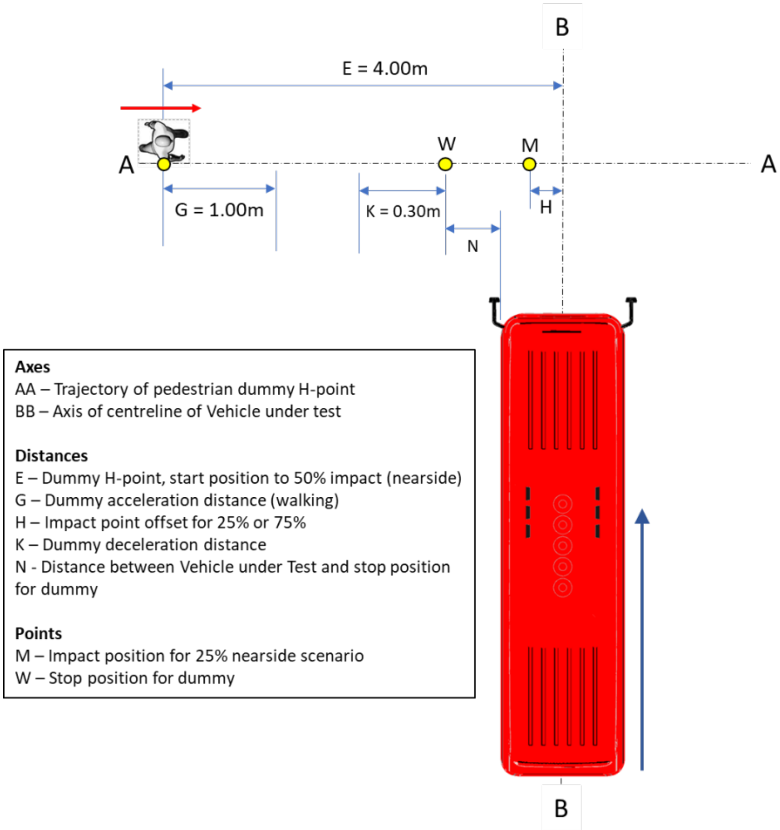


Figure 12: TT start and stop positions in aborted crossing test

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) Test Speed ≤ V_{VUT} ≤ Test Speed + 0.5 km/h;
b) Lateral deviation from VUT Test Path = 0 ± 0.05m;
c) Lateral deviation from TT path = 0 ± 0.05m;
d) Lateral Velocity of deviation from the Test Target path = 0 ± 0.15m/s;
e) VUT Yaw Velocity (Ψ'_{VUT}) = 0 ± 1.0˚/s; and
f) 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 13, below and defined by the corridor specified in XY co-ordinates in Appendix A.

8.6.1.1 False positive test

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), which is reduced to 0.2m (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.

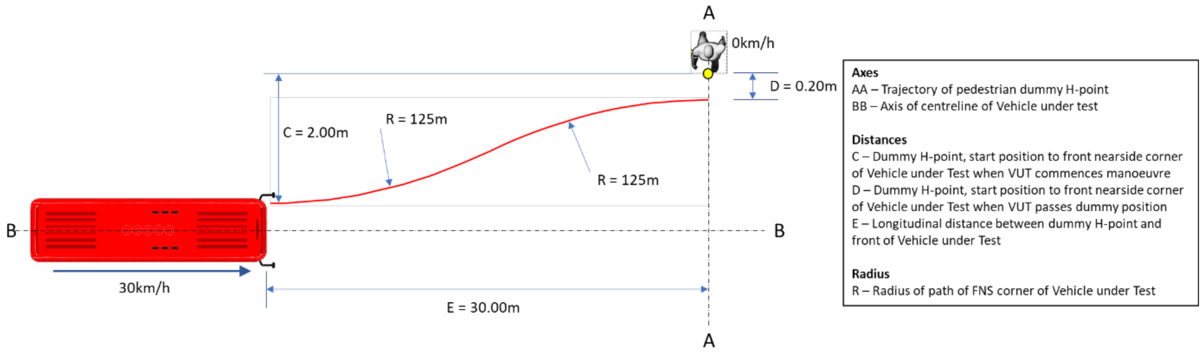


Figure 13: VUT Path and pedestrian position in false positive bus stop test

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

8.6.1.2 True positive test

In the true positive test 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) as defined in Figure 14, below.

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.

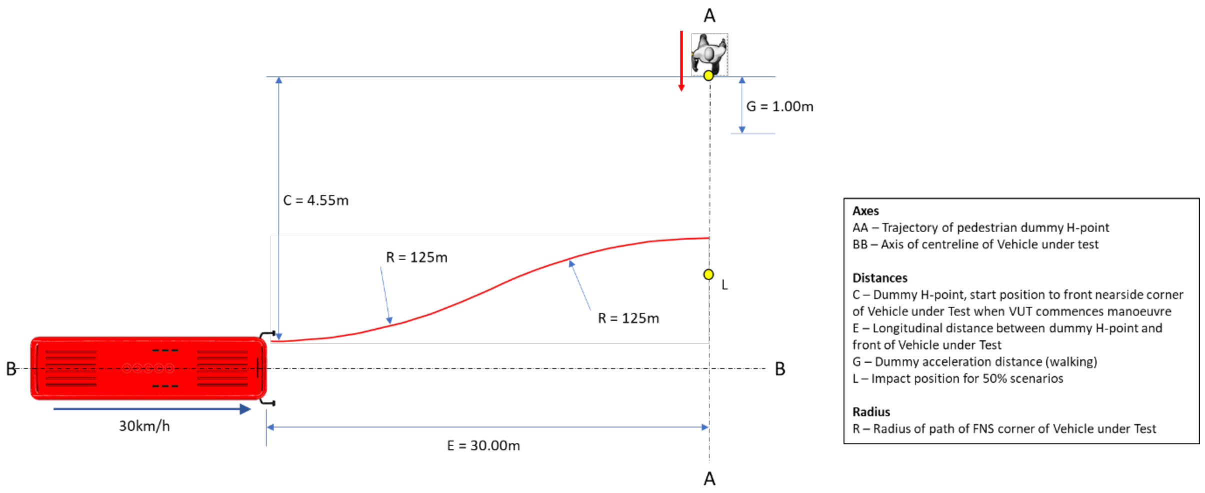


Figure 14: VUT path and TT position in true positive bus stop test

8.6.2 Sequence and number of test runs

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

8.6.3 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 by the corridor. When the front of the VUT reaches a position of 30m from that of 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.

8.6.4 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 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) Test Speed ≤ V_{VUT} ≤ Test Speed + 0.5 km/h; or

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 Vehicle Manufacturer supplied test data

The procedure as outlined above is intended to be applicable as an independent assessment of a bus equipped with AEB capable of standing alone. Where a Vehicle manufacturer 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 Vehicle Manufacturer's result, ensuring a broad cross section of variables are covered:

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; and

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

9 Assessment of results

9.1 Assessment criteria

9.1.1 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.

9.1.2 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:

Table 8: 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%

9.1.3 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:

9.2.1 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

9.2.2 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

9.2.3 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).

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

9.2.5 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 according to **Table 9Error! Reference source not found.**, containing hypothetical results as a worked example.

Table 9: 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

The weightings for the VRU crossing tests and a worked example are shown in **Error! Reference source not found.**.

Table 10: 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 11** below shows the scenario weighting and the calculation with a worked example.

Table 11: 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 T_{FCW}. The calculations are illustrated with a worked example in **Table 12**.

Table 12: 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 ($A_{PEAK\_VUT\_Long}$) measured during any activation. Where the system does not activate $A_{PEAK\_VUT\_Long}$ 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

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

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

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

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

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

g) $A_{PEAK\_VUT\_Long} = 0\ m/s^2$: 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 shown in the worked example in **Table 13Error! Reference source not found.**, below.

Table 13: 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 below.

Table 14: 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

10.1 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; and

c) Reference information.

10.2 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 8.3.2; and

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

10.3 To confirm protocol compliance, the Test Service shall:

a) Make available the video recordings as specified in section 0;

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; and

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

10.4 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; and

j) Test date(s).

Annex 1 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 4.2, assuming the vehicle width is 2.5m. For different vehicle widths then 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: Automated Emergency Braking (AEB) Guidance Notes

1 Introduction

Automated 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 manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 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.

2.1 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. 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 bus manufacturer 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.

A bus manufacturer 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 bus manufacturer must be able to present certificates to TfL as evidence that the bus brake system will continue to operate safely.

2.2 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.

2.3 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 manufacturer 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 bus manufacturer 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 manufacturers 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.

2.4 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.

2.5 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 manufacturers 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 manufacturers 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.

2.6 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 automated 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.

3 Training

3.1 For test houses

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 houses 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.

3.2 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.

3.3 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 manufacturer 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.

3.4 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 manufacturers' 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 bus manufacturer 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.

4 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs. Each manufacturer will have a set of between manufacturers, 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.

5 Repair

If during system maintenance checks (4) 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 manufacturer 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.

Attachment 17: Intelligent Speed Assistance (ISA) Assessment Protocol

1 Introduction

This document presents a procedure for objectively assessing the performance of systems fitted to new buses in order to restrict their speed to within the prevailing speed limit. These systems are collectively known as Intelligent Speed Assistance (ISA).

ISA systems are provided to assist drivers to keep within the speed limit, but do not absolve the driver of this responsibility. These systems act to limit further accelerator input when the bus is at the speed limit, but no warning is issued to the driver unless a fault is present.

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, Class II

3 Purpose

The purpose of this assessment is to test the ability of the ISA system fitted to a bus to restrict the speed of the bus to the prevailing speed limit. This protocol provides all parties involved (specifically bus OEMs, test houses, assessors) with instructions regarding the test and assessment of ISA.

4 Normative references

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

- London Bus Technical Specification: Safety Features - Intelligent Speed Assistance (ISA)
- Regulation No 89 of the Economic Commission for Europe of the United Nations (UN/ECE)

Note that miles per hour (mph) is used throughout this document, and takes precedence over any kilometres per hour (km/h) figure used which is for reference only.

5 Definitions

For the purpose of this Protocol:

- **AA: 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.
- **ISA: Intelligent Speed Assistance** – system fitted to a vehicle to restrict its speed to the prevailing speed limit.
- **ROM: Restricted Operating Mode** – A condition where the ISA system actively prevents acceleration beyond the prevailing speed limit
- **TS: Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority.
- **Test Speed** – The speed indicated on the VUT speedometer. The tolerances applied shall be the target speed $^{+0}_{-1}$ mph.
- **Test Track** – Any sealed area of carriageway without general access to the public.
- **TfL Digital Speed Map** – An electronic map provided by TfL which indicates the speed limit of roads within Greater London.
- **VM: Vehicle Manufacturer** – The body responsible for providing a completed bus to a bus operator
- **VUT: Vehicle Under Test** - means a vehicle that is being tested to this protocol.

6 Test Conditions

6.1 Test environment

The test procedure requires that the VUT is tested by driving it both on road, and in areas away from the public (referred to as a test track).

6.1.1 A test track area shall be used by the TS which permits the various tests required. The coordinates and speed limits shall be provided to TfL which will incorporate the details in to the TfL Digital Speed Map. The test track shall:

a) Be a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%; and
b) Be paved and shall not contain any irregularities (e.g. large dips or cracks, manhole covers) which might excessively slow the VUT.

6.2 An on-road route shall be devised by the TS which starts at least 1km outside the geographical area covered by the TfL Digital Speed Map. The route shall travel through the TfL Digital Speed Map and out of the other side to a point at least 1km outside of the area covered by the TfL Digital Speed Map. The route shall incorporate a 10mph (16.1km/h) section of a bus station, where the bus will be stopped and the system powered down, restarted and the journey continued. The route shall also incorporate 20mph (32.2km/h), 30mph (48.3km/h), and 40mph (64.4km/h) sections with transitions between each.

6.3 Weather and lighting

6.3.1 Tests shall be conducted in dry conditions with ambient temperature above 5°C.

6.3.2 No precipitation shall be falling.

6.3.3 Wind speeds shall be below 10m/s to minimise the effect of wind on bus speed. In case of wind speeds above 5m/s during test, the validity of the test is decided at the discretion of the TS using the VM predicted performance.

7 Pre-test submissions

7.1 It is necessary for the TS to understand details of and make certain additions to the ISA system being tested. Therefore the following documentation shall be provided by the VM prior to any testing:

a) Full identification of the ISA system hardware and software versions, and the applicable model of bus.

b) A test vehicle with an indicator system (visible to the bus driver) that displays the maximum speed limit of the ISA system when in restricted operating mode.

c) Evidence from an appropriately certified body that the system has been tested and approved as per the requirements of adjustable speed limitation devices within Regulation No 89 of the Economic Commission for Europe of the United Nations (UN/ECE) at speeds of: 10mph (16.1km/h); 20mph (32.2km/h); 30mph (48.3km/h); 40mph (64.4km/h).

d) A statement describing how the ISA system operates.

e) A written declaration that this ISA system does not have adverse effects on fuel consumption or emissions.

f) A statement regarding any relevant Type Approvals which apply to the ISA solution. If Type Approvals are not required then a statement of this shall be provided.

g) A description of the applicable iBus system type (1 or 2) and a schematic diagram of the GPS antenna connection to the ISA system.

h) Detail of London Buses' approval for use of the Radio Frequency splitter (if used).

i) A schematic diagram and description of where the ISA system obtains the vehicle speed information.

j) A demonstration of the receipt of a speed signal from either the FMS or CAN to the ISA system.

k) A statement confirming for which option the ISA is specified from either:

l) Option 1 – No intervention by any vehicle system to enforce a speed reduction; or

m) Option 2 – No intervention by the foundation brakes to enforce a speed restriction, however energy recovery and engine retardation is permitted.

n) A statement as to whether speed restriction is assisted by any system, and a description of the operation of this system.

o) A statement as to whether a function that provides an overspeed notification to the bus driver is fitted, and provide details of the form of this notification.

p) A statement that the vehicle performance characteristics are unaffected when the vehicle is not in restricted operating mode.

q) Instructions regarding how the ISA system is enabled and disabled.

r) A test vehicle modified with additional in-line switches to individually isolate cabled connections to the GPS, FMS and/or CAN speed signal in to the ISA system.

s) A description of potential failure modes of the ISA system.

t) A description of all mapping formats from the file format list provided in the London Bus Technical Specification which can be used on the ISA system.

u) A statement regarding how any bus mapping can be updated on an ad-hoc basis.

v) Instructions with/in the application for the updating of the digital speed map, and include any equipment necessary to facilitate this updating for the test. Two off-road test track-specific maps shall be provided, with different zones and speed limits as agreed with the test body. This shall also include the description of how the map update is protected from unauthorised access.

w) A declaration regarding any additional antenna for updating the digital speed map.

x) Instructions and any necessary equipment to read and clear any ISA system fault. A list of possible faults and their codes shall be provided and guidance on how to trigger these faults.

y) A photo of the ISA symbol as shown on the driver information screen.

z) A photo of the speed limit symbol as shown on the driver information screen.

aa) A copy of the ISA fitment information to the driver (sticker, light, voice instruction etc), in a suitable format such as a photo or video recording.

8 System checks

8.1 A number of checks should be made by the Test Service whilst the vehicle is static:

8.1.1 The TS shall physically observe a cabled connection from the GPS antenna to the ISA system. The test shall be deemed to have failed if this cabled connection cannot be observed.

8.1.2 Any speed retardation system declared by the VM shall be investigated and observed by the TS.

8.1.3 The TS shall enable and disable the system using the instructions provided by the VM.

8.1.4 The TS shall look for and attempt to non-destructively disable the system in those areas of the VUT accessible to the driver within a period of 2 minutes without tools. The system shall be deemed to fail this requirement if the ISA system can be disabled without tools within a 2 minute period.

8.1.5 The TS shall observe if the following dash lamps are fitted:

a) Green – The system is functioning correctly within the Digital Speed Map area;

b) White – The vehicle is not within the Digital Speed Map area; and

c) Amber – The ISA system has a fault.

d) The system shall be deemed to have failed if all the dash lamps are not fitted.

8.1.6 The TS shall, if possible, trigger an ISA system fault. The illumination status of the green, white, and amber dash lamps shall be recorded. The system shall be deemed to have failed if the green lamp is not extinguished and the amber lamps are not illuminated when a system fault is caused.

8.1.7 The TS shall, if possible, trigger a condition which would make the ROM not be activated. The illumination status of the green, white, and amber dash lamps shall be recorded. The system shall be deemed to have failed if the green lamp is not extinguished and the amber lamps are not illuminated when a system fault is caused.

8.1.8 The TS shall load each applicable mapping format and test that this has properly applied by driving the vehicle on the off-road test track and testing for the correct application of 20mph (32.2km/h) and 30mph (48.3km/h) speed limits. The test shall be deemed to have failed if this information is not provided. The test shall be deemed to have failed if these mapping formats fail to properly load and apply.

8.1.9 The TS shall observe that any outdated Digital Speed Map can be completely removed from the ISA system and replaced with an updated map. This test may require a computer connection to the ISA system to check upon file deletion and addition, and the system shall be deemed to have failed if outdated Digital Speed Maps cannot be completely removed.

8.1.10 The TS shall make an ad-hoc change to the Digital Speed Map. The system shall be deemed to have failed if in the assessment of the TS the bus Digital Speed Map cannot be updated on an ad-hoc basis.

8.1.11 Additional antenna for updating the Digital Speed Map is prohibited. The presence of such an antenna shall result in test failure.

8.1.12 The TS shall cause a fault within the ISA system and record the illumination status of the amber dash light. The system shall be deemed to have failed if the amber dash light does not illuminate.

a) The TS shall interrogate the ISA system for the fault and record if it matches the caused fault. The system shall be deemed to have failed if the system fault recorded does not match the system fault caused.

b) The TS shall clear the fault from the system and observe the illumination status of the amber light. The system shall be deemed to have failed if the system cannot be cleared and if the amber light does not extinguish.

9 Test procedure

9.1 Track testing

9.1.1 The following tests shall be undertaken at a suitable test track (see 6.1.1).

9.1.2 The VUT shall comply with either of the following two options, and the relevant test procedure shall be applied:

a) Option 1 – No intervention by any vehicle system to enforce a speed reduction.

b) Option 2 - No intervention by the foundation brakes to enforce a speed restriction, however energy recovery and engine retardation is permitted.

9.1.3 Option 1 tests

9.1.3.1 The VUT shall be driven on a test track whereby a portion of the track is entered into the VUT's Digital Speed Map as 30mph (48.3km/h), and a separate portion at 20mph (32.2km/h).

9.1.3.2 The VUT shall be driven at 30mph (48.3km/h) into the 20mph (32.2km/h) zone with the accelerator pedal fully depressed.

9.1.3.3 The TS shall observe for any evidence of systems activating to reduce speed for a period of 15 seconds of travel at 30mph (48.3km/h) within the 20mph (32.2km/h) zone.

9.1.3.4 The flashing frequency of the speed limit symbol shall be observed, and shall be 1-5Hz.

9.1.3.5 The ISA shall not actively reduce the speed of the VUT and the speed shall remain stable at 30mph (48.3km/h) for the duration of the test.

9.1.3.6 The VUT shall be driven at 30mph (48.3km/h) in the 30mph zone and enter into the 20mph (32.2km/h) zone with the accelerator pedal fully depressed, continuing to travel at 30mph (48.3km/h) for at least 10 seconds. After which the brake shall be applied to bring the speed of the VUT to between 22mph (35.4km/h) and 26mph (41.8km/h).

9.1.3.7 The VUT shall then be accelerated with the accelerator pedal fully depressed. The position of the accelerator pedal is to be maintained for at least 10 seconds whilst the VUT speed is monitored to determine if the speed exceeds 30mph (48.3km/h).

9.1.3.8 Whilst still in the 20mph (32.2km/h) zone, the brakes of the VUT shall then be applied to reduce the travel speed to between 12mph (19.3km/h) and 16mph (25.7km/h). Whilst still in the 20mph (32.2km/h) zone, the VUT shall be accelerated with the accelerator pedal fully depressed. The position of the accelerator pedal shall then be held for at least 10 seconds whilst observing if 20mph (32.2km/h) is exceeded.

9.1.3.9 When the VUT is in excess of the speed limit at any point during this test, the driver notification of such shall activate (only if this function is fitted).

9.1.3.10 The system shall be deemed to have failed if the bus speed does not comply with any of the conditions of this test.

9.1.4 Option 2 tests

9.1.4.1 The tests and requirements described in 9.1.3 shall be applied.

9.1.4.2 The TS shall attempt to trigger any enforced speed retardation (e.g. by ensuring the bus is in ROM and then permitting the VUT to attempt to exceed the speed limit downhill) on a test track and observe for the stated driver notification.

9.1.4.3 The system shall be deemed to have failed if the system does not operate as described in the application.

9.2 Other tests

9.2.1 To check that the ISA system does not affect the operation of the VUT below the speed limit, the VUT shall be accelerated from zero to 20mph (32.2km/h) in a 20mph (32.2km/h) zone of the test track and the time to reach 20mph (32.2km/h) shall be recorded. The ISA system shall then be disabled and the test repeated for the same section of track.

9.2.2 The test shall be repeated with a target speed of 30mph (48.3km/h) in a 30mph zone.

9.2.3 The system shall be deemed to have failed the tests if the difference in times to accelerate to each of the target speeds with and without the ISA activated is more than 10%.

9.2.4 The VUT shall be driven in a 20mph (32.2km/h) restricted zone with the accelerator pedal fully depressed with the VUT travelling at the 20mph (32.2km/h) limit. The VUT shall continue in to a 30mph (48.3km/h) zone for at least 10 seconds with the accelerator still fully depressed.

9.2.5 This test shall then be repeated with the 30mph (48.3km/h) zone being replaced with an unrestricted zone.

9.2.6 The system shall be deemed to have failed if the VUT exceeds a maximum acceleration of 1.2m/s2 under all load conditions.

9.2.7 It shall be possible for qualified personnel only to disable the speed limiting system and only when the ignition is on and the vehicle is stationary. The disabling of the system must be via an electronic device (e.g laptop, tablet or similar) connected to the vehicle. Additional control using a telematics system to manage the fleet is optional. The system shall be deemed to have failed if the conditions of the test cannot be met and if it would be possible for unequipped/unauthorised disabling of the system.

9.2.8 The TS shall check for the correct enabling and disabling of the ISA system by test driving the VUT in both conditions. The system shall be deemed to have failed if the ISA system does not properly enable or disable.

9.2.9 The VUT shall be driven in a 20mph (32.2km/h) restricted zone in ROM shall be operated to replicate a signal loss and the VUT speed shall be observed for 10 seconds and recorded. This test shall be repeated for the FMS and CAN cables as appropriate.

9.2.10 The system shall be deemed to have failed if the VUT is recorded as reaching speeds above 20mph (32.2km/h) during this test.

9.2.11 After the VUT has travelled for 10 seconds with the accelerator pedal fully depressed, the brakes of the VUT shall applied to reach a vehicle speed of 14mph (22.5km/h) or less. The VUT shall then accelerated to a speed above 20mph (32.2km/h).

9.2.12 The system shall be deemed to have failed if the VUT fails to reach speeds above 20mph (32.2km/h) during this part of the test.

9.2.13 The VUT shall be driven from a 20mph (32.2km/h) zone in to a 30mph (48.3km/h) zone in ROM at a speed of around 5mph (8km/h) (and less than 12mph (19.3km/h)). The distance within the 30mph (48.3km/h) zone that the indicator system displays the new speed limit shall be recorded in metres.

9.2.14 The system shall be deemed to have failed if the distance recorded is less than 30 metres.

9.2.15 This test shall be repeated with the VUT travelling from a 30mph (48.3km/h) zone into a 20mph (32.2km/h) zone. The system shall be deemed to have failed if the distance recorded is less than 30 metres.

9.2.16 The tests shall also record the time taken to indicate a new speed limit after entering that zone. The system shall be deemed to have failed if the time recorded is less than 5 seconds.

9.2.17 The VUT shall be driven in and out of a restricted 20mph (32.2km/h) zone at a continuous speed of 20mph (32.2km/h). Record the time and distance taken for the green dash lamp to illuminate upon entering or extinguish upon leaving the 20mph (32.2km/h) restricted zone:

a) The ISA system shall be deemed to have failed if the green light does not continuously illuminate after 5 seconds and greater than 30 metres after entering the 20mph (32.2km/h) restricted zone.

b) The ISA System shall be deemed to have failed if the green light does not extinguish after 5 seconds and greater than 30 metres after exiting the 20mph (32.2km/h) restricted zone in to an unrestricted zone.

9.2.18 The VUT shall be driven in ROM from a 20mph (32.2km/h) restricted zone in to a 30mph (48.3km/h) restricted zone at the maximum speeds possible for a distance of at least 100m. The illumination status of the green dash lamp shall be recorded.

9.2.19 The system shall be deemed to have failed if the continuous green lamp extinguishes during the test. This test shall be repeated with the VUT travelling from a 30mph (48.3km/h) restricted zone into a 20mph (32.2km/h) restricted zone.

9.2.20 The VUT shall be driven in ROM within a 20mph (32.2km/h) zone and the GPS, FMS, and CAN isolator switches shall be operated. The status of the white dash lamp shall be recorded and the time and distance taken to illuminate/extinguish shall be recorded.

9.2.21 The ISA system shall be deemed to have failed if the green dash lamp does not extinguish and the white continuous dash lamp does not illuminate after 5 seconds or 30 metres after when the signal isolator is operated.

9.2.22 The VUT shall be started and driven outside of a speed restricted zone. The status of the green and white dash lamps shall be recorded.

9.2.23 The ISA system shall be deemed to have failed if the green lamp is not extinguished and the white lamp is not illuminated.

9.2.24 The ISA system shall be disabled and then driven into and out of a speed restricted zone (for at least 100m in each zone). The status of the green and white dash lamps shall be recorded.

9.2.25 The ISA system shall be deemed to have failed if the green lamp is not extinguished and the white lamp is not illuminated.

9.2.26 The TS shall ensure that no Digital Speed Map is loaded on to the VUT then drive the VUT on the test track to confirm that no restriction exists.

9.2.27 The ISA system shall be deemed to have failed if a speed restriction is found on a bus with no Digital Speed Map loaded on to the system.

9.2.28 The TS shall update the Digital Speed Map using the instructions to upload the off-road test track area limits, and then drive the bus to confirm the correct uploading of the map zones and speed limits.

9.2.29 The VUT shall be deemed to have failed if the VUT speed restrictions are found to be different to those expected from the loaded map.

9.2.30 *Note: It may* be *useful to ensure that the zones and speed limits are clearly mapped against features/markers.*

9.3 On road testing

9.3.1 On road testing shall only be commenced upon completion of the track testing.

9.3.2 The VUT shall be driven on the on road testing infrastructure (see 6.2).

Note: The TS shall pre-determine a route for this test. It is prudent to choose times of day when the speed limits may be reached, and which limit risk (for example times when vulnerable children are less likely to be present).

Note: The TS shall create a printed map of the route using speed limit information from the applicable Digital Speed Map to allow test observer who is not the driver to cross reference actual location to the Digital Speed Map and the maximum speed limit indicator.

Note: The TS shall record the route and use a map of the route to assist with identifying each part of the test.

Note: A duplex video camera system, with one view of the speedometer and the other of the road ahead can assist in determining speed, location, and speed exceedances

9.3.3 When and where safe to do so, the speed limit shall be reached.

9.3.4 A visual comparison of the digital speed limit map and the (additionally added) speed limit indicator shall be made at a single point 30m or 5 seconds into each speed limit zone, whichever is closest to the start of the speed limit zone.

9.3.5 The system shall be deemed to have failed if the speed limit system and digital map do not match after 30m or 5 seconds, whichever places the bus closest to the change of speed limit zone into any speed restricted or unrestricted zone.

9.3.6 Any exceedances of the speed limit (according to the bus speedometer) shall be recorded, and the system shall be deemed to have failed if the VUT speed exceeds 2mph (3.2km/h) over the speed limit. This does not apply on any downhill section.

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10 Assessment of results

10.1 The following criteria will be used to asses if the ISA system has passed or failed the assessment.

10.1.1 Pre-test submissions

10.1.1.1 In order to receive a "Pass" certification the system must receive a "Pass" grade for each of the requirements on the assessment checklist.

10.1.1.2 The system shall be deemed to have failed the assessment if it received a single "Fail" grade on the pre-test submissions checklist.

10.1.2 System checks

10.1.2.1 In order to receive a "Pass" certification the system must receive a "Pass" grade for each of the requirements on the assessment checklist.

10.1.2.2 The system shall be deemed to have failed the assessment if it received a single "Fail" grade on the sytem checks checklist.

10.1.3 Track tests

10.1.3.1 In order to receive a "Pass" certification the system must receive a "Pass" grade for each of the requirements on the assessment checklist.

10.1.3.2 The system shall be deemed to have failed the assessment if it received a single "Fail" grade on the track testing checklist.

10.1.4 On-road tests

10.1.4.1 In order to receive a "Pass" certification the system must receive a "Pass" grade for each of the requirements on the assessment checklist.

10.1.4.2 The system shall be deemed to have failed the assessment if it received a single "Fail" grade on the on-road testing checklist.

10.1.5 Overall Assessment

10.1.5.1 In order to receive an overall "Pass" certification the ISA system must receive a "Pass" grade for each if the above sections on the checklists

10.1.5.2 The system shall receive an overall "Fail" grade in the assessment if a single "Fail" grade was awarded on any section of the assessment checklists.

10.1.6 To integrate this pass/fail test into the overall bus safety score an overall Pass will be deemed as a score of 100% and a fail will be deemed a score of 0%

11 Test report

11.1 The TS shall provide a comprehensive test report that will be made available to the AA. The test report shall consist of six distinct sections:

a) Completed pre-test submissions checklist

b) Completed system checks checklist;

c) Completed track tests checklist;

d) Completed on-road tests checklist.

e) Confirmation of protocol compliance against the specified performance requirement (option 1 or option 2); and

f) Reference information.

11.2 The reference information required includes as a minimum:

a) Vehicle make;

b) Vehicle model;

c) Vehicle model variant;

d) ISA Hardware version;

e) ISA Software version;

f) iBus version (1 or 2);

g) Braking option (1 or 2);

h) Applicable mapping types;

i) Details of the TS; and

j) Test date(s).

Annex 1 **Pre-test submissions checklist**

	Pre-test submissions	**Pass/Fail**
1	Full identification of the ISA system hardware and software versions, and the applicable model of bus provided by the bus OEM.	
2	A test vehicle provided by the bus OEM with an indicator system (visible to the bus driver) that displays the maximum speed limit of the ISA system when in restricted operating mode.	
3	Evidence from an appropriately certified body that the ISA system has been tested and approved as per the requirements of adjustable speed limitation devices within Regulation No 89 of the Economic Commission for Europe of the United Nations (UN/ECE) at speeds of: 10mph (16.1km/h); 20mph (32.2km/h); 30mph (48.3km/h); 40mph (64.4km/h).	
4	A statement provided by the bus OEM describing how the ISA system operates.	
5	A written declaration provided by the bus OEM that this ISA system does not have adverse effects on fuel consumption or emissions.	
6	A statement provided by the bus OEM regarding any relevant type approvals which apply to the ISA solution. If type approvals are not required then a statement of this shall be provided.	
7	A description provided by the bus OEM of the applicable iBus system type (1 or 2) and a schematic diagram of the GPS antenna connection to the ISA system.	
8	Detail of London Buses' approval for use of the Radio Frequency splitter (if used) used as part of the ISA system.	
9	A schematic diagram and description of where the ISA system obtains the vehicle speed information, provided by the bus OEM.	
10	A physical demonstration of the receipt of a speed signal from either the FMS or CAN to the ISA system, provided by the bus OEM	
11	A statement has been provided by the bus OEM in their application confirming which option is chosen from either: Option 1 – No intervention by any vehicle system to enforce a speed reduction Option 2 - No intervention by the foundation brakes to enforce a speed restriction, however energy recovery and engine retardation is permitted.	
12	A statement has been provided by the bus OEM of if speed restriction is assisted by any system, and to describe the operation of this system.	
13	A statement has been provided by the bus OEM of if an overspeed notification to the bus driver function is fitted, and provide details of the form of this notification.	
14	A statement has been provided by the bus OEM that the vehicle performance characteristics are unaffected when the vehicle is not in restricted operating mode.	

	Pre-test submissions	Pass/Fail
15	Instructions are provided by the bus OEM regarding how the ISA system is enabled and disabled.	
16	The bus OEM has provided a test vehicle modified with additional in-line switches to individually isolate cabled connections to the GPS, FMS and/or CAN speed signal in to the ISA system.	
17	The bus OEM has provided a description of potential failure modes of the ISA system.	
18	The bus OEM has provided a description of all mapping formats from the list which can be used on the ISA system.	
19	The bus OEM has provided a statement regarding how any bus mapping can be updated on an ad-hoc basis.	
20	The bus OEM has provided adequate instructions with/in the application for the updating of the digital speed map, and include any equipment necessary to facilitate this updating for the test. This shall also include the description of how the map update is protected from unauthorised access. Two off-road test track-specific maps shall be provided, with different zones and speed limits as agreed with the test body.	
21	The bus OEM has provided a declaration in their application regarding any additional antenna for updating the digital speed map.	
22	The bus OEM has provided instructions and any necessary equipment to read and clear any ISA system fault. A list of possible faults and their codes shall be provided and guidance on how to trigger these faults.	
23	A photo of the ISA symbol as shown on the driver information screen.	
24	A photo of the speed limit symbol as shown on the driver information screen.	
25	A copy of the ISA fitment information to the driver (sticker, light, voice instruction etc), in a suitable format.	

Result:

Annex 2 System checks

	System Checks	Pass/Fail
1	The cabled connection from the GPS antenna to the ISA system can be observed.	
2	If a speed retardation system was declared by the bus OEM, then it was investigated and observed by the test house.	
3	The system can be enabled and disabled by using the instructions provided by the Bus OEM.	
4	The ISA system could not be non-destructively disabled without tools within a 2 minute period.	
5	The green dash lamp, white dash lamp and an amber dash lamp are all fitted for the ISA System.	
6	A triggered ISA system failure caused the green lamp to extinguish and the amber lamps were illuminated.	
7	Triggered conditions cause ROM to not be implemented resulting in the green lamp extinguishing and the amber lamp (ISA system has a fault) were illuminated.	
8	The correct application of 20mph (32.2km/h) and 30mph (48.3km/h) speed limits with applicable mapping formats was observed.	
	The mapping format loaded and applied properly.	
9	The outdated Digital Speed Map can be completely removed from the ISA system.	
	A new map can be uploaded properly.	
10	An ad-hoc change to the Digital Speed Map can be properly uploaded.	
11	No additional antenna for updating the Digital Speed Map is found.	
12	A triggered fault within the ISA system caused the amber dash light to illuminate.	
13	Interrogation of the ISA system for the fault found a match to the caused fault.	
14	The fault can be cleared from the system.	
	The amber light was extinguished when the fault was cleared.	

Result:

Annex 3 Track testing checklist

Type of intervention option selected:

		Track testing	Pass/Fail
Option 1	1	During 15 seconds of driving at 30mph (48.3km/h) in a 20mph (32.2km/h) zone and the system does not actively reduce the speed which remains stable at around 30mph (48.3km/h).	
	2	During driving at 30mph (48.3km/h) in the 30mph (48.3km/h) zone in to the 20mph (32.2km/h) zone and continuing at 30mph (48.3km/h) for at least 10 seconds, after which braking lowered the vehicle speed to between 22mph (35.4km/h) and 26mph (41.8km/h), and then was accelerated with the accelerator pedal fully depressed until 30mph (48.3km/h) is reached then held for at least 10 seconds; the speed limit of 30mph (48.3km/h) was not exceeded.	
		Then after braking to bring the vehicle speed to between 12mph (19.3km/h) and 16mph (41.8km/h), and on entering the 20mph zone accelerating with the accelerator pedal fully depressed until 20mph (32.2km/h) is reached then held for at least 10 seconds, the speed limit of 20mph (32.2km/h) was not exceeded.	
		If an overspeed notification function is fitted it should operate when overspeed. The flashing frequency of the speed limit symbol shall be observed, and shall be 1-5Hz.	
Option 2	1	The triggering of enforced speed retardation actively slowed the bus as described by the vehicle OEM.	
		The driver notification of speed retardation was observed.	
	2	During driving at 30mph (48.3km/h) in the 30mph (48.3km/h) zone in to the 20mph (32.2km/h) zone and continuing at 30mph (48.3km/h) for at least 10 seconds, after which braking lowered the vehicle speed to between 22mph (35.4km/h) and 26mph (41.8km/h), and then was accelerated with the accelerator pedal fully depressed until 30mph (48.3km/h) is reached then held for at least 10 seconds; the speed limit of 30mph (48.3km/h) was not exceeded.	
		Then after braking to bring the vehicle speed to between 12mph (19.3km/h) and 16mph (25.7km/h), and on entering the 20mph zone accelerating with the accelerator pedal fully depressed until 20mph (32.2km/h) is reached then held for at least 10 seconds, the speed limit of 20mph (32.2km/h) was not exceeded.	
		The vehicle speed complied with the conditions of the	

		Track testing	Pass/Fail
Other	1	The acceleration time from zero to 20mph (32.2km/h)in a 20mph (32.2km/h) zone of the test track matches (or are not more than 10% different) between the ISA system being turned on and off.	
		The acceleration time from zero to 30mph (48.3km/h) in a 30mph (48.3km/h) zone of the test track matches (or are not more than 10% different) between the ISA system being turned on and off.	
	2	Driving at the 20mph (32.2km/h) limit in a 20mph (32.2km/h) restricted zone and the accelerator pedal fully depressed, and then entering a 30mph (48.3km/h) zone, the maximum rate of acceleration was not greater than 1.0 to 1.2 m/s2 under all load conditions.	
		Driving at the 30mph (48.3km/h) limit in a 30mph (48.3km/h) restricted zone and the accelerator pedal fully depressed, and then entering an unrestricted zone, the maximum rate of acceleration was not greater than 1.0 to 1.2 m/s2 under all load conditions.	
	3	The system cannot be disabled whilst in motion.	
		It is not possible to disable the ISA unless connected via a cable to a laptop.	
		The ISA system correct enabling and disabling is tested by attempting to exceed a known limit on the test track.	
	4	Speeds above 20mph (32.2km/h) can not be reached when driving in a 20mph (32.2km/h) zone with the GPS isolation cable switch is operated to mimic a signal loss.	
		After braking to below 14mph (22.5km/h) and then accelerating above 20mph (32.2km/h), with the signal loss continuing, the vehicle reached speeds above 20mph (32.2km/h).	
	5	During driving from a 20mph (32.2km/h) to a 30mph (48.3km/h) zone in ROM at a speed less than 12mph (19.3km/h) the distance at which the speed limit indicator changes is 30m or greater.	
		During driving from a 20mph (32.2km/h) to a 30mph (48.3km/h) zone in ROM the time at which the speed limit indicator changes was 5 seconds or greater.	
		During driving from a 30mph (48.3km/h) to a 20mph (32.2km/h) zone in ROM at a speed less than 12mph (19.3km/h) the distance at which the speed limit indicator changes is 30m or greater.	
		During driving from a 30mph (48.3km/h) to a 20mph (32.2km/h) zone in ROM the time at which the speed limit indicator changes was 5 seconds or greater.	

		Track testing	Pass/Fail
	6	During driving in and out of a 20mph (32.2km/h) restricted zone at a continuous 20mph (32.2km/h) speed the green lamp illuminates continuously after 5 seconds and greater than 30m after entering the 20mph (32.2km/h) zone.	
		The green lamp extinguishes after 5 seconds and greater than 30m after exiting the 20mph (32.2km/h) restricted zone into an unrestricted zone.	
	7	During driving in ROM from a 20mph (32.2km/h) restricted zone in to a 30mph (48.3km/h) restricted zone at the maximum speeds possible for a distance of at least 100m the green lamp remained lit continuously.	
		During driving in ROM from a 30mph (48.3km/h) restricted zone in to a 20mph (32.2km/h) restricted zone at the maximum speeds possible for a distance of at least 100m the green lamp remained lit continuously.	
	8	During driving in ROM within a 20mph (32.2km/h) zone the GPS isolator switch was isolated and the green lamp extinguished and the white lamp illuminated after 5 seconds or 30 m after the isolator was operated.	
		During driving in ROM within a 20mph (32.2km/h) zone the FMS isolator switch was isolated and the green lamp extinguished and the white lamp illuminated after 5 seconds or 30 m after the isolator was operated.	
		During driving in ROM within a 20mph (32.2km/h) zone the CAN isolator switch was isolated and the green lamp extinguished and the white lamp illuminated after 5 seconds or 30 m after the isolator was operated.	
	9	Outside of the speed restricted zone the vehicle was started and driven and the green lamp was extinguished and the white lamp was illuminated.	
	10	The ISA system was disabled and driving in and out of a speed restricted zone (for at least 100m in each zone) and the green lamp was extinguished and the white lamp illuminated when exiting the restricted area.	
	11	With no Digital Speed Map loaded there is no system activation and no speed restriction as proven by a test track drive.	
	12	With the off-road test track area limits uploaded via the appropriate map the speed restrictions shown on the vehicle matched the speeds expected from the map.	
	13	With an altered Digital Speed Map for the off-road test track so that different zones and limits applied the vehicle speed restrictions were matched against the altered map.	

Result:

Annex 4 **On-road testing checklist**

	On road testing	Pass/Fail
1	The speed limit can be reached with the system active.	
2	Multiple visual comparisons of the digital speed limit map and the (additionally added) speed limit indicator made at a single point 30m or 5 seconds into each speed limit zone all indicated a match after 30m or 5 seconds, whichever was closest to the start of the speed limit zone.	
3	There were no speeds exceedances of greater than 2mph (3.2km/h) (excluding downhill sections).	

Result: ☐

Attachment 18: Intelligent Speed Assistance (ISA) Guidance Notes

1 Introduction

This document sets out the guidance notes related to Intelligent Speed Assistance. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 ISA

Intelligent Speed Assistance (ISA) is a system fitted to buses which links an understanding of location (from GPS[19]) to an on-board map of speed limits (known as the Digital Speed Map), and a reading of the bus speed. It uses this information to limit the speed of the bus and at present it does this in two options:

- Option 1: By limiting further accelerator input when the bus has reached the speed limit
- Option 2: By doing the above but also activating regenerative braking.

The Digital Speed Map will be created and updated by Transport for London, and it will be the responsibility of the bus operator to update the maps in buses either on a periodic timeline, or if directed an emergency timeline. It is advised that the bus operator keeps records of the date and version number of any uploaded Digital Speed Map against each bus.

Vehicles fitted with ISA can exceed the speed limit, for example in locations where gravity (typically downhill) will allow the bus to exceed the speed limit, or where the bus enters a lower speed limit. It is also likely in some circumstances for a there to be a time lag between the implementation of a speed limit and the updating of the Digital Speed Map, and this is certainly likely to be the case for temporary speed restrictions such as roadworks.

<u>The driver is responsible for the vehicle speed and compliance with road speed limits at all times. ISA does not absolve the driver of responsibility for remaining within the speed limit.</u>

[19] GPS = Global Positioning System. GPS is a global navigation satellite system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. It allows the position of the bus to be identified in real time.

Below the speed limit the ISA has no impact upon the speed, acceleration, or any other operation of the bus.

When entering a lower speed limit it is the driver's responsibility to reduce the vehicle speed. The ISA will not brake or automatically reduce speed. If the driver keeps their foot on the accelerator pedal then the existing speed will be maintained; the driver must take action to reduce the speed.

When entering a higher speed limit the vehicle will not increase speed automatically. Speed will only increase in response to the level of pressure on the accelerator pedal. It is the driver's responsibility to accelerate safely and only when conditions are appropriate.

The system cannot anticipate speed changes. For example it will not begin slowing down in advance of a lower speed limit sign.

Driving at the speed limit is not always appropriate for the road curvature, surface, traffic, environmental conditions etc. The driver remains responsible for using an appropriate speed at all times.

3 Selection of buses/systems

ISA can be fitted on new-build buses and within this there are presently two options:

- Option 1: Accelerator input limiting
- Option 2: Accelerator input limiting and application of regenerative braking.

A further variation can be the retrofit of ISA to in-service vehicles in some circumstances. The use of aftermarket equipment is authorised on the condition if it is a vehicle OEM integrated solution and complies with all performance requirements of the ISA specification prior to the homologation process.

It is anticipated that a future version of iBus provided by TfL will integrate ISA, so this is worth considering when selecting a supplier.

4 Training

4.1 Driver training

The training required by drivers is expected to be minimal. This will likely only require a few minutes of discussion to:

- explain how the bus will operate
- how to understand the various warning lights
- what happens when transitioning between speed limits
- limitations of the system, operating limits
- emphasise that the driver remains responsible for speed limit compliance at all times.

The ISA supplier should be approached for specific advice appropriate to the system.

4.1 Maintenance training

It is expected that the bus operator will update the Digital Speed Map on each bus, and if this is the case then bus operator staff should be suitably trained to do so.

It is envisaged that the ISA supplier/Bus supplier will offer suitable maintenance training, covering at a minimum map updating, enabling and disabling the system (likely to take around an hour in training). Additionally and depending upon any warranty and maintenance agreement, training may extend to fault finding/repair (and this may take far longer depending upon the complexity of the system).

5 Maintenance

The ISA systems are specified so that they may not be easily interfered with by the driver, and the bus driver is not expected to undertake any maintenance.

It is envisaged that bus operators and the ISA supplier/Bus supplier will reach any agreement regarding responsibility for ISA system maintenance and repair, and that any personnel undertaking maintenance are suitably trained and have access to any relevant documentation (such as schematics, fault-finding, parts lists, fitment details).

It is envisaged that suitably trained and authorised persons (who are not the driver) within the bus operator will be able to disable the ISA system if required, and should be provided with any relevant tools or software/hardware to enable this.

Attachment 19: Bus Vision Standard Assessment Protocol

1 Introduction

This document presents a procedure, hereon referred to as the Bus Vision Standard (BVS), for objectively measuring the vision that the driver has of the environment in close proximity to a bus, both directly via the windows/windscreen and indirectly via mirrors and/or camera-monitor systems (CMS).

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 in the Consolidated Resolution on the Construction of Vehicles (R.E.3) as M_3; Class I, Class II.

3 Purpose

Over many years, driver blind spots have been identified as a contributory factor in collisions involving HGVs. The direct vision through the glazed areas of HGVs is such that, given their height from the ground, pedestrians and cyclists may be easily hidden in many areas that cannot be seen directly and in some areas that cannot be seen either directly or indirectly via the available mirrors.

The direct vision of buses is far superior to that from most HGVs, although fewer mirrors are legally required on buses, such that the indirect field of view is considered to be inferior. Generally, the blind spots surrounding buses are smaller; however, collisions where pedestrians and cyclists are either killed or seriously injured, when positioned in close proximity to a moving bus, do still occur.

Typically, direct vision blind spots in buses are not located in areas where vulnerable road users will be obscured by the lower edge of the windscreen. Instead, potential obstructions to driver visibility are typically caused by the A-pillars of the bus, the pillars around and at the centre of the front doors, the driver assault screen and by equipment in the driver cabin.

In the past, the majority of London buses ensured compliance with only the regulatory minimum requirements of rearward facing Class II mirrors. These alone, however, do not prevent blind spots from occurring, particularly in the areas just to the rear of the driver seat position and for wider fields of view.

The aim of the Bus Vision Standard (BVS) is to provide an objective assessment that can be used to quantify the vision performance of a bus, enforce minimum standards and encourage performance over and above these minimum standards, while still permitting beneficial innovations (e.g. replacing mirrors with camera-monitor systems (CMS)) without adversely affecting safety.

It should be noted that the BVS is designed around collision situations relating to low speed, close proximity manoeuvres. It does not assess the vision required for higher speed manoeuvres and so scoring well does not absolve the manufacturer from the responsibility to design appropriate vision for all circumstances.

4 Normative References

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

- 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.
- European Tyre and Rim Technical Organisation (ETRTO) Standards Manual
- 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.
- SAE J182 (2015) "Motor Vehicle Fiducial Marks and Three-dimensional Reference System".
- SAE J1100 (2009) "Motor Vehicle Dimensions".
- SAE J1516 (2011) "Accommodation Tool Reference Point for Class B Vehicles".
- SAE J1517 (2011) "Driver Selected Seat Position for Class B Vehicles - Seat Track Length and SgRP".
- UN ECE Regulation 107 Uniform provisions concerning the approval of category M_2 or M_3 vehicles with regard to their general construction.
- UN ECE Regulation 46 Uniform provisions concerning the approval of devices for indirect vision and of motor vehicles with regard to the installation of these devices.

5 Definitions

For the purpose of this Protocol:

- **Accelerator heel point (AHP) -** a point on the shoe located at the intersection of the heel of shoe and the depressed floor covering, when the shoe tool is properly positioned. (Essentially, with the ball of the foot contacting the lateral centre line of the undepressed accelerator pedal, while the bottom of the shoe is maintained on the pedal plane). As defined in SAE J1516, SAE J1517 and SAE J1100.
- **AHP height -** vertical height in the Z axis between the ground plane and AHP.
- **Ambinocular vision -** the total combined field of view that can be seen by at least one eye.
- **Angle of incidence -** the angle which a sightline makes with a plane that is angled perpendicular to the surface at the obstruction point
- **Approval Authority -** 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.
- **Assessment zone -** the volume around the vehicle under test defining the volume of space that needs to be seen by the driver in order to view vulnerable road users within the area of greatest risk. The assessment zone is defined by collision data and by the UN ECE Regulation 46 indirect field of vision requirements.
- **Assessment zone element -** an element of known volume, and with no single dimension exceeding [100]mm, that forms part of the overall assessment zone volume
- **Blind spot -** a blind spot is a volume of space around the vehicle under test that cannot be seen by a driver either through the daylight opening (DLO) or through the indirect vision devices installed on the vehicle.
- **Blind spot volume -** the proportion of the assessment zone that cannot be seen by the driver through either the direct or indirect fields of view
- **Bus vision standard performance score -** the proportion of each assessment zone visible to the driver through the direct field of view.
- **Camera -** a device that renders an image of the outside world and converts this image into a signal (e.g. video signal)
- **Camera point -** a point representing the origin of the field of view of a camera
- **Camera-monitor system (CMS) -** an indirect vision device where the field of vision is obtained by means of a UN ECE Regulation 46 certified combination of camera and monitor systems
- **Coordinate system -** the three-dimensional vehicle coordinate system that is established in SAE J182.

- **Daylight opening (DLO) -** an area of a vehicle, windscreen or other glazed surface, whose light transmittance (measured perpendicular to the surface) is not less than 70%. As defined in UN ECE Regulation 125.
- **Direct field of view -** the field of view seen without the aid of any additional devices.
- **Direct vision volume -** the proportion of the assessment zone visible to the driver through the direct field of view.
- **Direct vision performance score -** the proportion of each assessment zone visible to the driver through the direct field of view.
- **Eye points (E_L, E_R) -** two points representing the driver's left and right eyes. These are the points from which sightlines originate.
- **ETRTO -** European Tyre and Rim Technical Organisation
- **Gross vehicle weight (GVW) -** the maximum permitted mass of a vehicle when fully loaded.
- **Ground plane -** horizontal plane, parallel to the XY plane, at ground level.
- **Indirect field of view -** the field of view seen through the aid of an additional device such as mirrors or camera-monitor systems (CMS).
- **Indirect vision volume -** the proportion of the assessment zone visible to the driver through the indirect field of view.
- **Indirect vision performance score -** the proportion of each assessment zone visible to the driver through the indirect field of view.
- **Monitor -** a device that converts a signal into images that are rendered into the visual spectrum.
- **Monocular vision -** the total field of view that can be seen by a single eye or camera.
- **Neck pivot point (P) -** point about which a driver's head turns on a horizontal plane.
- **Obstruction point -** a point located on the vehicle structure that obstructs the driver field of view.
- **Reference eye point (E_{ref}) -** midpoint between left and right eye points at centre line of driver.
- **Reflection point -** a point located on a mirrored surface that reflects the driver field of view.
- **Sightline -** a line representing the driver's line of sight from an eye point to an obstruction point, reflection point or a given angle.
- **Test service -** the organisation undertaking the testing and certification of the results to the Approval Authority.
- **Total driver vision volume -** the proportion of the assessment zone visible to the driver through ether the direct or indirect fields of view.

- **Vehicle length -** the distance in the X axis between two points located at the foremost and rearmost aspect of the vehicle structure, excluding all features listed in Appendix A.
- **Vehicle structure -** all relevant vehicle glazing and bodywork, excluding all features listed in Appendix A.
- **Vehicle under test (VUT) -** the vehicle tested according to this protocol.
- **Vehicle width -** the distance in the Y axis between two points located at the most lateral aspects of the vehicle structure coincident to the first axle, excluding all features listed in Appendix A.

6 Test conditions

6.1 Eye Points

6.1.1 The field of view of the driver shall be defined by ambinocular vision from two eye points (EL and ER), rotating about a neck pivot point (P), from which sightlines will originate. EL, ER and P locations and ranges of motion are defined in relation to the Eref position, which in turn is defined in relation to the AHP.

6.2 Reference Eye Point Location (Eref)

6.2.1 The reference eye point (E_{ref}) is defined as an offset from the AHP of [678]mm in the X axis and [1163.25]mm in the Z axis, as shown by Figure 15. The reference eye point position in the X/Z-axes (E_{ref_x}, E_{ref_z}) shall therefore be positioned relative to the AHP position (AHP_x, AHP_z) according to the following equations:

6.2.2 $E_{ref\_x} = AHP_x + [678]mm$

6.2.3 $E_{ref\_z} = AHP_z + [1163.25]mm$

6.2.4 The reference eye point position in the Y axis (E_{ref_y}) shall be located in line with the central plane of the driver seat.

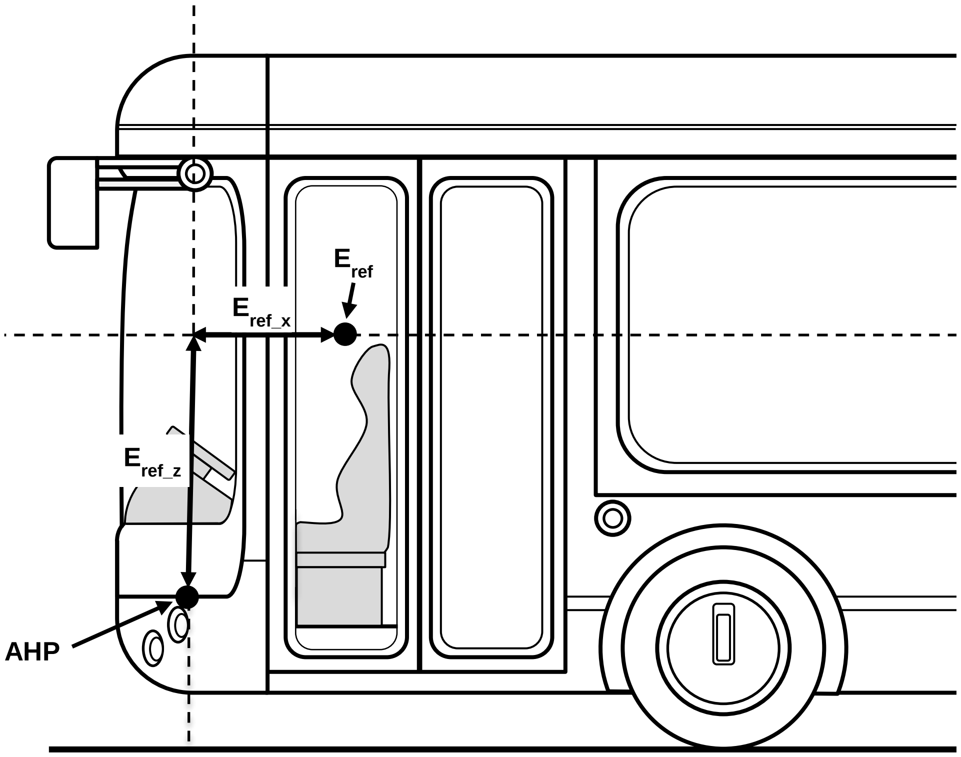

Figure 15: Definition of vertical (E_{ref_z}) and rearward (E_{ref_x}) offset of the reference eye point (E_{ref}) from the accelerator heel point (AHP)

6.3 Neck Pivot Point Location (P)

6.3.1 The neck pivot point (P) is defined as an offset of -98mm from the E_{ref} point in the X axis, as shown in Figure 16.

6.4 Left and Right Eye Point Locations (E_L, E_R)

6.4.1 The left and right eye points (EL and ER) are defined as an offset of ±32.5mm from the Eref point in the Y axis, as shown in Figure 16.

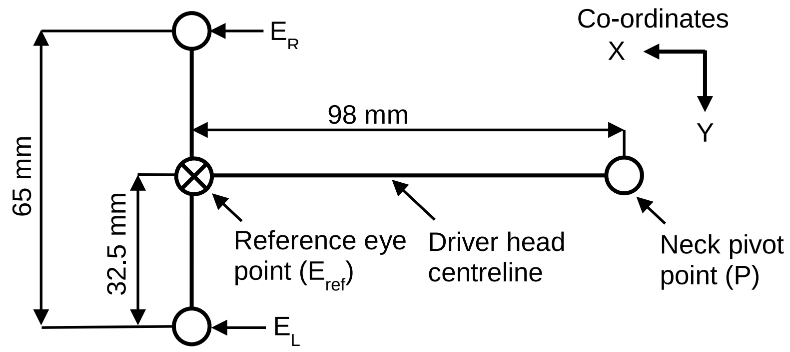

Figure 16: Definition of left and right eye point (E_L and E_R) positions relative to the neck pivot point (P) and reference eye point (E_{ref})

6.5 Neck Pivot Point Range of Motion (β)

6.5.1 The horizontal rotation (β) of the neck pivot point, which determines the relative motion of the eye points, is defined by a maximum range of motion of [±90°] rotation about the neck pivot point (P), as shown in Figure 17. For the assessment procedure, β shall be adjusted in increments of [10°].

6.5.2 There shall be no vertical rotation about the neck pivot point.

6.6 Eye Point Range of Motion (θ)

6.6.1 The horizontal rotation (θ_L, θ_R) of both eye points is defined by a maximum range of motion of [±30°] rotation about each eye point (E_L and E_R), as shown in Figure 17. For the assessment procedure, θ_L and θ_R will be adjusted in increments of [3°].

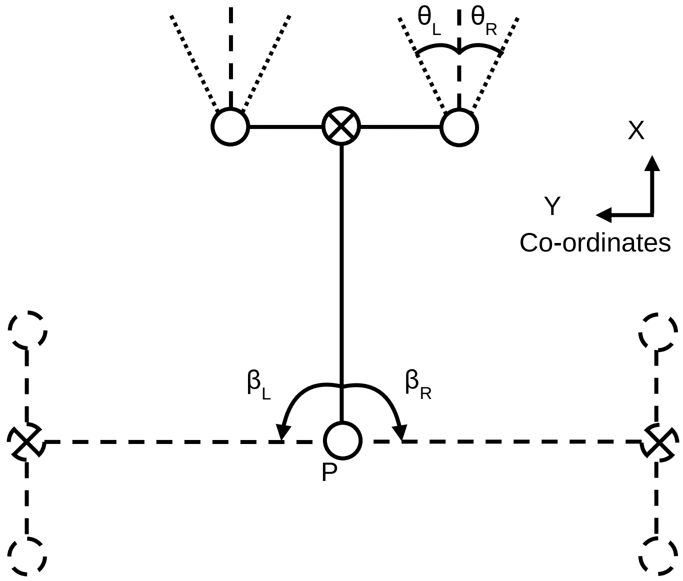

Figure 17: Plan view of horizontal neck point and eye point rotations

6.6.2 The vertical rotation (θ_U, θ_D) of both eye points is defined by a maximum range of motion of [45°] upwards and [60°] downwards about each eye point (E_L and E_R), as shown in Figure 18. For the assessment procedure, θ_U and θ_D will be adjusted in increments of [3°].

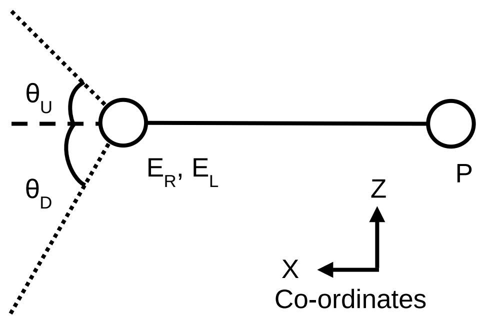

Figure 18: Side view of vertical eye point rotations

6.7 Camera Points

6.7.1 The field of view provided by each camera of a camera-monitor system (CMS) shall be defined by monocular vision originating from a specified camera point location from which sightlines will originate. Multiple camera point locations (C_1, C_2… C_n) and fields of view may be defined for assessment.

6.8 Camera Point Locations (C)

6.8.1 Camera point locations (C), relative to the origin of the global coordinate system, shall be provided by the manufacturer for all CMS included in the BVS assessment. Each camera point location (C_1, C_2… C_n) shall be

6.9 Camera Point Fields of View (α, λ)

6.9.1 The angle of the centre of the field of view shall be provided for each camera point (C_n) by the manufacturer, as shown in Figure 19 and Figure 20. The horizontal angle shall be formed between the centre of the field of view and XZ plane (α_n), with a positive value used when angled outboard relative to the longitudinal centreline of the VUT. The vertical angle shall be formed between the centre of the field of view and XY plane (λ_n), with a positive value used when angled downward relative to the XY plane.

6.9.2 The maximum range of the horizontal field of view, both inboard and outboard (α_{n_I}, α_{n_O}), for each camera point (C_n) shall be provided by the manufacturer, as shown in Figure 19. For the assessment procedure, α_{n_I} and α_{n_O} will be adjusted in increments of [3°] between the extents of the maximum ranges.

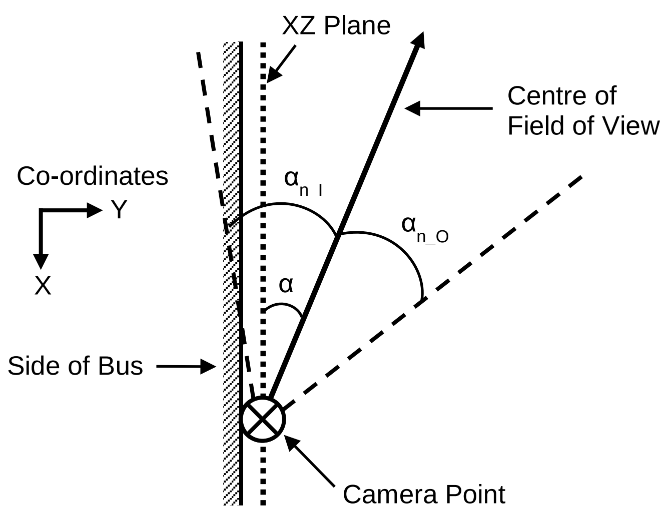

Figure 19: Plan view of horizontal field of view range for camera point

6.9.3 The maximum range of the vertical field of view, both upward and downward (λ_{n_U}, λ_{n_D}), for each camera point (C_n) shall be provided by the manufacturer, as shown in Figure 20. For the assessment procedure, λ_{n_U} and λ_{n_D} will be adjusted in increments of [3°] between the extents of the maximum range of motion.

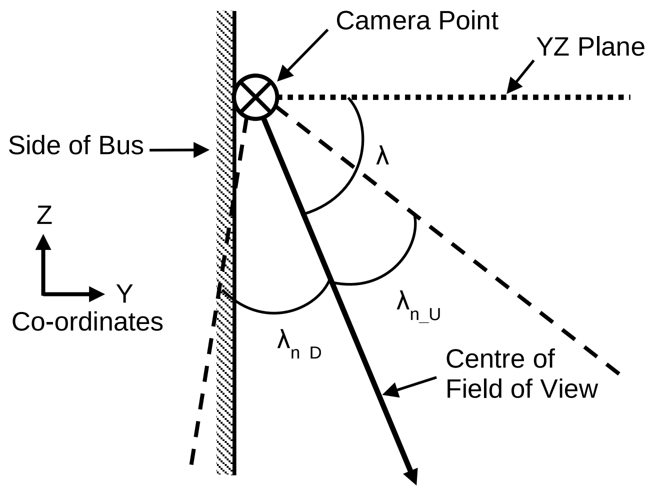

Figure 20: Frontal view of vertical field of view range for camera point

6.10 Assessment Zones

6.10.1 **The following three assessment zones shall be defined:**

a) Forward Close Proximity Zone

b) Rearward Close Proximity Zone

c) Wide-Angle Zone

6.10.2 Where these assessment zones are defined in relation to the limits of the vehicle length and width, these limits shall include all relevant vehicle glazing and bodywork, but exclude all features listed in Appendix A.

6.11 Assessment Zone Height

6.11.1 Each assessment zone shall be formed by a volume, including the following defined areas, at heights of Z = [0]m through to Z = [1.602]m from the ground plane.

6.12 Forward Close Proximity Zone

6.12.1 The dimensions of the forward close proximity assessment zone are shown in Figure 21 and described below:

a) The forward outer boundary of the assessment zone is defined by a plane parallel to the YZ plane and located [2]m in front (+X axis) of the foremost aspect of the vehicle structure.

b) The nearside (left side) outer boundary of the assessment zone is defined by a plane parallel to the XZ plane and located [4.5]m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure.

c) The offside (driver side) outer boundary of the assessment zone is defined by a plane parallel to the XZ plane and located [2]m outboard (-

Y axis) from the most lateral aspect of the offside of the vehicle structure.

d) The rearward outer boundary of the assessment zone is defined by a plane parallel to the YZ plane and located [1.75]m to the rear (-X axis) of the reference eye point (E_{ref}).

e) The inner boundary is defined by a curve located 0.3m from the outermost aspect of the vehicle structure, when measured normal to the relevant vehicle structure (Figure 22).

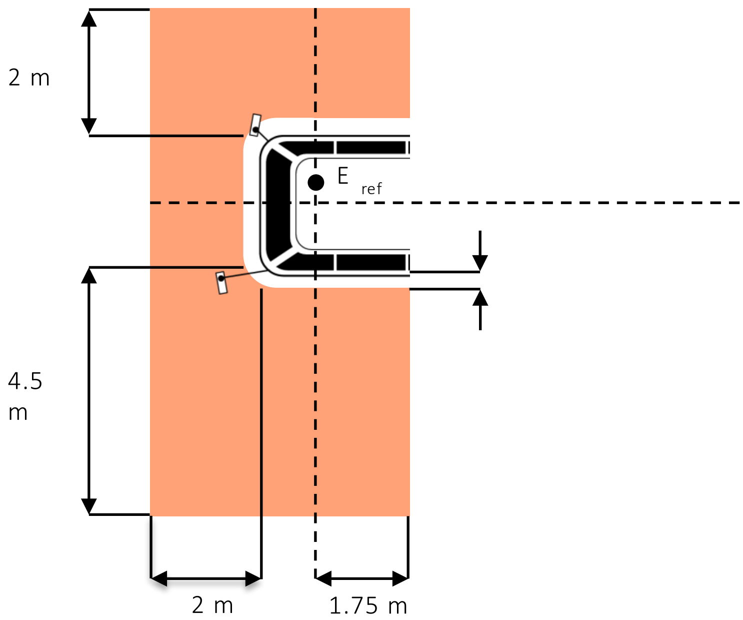

Figure 21: Plan view of forward close proximity assessment zone

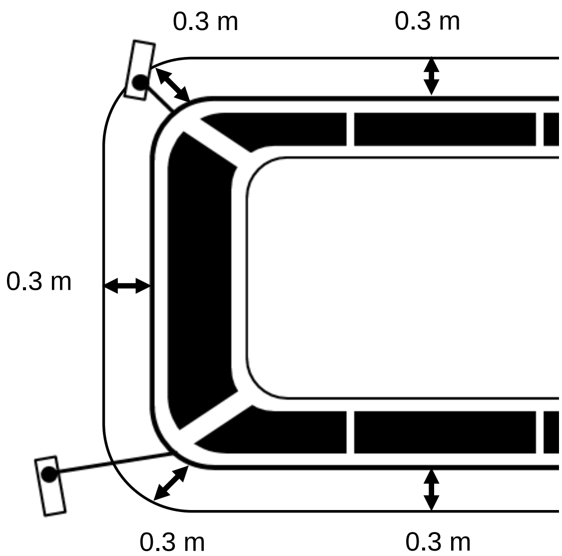

Figure 22: Illustration of profile for defining inner boundary of assessment

6.13 Rearward Close Proximity Zone

6.13.1 The dimensions of the rearward close proximity assessment zone are shown in Figure 23 and described below:

a) The rearward outer boundary of the assessment zone is defined by a plane parallel to the YZ plane and located [1.75]m to the rear (-X axis) of the reference eye point (E_{ref}).

b) The nearside (left side) outer boundary of the assessment zone is defined by a plane parallel to the XZ plane and located [4.5]m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure.

c) The offside (driver side) outer boundary of the assessment zone is defined by a plane parallel to the XZ plane and located [2]m outboard (-Y axis) from the most lateral aspect of the offside of the vehicle structure.

d) The rearward outer boundary of the assessment zone is defined by a plane parallel to the YZ plane and located [5]m to the rear (-X axis) of the rearmost aspect of the vehicle structure.

e) The inner boundary is defined by a curve located 0.3m from the outermost aspect of the vehicle structure, when measured normal to the relevant vehicle structure (Figure 23).

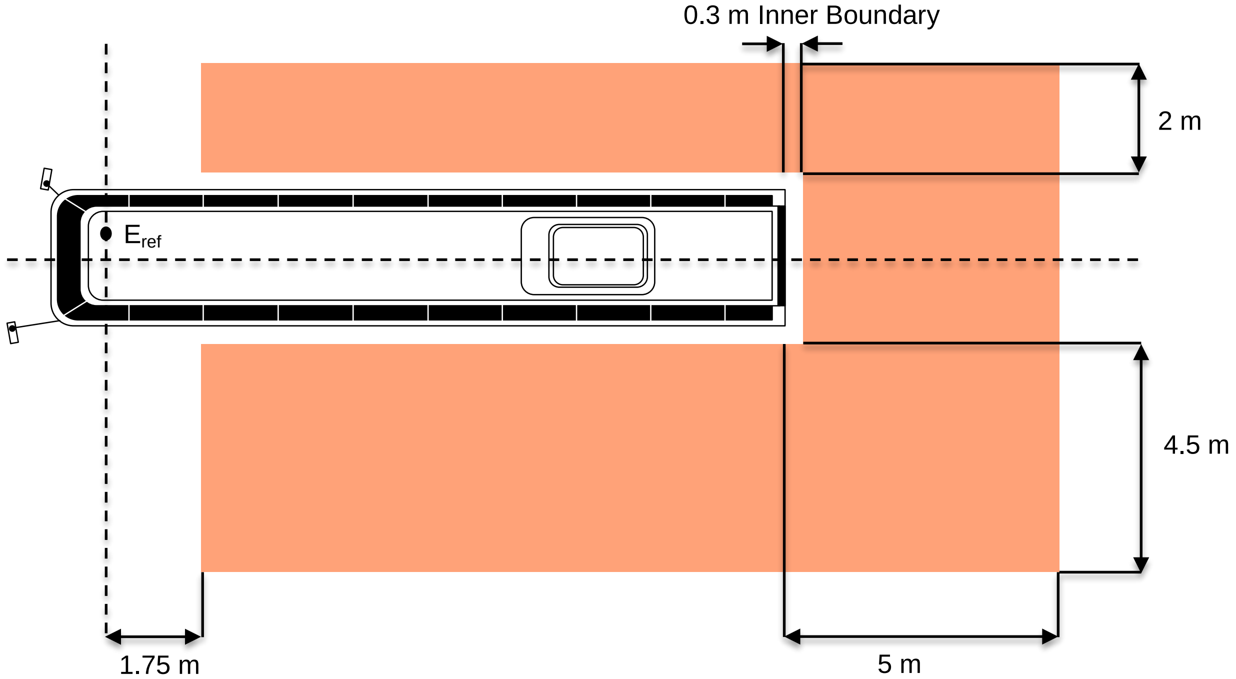

Figure 23: Plan view of rearward close proximity assessment zone

6.14 Wide-Angle Zone

6.14.1 The dimensions of the wide-angle assessment zones, which are principally based on the field of vision zones specified for Class IV mirrors in UN ECE Regulation 46, are shown in Figure 24 and described below:

6.14.2 Nearside (left side) wide-angle assessment zone:

a) The rearward boundary of the assessment zone is defined by a plane parallel to the YZ plane and located [25]m to the rear (-X axis) of the reference eye point (E_{ref}).

b) The outer boundary of the assessment zone is defined by a plane parallel to the XZ plane, located [15]m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure and extending between [10]m to the rear (-X axis) of the reference eye point (E_{ref}) and the rearward boundary of the assessment zone.

c) The inner boundary of the assessment zone is defined by a plane parallel to the XZ plane, located [4.5]m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure and extending between [1.5]m to the rear (-X axis) of the reference eye point (E_{ref}) and the rearward boundary of the assessment zone.

6.14.3 Offside (driver side) wide-angle assessment zones:

a) The forward boundary of the assessment zone is defined by a plane parallel to the YZ plane, located [1.5]m to the rear (-X axis) of the reference eye point (E_{ref}) and extending to [4.5]m outboard (-Y axis) from the most lateral aspect of the offside of the vehicle structure.

b) The rearward boundary of the assessment zone is defined by a plane parallel to the YZ plane and located [25]m to the rear (-X axis) of the reference eye point (E_{ref}).

c) The outer boundary of the assessment zone is defined by a plane parallel to the XZ plane, located [15]m outboard (-Y axis) from the most lateral aspect of the nearside of the vehicle structure and extending between [10]m to the rear (-X axis) of the reference eye point (E_{ref}) and the rearward boundary of the assessment zone.

d) The inner boundary of the assessment zone is defined by a plane parallel to the XZ plane and located [2]m outboard (-Y axis) from the most lateral aspect of the nearside of the vehicle structure.

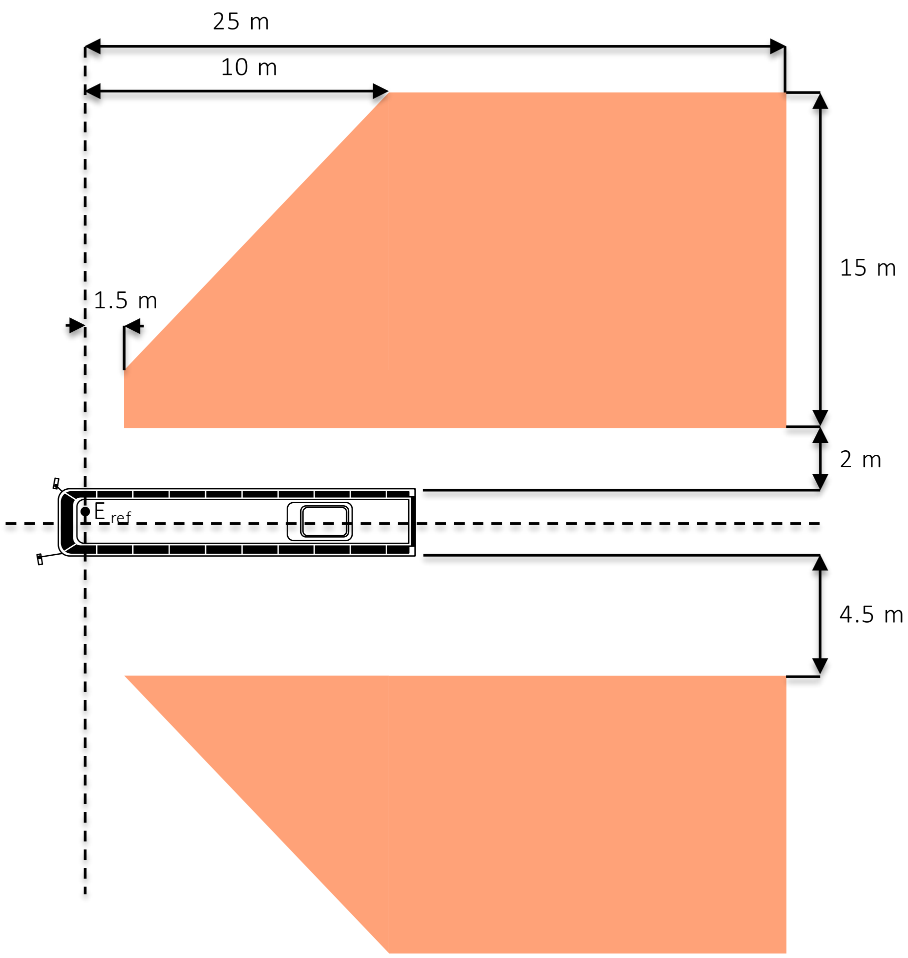

Figure 24: Plan view of wide-angle assessment zone

6.15 Assessment Zone Elements

6.15.1 Each assessment zone shall be split into individual elements, approximately equal in both size and shape, with no single dimension exceeding [100]mm.

7 Vehicle preparation

7.1 Coordinate System

7.1.1 A global coordinate system (X,Y,Z) for the VUT shall be defined such that the X axis points toward the front of the vehicle, the Y axis towards the left (nearside) and the Z axis upwards, as shown in Figure 1.

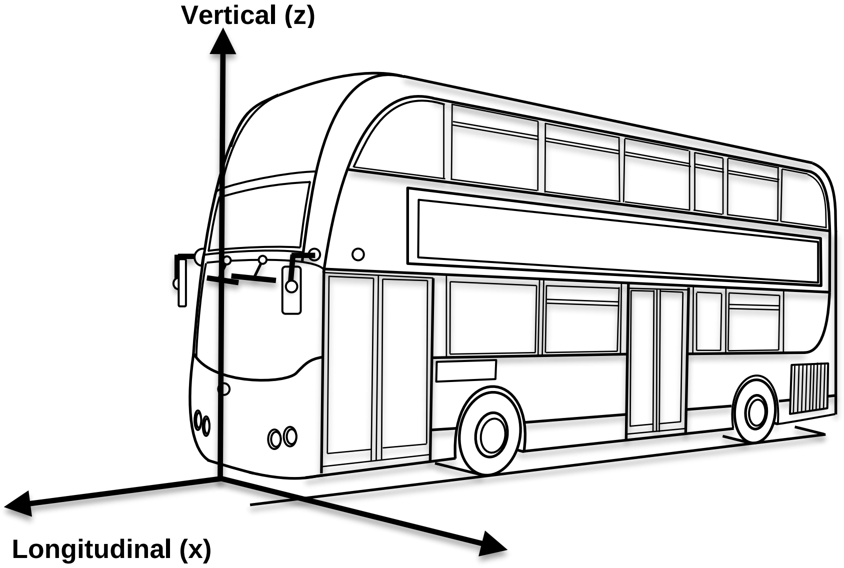

Figure 25: Global coordinate system and notation

7.1.2 The origin of the co-ordinate system shall lie on the ground plane, on the centre line of the vehicle at its foremost point.

7.2 CAD Model

7.2.1 The assessment requires a CAD model of the VUT that is of sufficient detail to allow accurate measurement of the direct and indirect fields of view available to the driver. This can either be supplied by the manufacturer or generated from laser scanning a physical vehicle where independent evaluation is considered necessary. The resulting CAD data must include any interior and exterior component geometry which may obstruct or reflect the sightline (Figure 26), including but not limited to:

a) Exterior panels that bound any transparent area

b) Exterior panels that define the extents of the vehicle to the front (bumper) and sides (wheel arches)

c) Exterior elements that may occlude driver vision including mirrors and mirror arms, wipers and any other manufacturer fit feature or equipment

d) Exterior mirrored surfaces that may reflect driver vision

e) Interior surfaces that may occlude driver vision including: the driver assault screen frame, dashboard, window seals/rubbers, trim panels on doors, A-pillars, B-pillars, grab handles, etc.

f) Interior equipment that may occlude driver vision including: ticket machines, rain sensors, monitors/screens or other controls or displays

g) Key elements of the driver packaging including seats, steering wheel, AHP.

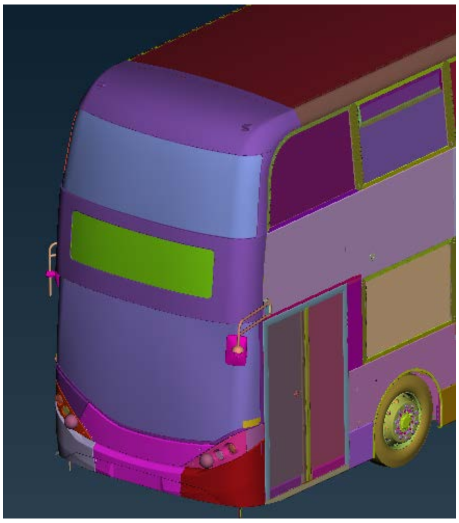

Figure 26: Example CAD data required for bus vision standard assessment

7.3 Glazing Frit

7.4 Where glazing incorporates a 'frit' (also known as 'black-off' or 'fade-off'), this area should be considered opaque. Thus, the daylight opening (DLO) boundary is defined by the inner boundary of any patterned area, as shown in Figure 27 below.

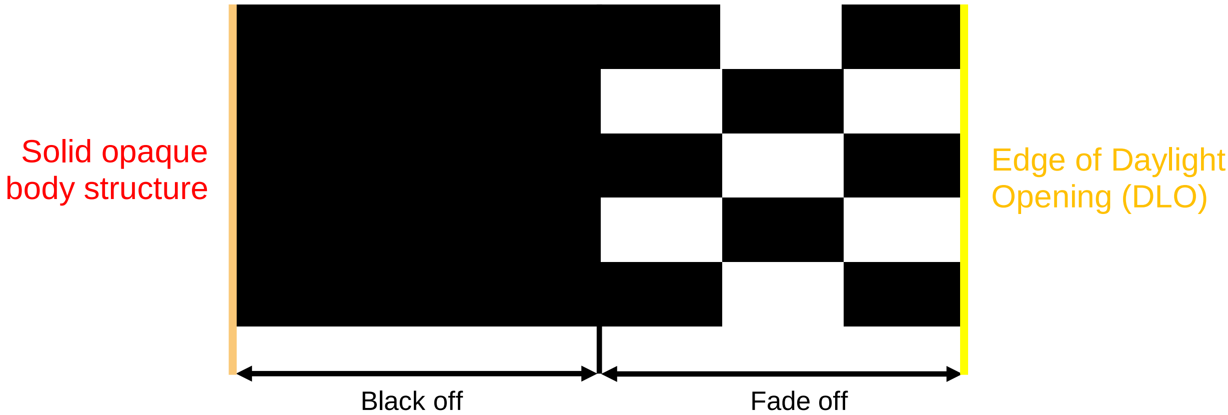

Figure 27: Definition of daylight opening (DLO) at window edges with black-off or fade-off areas

7.5 Tinting

7.5.1 Where any area of a windscreen or other glazed surface has a light transmittance of less than 70% (when measured normal to the surface), this area should be considered opaque. Thus, the DLO boundary is further defined by the boundaries of any tinted areas.

7.6 Glazing Angle

7.6.1 Where the angle of incidence (θ_I) between the surface of [any section of glazing] and the sightline from at least one eye is angled at greater than [70°], [when looking at the surface from any angle,] this area shall be considered opaque (Figure 28). The DLO boundary is therefore further defined by the boundaries of any glazed surfaces defined as opaque.

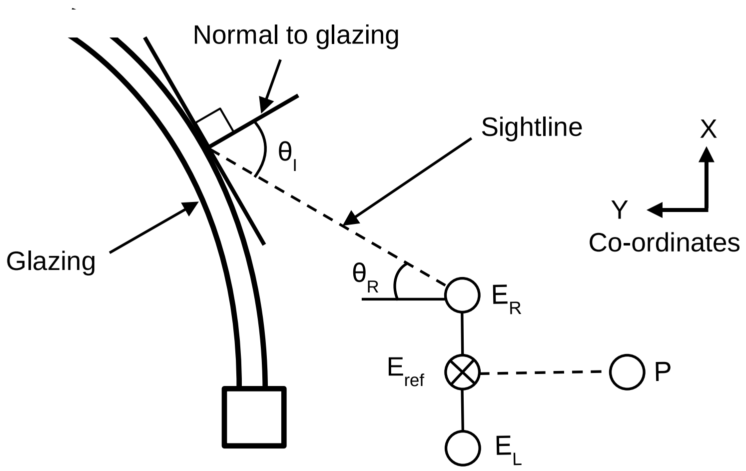

Figure 28: Illustration of angle of incidence between the sightline and glazing

7.7 Mirror Positioning

7.7.1 Accurate CAD models of mirror surfaces, mirror housings and mirror arms shall be included and shall include accurate representation of the curved surfaces for non-planar mirrors. Mirror surfaces and mirror arm model information shall be recorded.

7.7.2 Mirror arms and housing shall be positioned in their in-use position, i.e. not stowed away.

7.7.3 If mirror housings provide a range of adjustment in their in-use position, they shall be adjusted to a representative position for the assessment. The angles that the mirror housing makes relative to the X/Y/Z-axes of the vehicle shall be recorded, alongside the position of the attachment to the mirror arm.

7.7.4 Mirror surfaces shall then be adjusted within the mirror housing to meet UN ECE Regulation 46 requirements.

7.7.5 All mirrors, mirror housings and mirror arms shall be adjusted within manufacturer defined ranges of motion. All mirrored surfaces shall comply with the requirements relating to the radii of curvature in UN ECE Regulation 46. Any mirror not complying with these requirements shall be designated as part of the vehicle structure.

7.8 Camera-Monitor Systems (CMS)

7.8.1 Accurate CAD models of the exterior geometries for the camera, camera housing and monitor shall be included. Monitors shall be positioned in their manufacturer recommended positions, i.e. not stowed away. All camera-monitor systems (CMS) shall comply with UN ECE Regulation 46 requirements. Any CMS not complying with these requirements shall be designated as part of the vehicle structure.

7.9 Accelerator Heel Point (AHP) Height

7.9.1 Where different running gear (tyres, wheels, suspensions) are available on the same model, then by default, the CAD data shall reflect the worst-case configuration. This shall be the configuration that results in the AHP being at the greatest possible distance from the ground plane. The results of this assessment may then be applied to all variants with identical body work and mirror arrangements where the AHP is nearer to the ground. Alternatively, the manufacturer may at their discretion assess more than one variant. CAD data shall represent a bus in the following running order:

a) the suspension enabling the vehicle ground clearance to be adjusted, if applicable, is set to the highest setting for normal driving
b) the specified tyres should be at their maximum ETRTO diameter
c) the tyre pressures are set according to manufacturer's recommendations
d) the fuel tank is filled to no greater than 10% of the capacity specified by the manufacturer
e) other fluid levels, such as lubricants, coolants, etc., are set according to manufacturer's recommendations
f) the driver seat is occupied with a driver of 68 kg mass
g) no additional payload or passenger ballast is added

7.10 Steering Wheel Position

7.10.1 The steering wheel shall be positioned in the geometric centre of the steering wheel adjustment envelope, as defined by the manufacturer.

7.11 Driver Seat Position

7.11.1 The driver seat shall be located at the rearmost and lowest point of the driver seat adjustment envelope, as defined by the manufacturer.

7.12 Accelerator Heel Point (AHP)

7.12.1 The CAD data shall also contain a definition of the Accelerator Heel Point (AHP). The AHP is a key reference point for the definition of the eye points used for the assessment and shall be defined as per the process documented in SAE J1516, SAE J1517 and SAE J1100.

7.13 Other Vehicle Components

7.13.1 Adjustable equipment designed for intermittent use during rare circumstances while driving, such as windscreen wipers or windscreen sun visors, or for non-driving use shall be set in the not-in-use or stowed away position.

7.13.2 Adjustable equipment designed for regular use or that may reasonably be expected to be left permanently in the in-use position by most drivers, such as adjustable armrests, shall be in the in-use position and adjusted to represent the worst-case obstruction to direct vision, as determined by the test service.

7.13.3 All internal components entirely obstructed by the driver cab, such as passenger seats, poles, staircase, may be removed to speed up the simulation process. Such internal components have no effect on the vision zones.

8 Test procedure

8.1 Sightline Projections

8.1.1 Every combination of neck pivot point and eye point angles (β, θ), within the ranges defined in Section 6, and camera field of vision angles (α, λ), within the ranges specified by the manufacturer, shall be analysed according to the following protocol. It is recommended that this process is automated through a computer programme. A breakdown of the neck pivot point and eye point angles to be assessed is provided in Appendix B.

8.1.2 Each sightline shall be projected from a point of origin located at each eye point and camera point location to be assessed. Each sightline shall be increased in length in increments of [100]mm, to project along the eye point or camera point angle, until the sightline reaches a length of [40]m or intersects with the following:

a) an opaque vehicle structure that is defined as a mirrored surface. In this case, the sightline shall be geometrically reflected by mirroring the angle of incidence relative to the normal of the mirror surface at the obstruction point.

b) an opaque vehicle structure not defined as a mirrored surface. In this case, the projection of the sightline shall be terminated at the obstruction point.

8.2 Determining the Direct Vision Volume (V_D)

8.2.1 All assessment zone elements intersected by a sightline originating from either driver eye point (i.e. not at a camera point), but that has not been reflected from a mirrored surface, shall be designated as visible through the direct field of vision of the driver. The volume of these individual elements shall be summed to form the direct vision volume (V_D).

8.3 Determining the Indirect Vision Volume (V_I)

8.3.1 Mirrors (V_{I_M})

8.3.2 All assessment zone elements intersected by a sightline originating from either driver eye point (i.e. not at a camera point) after reflection from a mirrored surface, but that have not been designated as visible via the direct field of vision, shall be designated as visible through the indirect field of vision of the driver using a mirror. The volume of the individual elements shall be summed to form the indirect vision volume for mirrors (V_{I_M}).

8.4 Camera-monitor Systems (CMS) (V_{I_C})

8.4.1 All assessment zone elements intersected by a sightline originating from a camera point, but that have not been designated as visible via either the direct field of vision or via reflection by a mirrored surface, shall be designated as visible through the indirect field of vision of the driver using a CMS. The volume of the individual elements shall be summed to form the indirect vision volume for CMS (V_{I_C}).

8.5 Indirect Vision Volume (V_I)

8.5.1 The indirect vision volume (V_I) associated with each assessment zone shall be calculated through the summation of the indirect vision volume for mirrors (V_{I_M}) and the indirect vision volume for CMS (V_{I_C}).

8.5.2 Thus, for each assessment volume:

$$V_I = V_{I\_M} + V_{I\_C}$$

8.5.3 All volumes shall be calculated in cubic millimetres (mm^3) and to the nearest decimal place.

8.6 Determining the Total Driver Vision Volume (V_T)

8.6.1 The total driver vision volume (V_T) associated with each assessment zone shall be calculated through the summation of the direct vision volume (V_D) and the indirect vision volume (V_I).

8.6.2 Thus, for each assessment volume:

$$V_T = V_D + V_I$$

8.6.3 All volumes shall be calculated in cubic millimetres (mm^3) and to the nearest decimal place.

8.7 Determining the Blind Spot Volume (V_B)

8.7.1 The blind spot volume (V_B) associated with each assessment zone shall be calculated through the subtraction of the total driver vision volume (V_T) from the assessment zone volume (V_A).

8.7.2 Thus, for each assessment volume:

$$V_B = V_T + V_A$$

8.7.3 All volumes shall be calculated in cubic millimetres (mm^3) and to the nearest decimal place.

9 Assessment of results

9.1 Direct Vision Performance Score (DVS)

9.1.1 The direct vision performance score calculates the proportion of each assessment zone visible to the driver through the direct field of view. This is calculated by dividing the assessment zone volume (V_A) by the relevant direct vision volume (V_D).

9.1.2 Thus, for each assessment volume:

$$DVS = \frac{V_D}{V_A} \%$$

9.1.3 The direct vision performance score shall be calculated as a percentage to [a single] decimal place.

9.2 Indirect Vision Performance Score (IVS)

9.2.1 The indirect vision performance score calculates the proportion of each assessment zone visible to the driver through the direct field of view. This is calculated by dividing the assessment zone volume (V_A) by the relevant indirect vision volume (V_I).

9.2.2 Thus, for each assessment volume:

$$IVS = \frac{V_I}{V_A} \%$$

9.2.3 The indirect vision performance score shall be calculated as a percentage to [a single] decimal place.

9.3 Total Driver Vision Performance Score (TVS)

9.3.1 The total driver vision performance score calculates the proportion of each assessment zone visible to the driver through the direct and indirect fields of view. This is calculated by dividing the assessment zone volume (V_A) by the relevant total driver vision volume (V_T).

9.3.2 **Thus, for each assessment volume:**

$$TVS = \frac{V_T}{V_A} \%$$

9.3.3 The total driver vision performance score shall be calculated as a percentage to [a single] decimal place.

9.4 Bus Vision Standard Performance Rating Score (BVS)

9.4.1 The bus vision standard performance rating score calculates a normalised, weighted, score to provide an overall rating score to describe the relative safety performance of different vehicles.

9.4.2 [London collision data has been used to weight the importance of each assessment zone with respect to the potential casualty prevention potential of each zone around the vehicle.] This has been combined with research further weighting the differences in importance between direct and indirect vision with respect to their relative casualty prevention potentials. These weighting factors are shown in Table 15.

Table 15: Weighting factors for each assessment zone

Assessment Zone	Direct Vision Weighting Factor (W_D)	Indirect Vision Weighting Factor (W_I)	Casualty Weighting Factor (W_C)
Forward Close Proximity Zone	100%	50%	[69]%
Rearward Close Proximity Zone	-	100%	[28]%
Wide Angle Zones	-	100%	[3]%

Note: Rearward close proximity and wide angle zones should be visible through indirect vision only

9.4.3 The weighted bus vision standard performance rating score for each assessment zone is calculated by multiplying the summation of the weighted direct and indirect vision performance scores with the relevant casualty weighting factor.

9.4.4 The overall bus vision standard performance rating score (BVS) of the VUT shall be calculated by summing the weighted scores of each assessment zone and shall be calculated as a percentage to a single decimal place.

9.4.5 Table 16 shows hypothetical results as a worked example.

Table 16: Example scoring and weighting process to obtain the overall bus vision standard performance rating score (BVS) for the VUT

Assessment Zone	DVS	W_D	IVS	W_I	W_C	BVS
Forward Close Proximity Zone	89.7%	100%	5.2%	50%	[69]%	63.7%
Rearward Close Proximity Zone	-	-	30.3%	100%	[28]%	8.5%
Wide Angle Zones	-	-	12.8%	100%	[3]%	0.4%
					Overall BVS	72.6%

10 Test report

10.1 The Test Service shall provide a comprehensive Test Report that will be made available to TfL. The test report shall consist of three distinct sections:

a) Performance data

b) Confirmation of protocol compliance

c) Reference information

10.2 Performance Data

10.2.1 Table 17 shows the performance data to be produced for each vehicle assessed.

Table 17: Performance data template for test report

Performance Measure	Forward Close Proximity Zone	Rearward Close Proximity Zone	Wide Angle Zones
Assessment Zone Volume (V_A) /mm^3			
Direct Vision Volume (V_D) /mm^3		-	-
Indirect Vision Volume for Mirrors (V_{I_M}) /mm^3			
Indirect Vision Volume for Cameras (V_{I_C}) /mm^3			
Indirect Vision Volume (V_I) /mm^3			
Total Driver Vision Volume (V_T) /mm^3			
Blind Spot Volume (V_B) /mm^3			
Direct Vision Performance Score (DVS) /%			
Indirect Vision Performance Score (IVS) /%			
Total Driver Vision Performance Score (TVS) /%			
Bus Vision Standard Performance Score (BVS) /%			
Overall Bus Vision Standard Performance			

Score (BVS) /%	

10.2.2 In addition to the necessary performance data, the Test Service shall provide images with the Test Report illustrating the visible volumes and blind spots associated with each assessment volume. As a minimum requirement, these images shall include a plan view of the blind spot volumes associated with each assessment zone, but may also be combined with images including isometric views, side views, etc. to support understanding of the principle causes of the blind spots. Such images shall be colour coded to distinguish between the visible and blind spot volumes and may also be separated by whether areas are visible by direct or indirect vision (mirrors/cameras). A legend to the colour coding shall be provided within the Test Report. Hypothetical examples are shown in Figure 29.

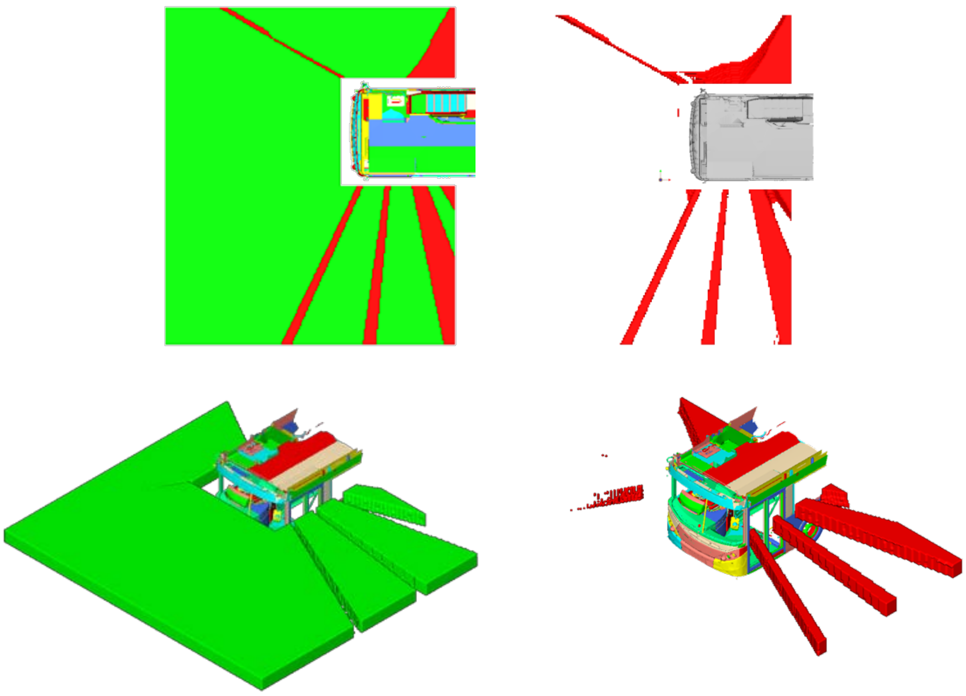

Figure 29: Example images showing Direct Vision Volume (green) and Blind Spot Volume (red) for the forward close proximity assessment zone

10.3 Protocol Compliance

10.3.1 To confirm protocol compliance, the Test Service shall provide information including:

a) Details of the software packages used (e.g. CAD software)

b) Origin of the CAD model (i.e. from manufacturer or result of laser scan).

c) Information that may be used to verify the level of detail of the CAD model.

d) Minimum and maximum element sizes used for the assessment zones.

10.4 Reference Information

10.4.1 As a minimum, the Test Service shall provide reference information including:

a) Vehicle make;

b) Vehicle model;

c) Vehicle model variant;

d) Vehicle running order information;

e) Vehicle steering wheel and driver seat positions;

f) AHP location;

g) Mirror and mirror arm model/s fitted;

h) CMS model/s fitted, if applicable;

i) Mirror positioning, including information on locations and adjustment angles;

j) CMS information, including locations and fields of view;

k) Details on any glazed areas defined as opaque (due to frit/tinting/angle);

l) Details of the Test Service; and

m) Test date(s).

Annex 2 Components excluded in defining the assessment zones

Vehicle length

Vehicle length relates to a dimension is measured according to ISO standard 612-1978, term No. 6.1. In addition to the provisions of this standard, when measuring vehicle length, the following components shall not be taken into account:

- wiper and washer devices,
- front or rear marker-plates,
- customs sealing devices and their protection,
- devices for securing the load restraint(s)/cover(s) and their protection,
- lighting and light signalling devices,
- mirrors or other devices for indirect vision,
- reversing aids,
- air-intake pipes,
- length stops for demountable bodies,
- access steps and hand-holds,
- ram rubbers and similar equipment,
- lifting platforms, access ramps and similar equipment in running order, not exceeding 300 mm,
- coupling and recovery towing devices for power driven vehicles,
- trolleybus current collection devices in their elevated and retracted positions,
- external sun visors,
- de-mountable spoilers,
- exhaust pipes.

Vehicle width

Vehicle width relates to a dimension is measured according to ISO standard 612-1978, term No. 6.2. In addition to the provisions of this standard, when measuring the vehicle width, the following components shall not be taken into account:

- customs sealing devices and their protection,
- devices for securing the tarpaulin and their protection,
- tyre failure tell-tale devices,
- protruding flexible parts of a spray-suppression system,
- lighting and light signalling devices,
- for buses, access ramps, lifting platforms and similar equipment in their stowed position.
- rear-view mirrors or other devices for indirect vision,
- tyre-pressure indicators,
- retractable steps,
- the deflected part of the tyre walls immediately above the point of contact with the ground,
- external lateral guidance devices of guided buses,
- running boards,
- de-mountable mudguard broadening

Annex 2 Breakdown of head and eye angles

Head Angles (degrees)

		-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
Vertical	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Eye Angle (degrees)

		Horizontal																				
		-30	-27	-24	-21	-18	-15	-12	-9	-6	-3	0	3	6	9	12	15	18	21	24	27	30
Vertical	-60	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-57	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-54	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-51	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-48	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-45	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-42	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-39	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-36	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-33	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-27	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-24	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-21	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-18	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	-3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	18	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	21	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	24	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	27	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	33	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	36	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	39	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	42	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	45	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Attachment 20: Bus Vision Standard Guidance Notes

1 Introduction

All buses shall allow the driver to have sufficient vision of their surroundings to allow the execution of all driving tasks required in service in London.

All buses shall have a high standard of direct and indirect vision in areas close to the vehicle where vulnerable road users are at particular risk of collision with a bus undertaking low speed manoeuvres. This is referred to as close proximity vision.

This document sets out the guidance notes related to the assessment of Direct and Indirect Vision. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The Direct and Indirect Vision requirements may be assessed against a new build bus, or against a vehicle fitted with an aftermarket retrofit vision system.

2.1 Compliance and warranty

A bus operator should ask to see compliance certificates for UNECE Regulation 46 and warranty information for any camera monitor system (CMS) from the bus manufacturer and/or the aftermarket supplier.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

The requirements relate to both direct vision, where the driver looks directly through the windows and transparent areas of the bus structure in order to see the road and traffic environment outside, and indirect vision, where the driver looks in mirrors, monitors or other devices to see parts of the road and traffic environment around the vehicle.

In order to recognise a potentially dangerous situation in low speed manoeuvring and successfully avoid a collision the following elements are required:

- **Available to be seen:** The hazard (pedestrian, cyclist, other vehicle etc.) needs to be available to be seen by the driver sufficiently ahead of time to allow avoiding action to be taken. That means the hazard needs to be in view at least approximately 2 seconds before collision
- **Alert and attentive:** The driver needs to be attentive to the road and traffic environment and alert to the possible need to react
- **Looking in the right direction**: In complex driving situations, the driving task can demand attention in multiple different directions; the driver needs to be looking in the right direction at the right time to see the hazard. In dynamic moving environments this is not guaranteed even if the driver is alert and attentive.
- **Recognition:** Once the hazard is seen, then the driver must recognise the hazard and the risk that it poses
- **Reaction:** Once the risk is recognised, the driver must react quickly and correctly to the risk; in some circumstances this may be steering around the hazard, in many it will be braking the vehicle to a stop and in others it might simply be to remain stationary instead of moving off from rest.

Direct vision and each different form of indirect vision have different benefits and disbenefits. The Bus Vision Standard (BVS) and associated vision test and assessment procedure recognises that current buses already have very good direct vision relative to other large vehicles and so sets a minimum standard that ensures that standard is maintained in the face of other competing pressures in future. It will recognise improvements over and above this minimum standard but also recognises the opportunities for improvement are relatively small.

In addition to this, the BVS will set a minimum standard for the overall level of vision, whether implemented via direct or indirect vision. However, it will not prescribe how this will achieved and will recognise vision performance over and above the minimum standard. This leaves manufacturers and operators to choose the solutions that work best with their designs and operations. In making those choices, manufacturers and operators should bear in mind the requirements above, the guidance below about different aspects of different solutions and the interaction with systems such as blind spot warning or intervention systems (BSW) (see separate BSW requirements, test procedures and guidance documents).

2.3 Direct vision

Direct vision is generally seen as being more effective than indirect vision. This is because it offers benefits in the ‘recognition’ phase described above. For example, objects appear at life size, free from distortion and movement of a hazard relative to the vehicle is large and more likely to attract attention in peripheral vision. In addition to this, it is possible for drivers to make eye-contact with other road users around the vehicle which is thought to improve confidence that people have been seen and to help read intention of next moves. There is experimental evidence to show that drivers react significantly more quickly to the presence of vulnerable road users around the vehicle when they are seen via direct vision, rather than via indirect vision.

However, it is not practically possible to see all necessary areas around a large eye point will be difficult because of the need for the driver to rotate eyes, neck and even body to direct their view there and because buses serve a purpose and seats, passengers and other structural elements cannot all be made transparent.

2.4 Indirect vision

The use of mirrors or camera monitor systems can be cost effective solutions that allow areas to the rear of the driver's eyes or specific blind spots in the forward field of view to be easily seen. However, the ability of drivers to recognise hazards can be more difficult:

- **Image size:** Hazards seen in mirrors or monitors will typically be smaller than life size and their relative motion with the vehicle less easy to identify in peripheral vision. Thus, larger mirrors or monitors may be preferable to smaller devices.
- **Conflicts with direct vision:** Mirrors or monitors placed in areas around windows will cause some obstruction to direct vision. In this case smaller devices may be considered preferable. However, compromises that position devices in places where direct vision is less important or where it coincides with existing less avoidable obstructions such as A-pillars already exist may be better, bearing in mind the possible recognition benefits of larger images.
- **Distortion:** strongly curved mirrors or fish eye camera lenses can produce very large fields of view from a single source, which can be seen as a benefit if the size of the view is all that is considered and not the quality of the image. Each of these techniques can produce distorted images that may make it harder for drivers to recognise hazards and interpret risk particularly during quick mirror checks. However, sophisticated software in some camera monitor systems may be able to enhance images in poor conditions such that image quality is higher than with equivalent mirrors.
- **Driver workload:** Evidence in HGVs suggests that scanning direct vision and up to 6 mirrors during a complex low speed manoeuvre takes a significant amount of time. This increases driver workload such that although a hazard may more often be 'available to be seen' the driver may be looking in the right place at the right time less frequently, while still being diligently attentive and alert. Thus, indirect vision devices that add to driver workload by increasing the number of places they need to look or by requiring them to move their gaze further from the other areas they need to scan are likely to increase driver workload. This may detract from, or even reverse, the other benefits that the devices provide.
- **Adjustment:** Poor adjustment can very substantially reduce the useful available view from a device. Operators should request guidance from the bus manufacturer or aftermarket supplier regarding the correct adjustment of the mirror or CMS.

The protocol has been designed to minimise the likelihood of such occurrences and requires compliance with the minimum standards set in these respects by UNECE Regulation 46. However, a wide range of differences in approach are still possible within these constraints and manufacturers and operators should aim to select the best solutions they can bearing in mind these factors and their other operational

It is possible that some camera monitor systems intended to replace mirrors may emerge that attempt to resolve some of these conflicts by varying the views displayed on the monitors, depending on the vehicle and traffic situation at the time. For example, class II mirrors may be removed and replaced by a rectangular monitor mounted on each A-pillar. However, the camera system may also be capable of showing a class V close proximity side view and/or a rear view immediately behind the vehicle. When travelling forward at normal speeds the offside mirror may show the class II display only, the nearside may show a large class II display and a small class V display. At low speeds when indicators are activated this ratio may reverse such that a large class V view is displayed and a small class II. When reverse is selected perhaps both monitors may show a 50/50 class II and rear vision view. This approach has clear potential benefits but is a new technology and the workload requirements and effects on recognition are not clearly understood at this time. Such systems are well worth investigation but operators may wish to consider trialling them in pilot phases with objective feedback from drivers before widespread rollout.

3 Training

3.1 For test houses

The recommended method to complete the assessment involves the use of CAD and finite element (FE) modelling so test houses should have experience of such techniques.

Test houses accredited to undertake approval tests to UNECE Regulation 46 will be considered suitable to undertake performance tests if they have the necessary CAD and FE experience. Test houses 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.

3.2 Bus drivers

Drivers should be trained to correctly adjust mirrors and/or CMS to provide the required field of view.

Where a monitor is used to meet the indirect vision requirements, drivers should be trained to understand the orientation and perspective of the image. In particular, where a camera monitor system replaces existing mirrors, drivers should be thoroughly familiarised with the system.

3.3 Shift Supervisors

Supervisors should aim to ensure drivers are correctly adjusting mirrors and/or CMS to provide the required field of view and that they are familiar with the image provided by camera monitor systems.

3.4 Bus maintenance engineers

The engineers carrying out general bus maintenance should be aware of the location and details of any cameras related to a CMS. Training should be based on the importance of ensuring the cameras are correctly aligned, undamaged and unobstructed.

4 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs.

5 Repair

If during system maintenance checks (section 4) any of the mirrors and/or cameras is deemed to be faulty or failing they should be replaced as soon as possible. The extent of the vision provided by the mirrors and/or cameras is completely contingent on the mirrors and cameras being clean and undamaged.

Attachment 21: Blind Spot Mirrors Guidance Notes

1 Introduction

All buses shall allow the driver to have sufficient vision of their surroundings to allow the execution of all driving tasks required in service in London.

All buses shall have a high standard of direct and indirect vision in areas close to the vehicle where vulnerable road users are at particular risk of collision with a bus undertaking low speed manoeuvres. This is referred to as close proximity vision.

This document sets out the guidance notes related to the assessment of Direct and Indirect Vision. Specifically, in relation to blind spot mirrors. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The Direct and Indirect Vision requirements may be assessed against a new build bus, or against a vehicle fitted with an aftermarket retrofit blind spot mirror system.

2.1 Compliance and warranty

A bus operator should ask to see documentary evidence of compliance with the requirements.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

The use of mirrors can be a cost effective solution that allow areas to the rear of the driver's eyes or specific blind spots in the forward field of view to be easily seen. However, the ability of drivers to recognise hazards can be more difficult:

- Image size: Hazards seen in mirrors will typically be smaller than life size and their relative motion in regards to the vehicle less easy to identify in peripheral vision. Thus, larger mirrors may be preferable to smaller devices.
- Distortion: strongly curved mirrors can produce very large fields of view from a single source, which can be seen as a benefit if the size of the view is all that

is considered and not the quality of the image. This can produce distorted images that may make it harder for drivers to recognise hazards and interpret risk particularly during quick mirror checks.

- Driver workload: Evidence in HGVs suggests that scanning direct vision and up to 6 mirrors during a complex low speed manoeuvre takes a significant amount of time. This increases driver workload such that, although a hazard may more often be ‘available to be seen’, the driver may be looking in the right place at the right time less frequently, while still being diligently attentive and alert. Thus, indirect vision devices that add to driver workload by increasing the number of places they need to look or by requiring them to move their gaze further from the other areas they need to scan are likely to increase driver workload. This may detract from, or even reverse the other benefits that the devices provide.
- Adjustment: Poor adjustment can vary substantially and therefore reduce the useful available view from a device. Operators should request guidance from the bus manufacturer or aftermarket supplier regarding the correct adjustment of the mirror.

The protocol has been designed to minimise the likelihood of such occurrences and requires compliance with the minimum standards set in these respects by UNECE Regulation 46. However, a wide range of differences in approach are still possible within these constraints and manufacturers and operators should aim to select the best solutions they can bearing in mind these factors and their other operational constraints.

3 Training

3.1 Bus drivers

Drivers should be trained to appropriately install and correctly adjust mirrors to see the relevant visibility zones.

3.2 Shift Supervisors

Supervisors should aim to ensure drivers are correctly adjusting mirrors to provide the required field of view.

4 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs.

5 Repair

If during system maintenance checks (section 4) any of the mirrors are deemed to be faulty or they should be replaced as soon as possible. The extent of the vision provided by the mirrors is completely contingent on them being clean and undamaged.

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Attachment 22: Camera Monitor Systems (CMS) Guidance Notes

1 Introduction

All buses shall allow the driver to have sufficient vision of their surroundings to allow the execution of all driving tasks required in service in London.

All buses shall have a high standard of direct and indirect vision in areas close to the vehicle where vulnerable road users are at particular risk of collision with a bus undertaking low speed manoeuvres. This is referred to as close proximity vision.

This document sets out the guidance notes related to the assessment of Direct and Indirect Vision. Specifically, in relation to camera monitor systems. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The Direct and Indirect Vision requirements may be assessed against a new build bus, or against a vehicle fitted with an aftermarket retrofit camera monitor system.

2.1 Compliance and warranty

A bus operator should ask to see compliance certificates for UNECE Regulation 46 and warranty information for any camera monitor system (CMS) from the bus manufacturer and/or the aftermarket supplier.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

The use of camera monitor systems can be an effective solution to allow areas to the rear of the driver’s eyes or specific blind spots in the forward field of view to be easily seen. However, the ability of drivers to recognise hazards can be more difficult:

- Image size: Hazards seen in monitors will typically be smaller than life size and their relative motion with the vehicle less easy to identify in peripheral vision. Thus, larger monitors may be preferable to smaller devices.

- Conflicts with direct vision: Monitors placed in areas around windows will cause some obstruction to direct vision. In this case smaller devices may be considered preferable. However, compromises that position devices in places where direct vision is less important or where it coincides with existing less avoidable obstructions (e.g. A-pillars or driver assault screen frames) may be better, bearing in mind the possible recognition benefits of larger images.
- Distortion: fish-eye camera lenses can produce very large fields of view from a single source, which can be seen as a benefit if the size of the field of view is all that is considered and not the quality of the image. This can produce distorted images that may make it harder for drivers to recognise hazards and interpret risk particularly during quick mirror checks. However, sophisticated software in some camera monitor systems may be able to enhance images in poor conditions such that image quality is higher than with equivalent mirrors.
- Driver workload: Evidence in HGVs suggests that scanning direct vision and up to 6 mirrors during a complex low speed manoeuvre takes a significant amount of time. This increases driver workload such that, although a hazard may more often be ‘available to be seen’, the driver may be looking in the right place at the right time less frequently, while still being diligently attentive and alert. Thus, indirect vision devices that add to driver workload by increasing the number of places they need to look or by requiring them to move their gaze further from the other areas they need to scan are likely to increase driver workload. This may detract from, or even reverse the other benefits that the devices provide.
- Adjustment: Poor adjustment can vary substantially and therefore reduce the useful available view from a device. Operators should request guidance from the bus manufacturer or aftermarket supplier regarding the correct adjustment of the CMS.

The protocol has been designed to minimise the likelihood of such occurrences and requires compliance with the minimum standards set in these respects by UNECE Regulation 46. However, a wide range of differences in approach are still possible within these constraints and manufacturers and operators should aim to select the best solutions they can bearing in mind these factors and their other operational constraints.

It is possible that some camera monitor systems intended to replace mirrors may emerge that attempt to resolve some of these conflicts by varying the views displayed on the monitors, depending on the vehicle and traffic situation at the time. For example, class II mirrors may be removed and replaced by a rectangular monitor mounted on each A-pillar. However, the camera system may also be capable of showing a class V close proximity side view and/or a rear view immediately behind the vehicle. When travelling forward at normal speeds the offside mirror may show the class II display only, the nearside may show a large class II display and a small class V display. At low speeds when indicators are activated this ratio may reverse such that a large class V view is displayed and a small class II. When reverse selected perhaps both monitors may show a 50/50 class II and rear vision view. This approach has clear potential benefits but is a new technology and the workload requirements and effects on recognition are not clearly understood at this time. Such systems are well worth investigation but operators may wish to consider trialling them in pilot phases with objective feedback from drivers before widespread rollout.

3 Training

3.1 Bus drivers

Drivers should be trained to correctly adjust the CMS to provide the required field of view.

Where a monitor is used to meet the indirect vision requirements, drivers should be trained to understand the orientation and perspective of the image. In particular, where a camera monitor system replaces existing mirrors, drivers should be thoroughly familiarised with the system.

Further guidance on installation is to be provided when CMS HMI guidelines are produced.

3.2 Shift Supervisors

Supervisors should aim to ensure drivers are correctly adjusting CMS to provide the required field of view and that they are familiar with the image provided by camera monitor systems.

4 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs.

5 Repair

If during system maintenance checks (section 4) any of the cameras are deemed to be faulty or they should be replaced as soon as possible. The extent of the vision provided by the CMS is completely contingent on the cameras and monitors being clean and undamaged.

Training should be provided to mechanics/engineers on how to appropriately maintain and replace CMS systems.

Attachment 23: Rear view Camera Monitor Systems (CMS) Guidance Notes

1 Introduction

All buses shall allow the driver to have sufficient vision of their surroundings to allow the execution of all driving tasks required in service in London.

All buses shall have a high standard of direct and indirect vision in areas close to the vehicle where vulnerable road users are at particular risk of collision with a bus undertaking low speed manoeuvres. This is referred to as close proximity vision.

This document sets out the guidance notes related to the assessment of Direct and Indirect Vision. Specifically, in relation to rear-view camera monitor systems. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The Direct and Indirect Vision requirements may be assessed against a new build bus, or against a vehicle fitted with an aftermarket retrofit rear-view camera monitor system.

2.1 Compliance and warranty

A bus operator should ask to see compliance certificates for UNECE Regulation 46 and warranty information for any rear-view camera monitor system (CMS) from the bus manufacturer and/or the aftermarket supplier. The compliance is with regard to the technical quality of view only.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

The use of camera monitor systems can be an effective solution to allow areas to the rear of the driver’s eyes or specific blind spots in the forward field of view to be easily seen. However, the ability of drivers to recognise hazards can be more difficult:

- Image size: Hazards seen in monitors will typically be smaller than life size and their relative motion with the vehicle less easy to identify in peripheral vision. Thus, larger monitors may be preferable to smaller devices.
- Conflicts with direct vision: Monitors placed in areas around windows will cause some obstruction to direct vision. In this case smaller devices may be considered preferable. However, compromises that position devices in places where direct vision is less important or where it coincides with existing less avoidable obstructions (e.g. A-pillars or driver assault screen frames) may be better, bearing in mind the possible recognition benefits of larger images.
- Distortion: fish-eye camera lenses can produce very large fields of view from a single source, which can be seen as a benefit if the size of the field of view is all that is considered and not the quality of the image. This can produce distorted images that may make it harder for drivers to recognise hazards and interpret risk particularly during quick mirror checks. However, sophisticated software in some camera monitor systems may be able to enhance images in poor conditions such that image quality is higher than with equivalent mirrors.
- Driver workload: Evidence in HGVs suggests that scanning direct vision and up to 6 mirrors during a complex low speed manoeuvre takes a significant amount of time. This increases driver workload such that, although a hazard may more often be ‘available to be seen’, the driver may be looking in the right place at the right time less frequently, while still being diligently attentive and alert. Thus, indirect vision devices that add to driver workload by increasing the number of places they need to look or by requiring them to move their gaze further from the other areas they need to scan are likely to increase driver workload. This may detract from, or even reverse the other benefits that the devices provide.
- Adjustment: Poor adjustment can vary substantially and therefore reduce the useful available view from a device. Operators should request guidance from the bus manufacturer or aftermarket supplier regarding the correct adjustment of the CMS.

The protocol has been designed to minimise the likelihood of such occurrences and requires compliance with the minimum standards set in these respects by UNECE Regulation 46. However, a wide range of differences in approach are still possible within these constraints and manufacturers and operators should aim to select the best solutions they can bearing in mind these factors and their other operational constraints.

3 Training

3.1 Bus drivers

Drivers should be trained, whether necessary, to correctly adjust the rear-view CMS to provide the required field of view.

Where a monitor is used to meet the rear-view indirect vision requirements, drivers should be trained to understand the orientation and perspective of the image.

Further guidance on installation is to be provided when CMS HMI guidelines are produced.

3.2 Shift Supervisors

Supervisors should aim to ensure drivers are correctly adjusting CMS to provide the required field of view and that they are familiar with the image provided by camera monitor systems.

4 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs.

5 Repair

If during system maintenance checks (section 4) any of the cameras are deemed to be faulty or they should be replaced as soon as possible. The extent of the vision provided by the CMS is completely contingent on the cameras and monitors being clean and undamaged.

Training should be provided to mechanics/engineers on how to appropriately maintain and replace CMS systems.

Attachment 24: Blind Spot Warning Assessment Protocol

1 Introduction

This document presents a procedure for objectively measuring the performance of Blind Spot information signal, Warning and intervention (BSW) systems.

1.1 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 in the Consolidated Resolution on the Construction of Vehicles (R.E.3) as M3; Class I, Class II.

Note, this standard is intended for application in the UK where vehicles drive on the left hand side of the road. However, application to regions where vehicles drive on the right hand side can be achieved by reflecting all scenarios and references to left and right about the longitudinal plane of the vehicle (global X-axis).

1.2 Purpose

Over many years, blind spots have been identified as contributory factors in collisions between heavy goods vehicles (HGVs) and vulnerable road users (VRUs). The direct vision through the glazed areas of HGVs is such that, given their height from the ground, pedestrians and cyclists can be easily hidden in many areas that cannot be seen directly and in some areas that cannot be seen either directly or indirectly through the available mirrors.

The direct vision of buses is superior to that from most HGVs, though fewer mirrors are legally required on buses resulting in an inferior indirect vision field of view. In total the blind spot areas in close proximity to buses are smaller. However, collisions where pedestrians and cyclists are killed or seriously injured when positioned in close proximity to a moving bus do still occur.

Overall London buses present a much lower risk of cyclist fatality per bus km than HGVs do. However, the proportion of relevant fatalities that occur in collisions where the vehicle turned left and hit a cyclist at the nearside or front, thought to be a highly relevant manoeuvre for blind spots, is only slightly lower than that for HGVs.

By contrast, London buses present a much higher risk of pedestrian fatality per bus km than HGVs do. However, the proportion of those collisions that involve a vehicle moving off from rest and running over a pedestrian positioned immediately ahead of the vehicle, again thought to be a highly relevant manoeuvre for blind spots, is substantially less than for HGVs.

Direct and indirect vision will be factors in the differences between these vehicle types, but it is clear that better vision alone does not eliminate risk. Drivers must be attentive, looking in the right direction at the right time during potentially demanding driving situations and, having identified a potential collision, take the correct action. Blind spot information signal, warning systems therefore have a role to play in helping ensure the driver pays attention to the presence of a pedestrian or cyclist in close proximity to a bus and assisting the driver with taking the correct action if a collision is imminent.

A regulation defining minimum standards for such systems is under development as part of a UN ECE Regulation. However, it will not initially be mandatory, may only apply to HGVs and not buses, is a minimum pass/fail standard and only covers information signal and not necessarily warning or intervention systems.

The aim of this protocol is to provide objective assessments that can be used to enforce minimum standards even where the forthcoming regulation does not apply and to encourage performance over and above those minimum standards.

It should be noted that this protocol only covers collision situations related to low speed, close proximity manoeuvring. It does not consider forward collision warnings of the type relevant at higher speeds with the vehicle travelling in a straight line such as those scenarios covered by TfL’s AEB testing and assessment protocol.

It should further be noted that this protocol does not require or reward automated emergency braking systems in the low speed close proximity manoeuvres that are in scope.

2 Normative References

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

- 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
- Articulated Pedestrian Target Specification document version 1.0.
- Bicyclist Target Specification document version 1.0.
- UNECE Regulation 10. Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility
- BS EN 50498:2010 Electromagnetic compatibility (EMC). Product family standard for aftermarket electronic equipment in vehicles.
- ISO 11452-9 ‘Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 9: Portable transmitters’
- ISO 11451-3 ‘Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 3: On Board Transmitter Simulation’
- UNECE Regulation 61 Uniform provisions on the external projections of commercial vehicles
- Commission Regulation (EU) No 1230/2012 implementing Regulation (EC) No 661/2009 of the European Parliament and of the Council with regard to type-approval requirements for masses and dimensions of motor vehicles and their trailers and amending Directive 2007/46/EC of the European Parliament and of the Council.
- ISO 612:1978 Road Vehicles – Dimensions of motor vehicles and towed vehicles – terms and definitions.
- ISO 15006: 2011. Ergonomic aspects of transport information and control systems – specifications for in-vehicle auditory presentation

- ISO 15008: 2009. Road vehicle – Ergonomics aspects of transport information and control systems – Specification and test procedure for in-vehicle visual presentation
- ISO 15998:2008 Earth moving machinery – Machine control systems (MCS) using electronic components – performance criteria and tests for functional safety
- ISO 16001: 2008. Earth moving machinery. Object detection systems and visibility aids
- ISO 15037-2: 2006: *Road Vehicles – Vehicle dynamics test methods - General conditions for heavy vehicles and buses*

3 Definitions

For the purpose of this Protocol:

- **Accelerator heel point (AHP) -** a point on the shoe located at the intersection of the heel of shoe and the depressed floor covering, when the shoe tool is properly positioned. (Essentially, with the ball of the foot contacting the lateral centre line of the undepressed accelerator pedal, while the bottom of the shoe is maintained on the pedal plane). As defined in SAE J1516, SAE J1517 and SAE J1100.
- **Approval Authority** - 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.
- **Aftermarket system** - a BSW system that is fitted to the vehicle after it has been registered and delivered for the first time, by agencies other than the vehicle manufacturers or their authorised dealer.
- **Blind spot -** the volume of space around the test vehicle that cannot be seen by the driver either through the glazed areas of the vehicle cab or through the indirect vision devices installed on the vehicle.
- **Blind Spot information signal, Warning and intervention (BSW) system** - a complete system, encompassing both the defined blind spot safety functions and enabling technologies, that informs the driver of a VRU in close proximity to the vehicle, warns the driver of an imminent collision with a VRU and/or intervenes directly with the drive controls to prevent a collision.
- **Blind spot safety function** – these functions are defined by the action that the enabling technologies take to either improve the chances of a driver acting appropriately should a VRU be in the vehicle blind spot or to automatically avoid a collision should the driver fail to take the appropriate action. They include:

  (a) **VRU proximity information signal -** a signal informing the driver that a VRU has been detected in close proximity to the vehicle. A proximity information signal (which may be referred to as an information signal), is a medium urgency signal that reflects the fact that the driver may or may not be aware of the presence of the VRU and that there may or may not be an imminent risk of collision.

  (b) **VRU collision warning signal** - a signal issued to the driver where an imminent collision between the VRU and the vehicle is calculated as likely. Such a system shall not warn the driver of the simple presence of a VRU in close proximity if the trajectories of each are such that a collision is not imminent. A collision warning is a high urgency signal that warns the driver of the vehicle that a collision is imminent.

  (c) **Motion inhibit** - a system that prevents a vehicle from moving off from rest when a VRU is located in front of the vehicle is at risk of an imminent collision. The system may achieve the function through intervention in throttle, gear selection or braking. The system shall be type approved for use by the Original Equipment Manufacturer (OEM) of the vehicle.

- **Dealer fit system** – a BSW system that is fitted as a standard component to the vehicle after production (i.e. not integrated in the original vehicle design). However, the installation of the device is approved by the manufacturer of the vehicle and fitted by its authorised dealers prior to delivery and registration.
- **Enabling technologies** - the technologies that enable the blind spot safety function through the combination of sensor components, decision-making algorithms and the components utilised to implement the blind spot safety function. Sensor and vehicle components may be used for multiple purposes (e.g. cameras may also be used by camera monitoring systems replacing external mirrors or for CCTV recording purposes) or a single function may require more than one sensing technology (e.g. the use of both camera and RADAR sensors in a process known as sensor fusion).
- **Human Machine Interface (HMI)** - the part of a BSW system that interacts with the driver and includes controls and settings for activating or adjusting the application as well as the means by which information and warning signals are communicated from the system to the driver.
- **Horizontal field of view angle** - the angle between the longitudinal plane of the test vehicle and the sightline
- **Original Equipment Manufacturer (OEM) system** - a BSW system that is integrated into the design of the vehicle and is fitted in the factory.
- **Motion inhibit over-ride** - a manual over-ride function that, when applied, deactivates the motion inhibit blind spot safety function
- **RADAR** - radio detection and ranging. A sensor component that uses radio waves to detect the range and positions of objects.
- **Reference eye point** - a point representing the centre point of the driver's left and right eyes and offset from the AHP by [678]mm in the X axis and [1163.25]mm in the Z axis. This is the point from which the sightline originates.
- **Signal** - the transmission of an identifiable alert to a bus driver through the HMI notifying them to the hazards that may be caused by the interaction of their vehicle with a VRU. Signals may be transmitted to the driver by the HMI through a number of different signal modes.
- **Signal mode** - the method of transmitting a signal to a driver and consisting of four key modes including: audible (tonal), audible (speech), visual or haptic.
- **Sightline** - a line parallel to the XY plane that passes through the reference eye point and is angled according to a specified horizontal field of view angle
- **Standardised environmental clutter** - the minimum set of roadside furniture (described below), that is positioned to simulate a realistic environment that has the potential to affect the performance of the sensors often used for the enabling technology.

   a) **Advertising hoarding** - A standard advertising hoarding measuring approximately 2 m tall by 1 m wide. A life size image of the Euro NCAP adult pedestrian dummy shall be displayed on the advertising hoarding towards the test vehicle trajectory. The image and sign shall be positioned such that the lower edge of the dummies feet is as close to the ground as possible and no more than 200 mm from the ground.

Figure 30: Example of the standard advertising hoarding and image

b) **Traffic sign** - a 30mph speed limit sign complying with the C14 standard of the Vienna Convention on Road Signs and Signals. It shall be mounted on a pole such that the lowest point of the sign shall be located 2 m vertically above the test track surface.

c) **Railing** - A typical city kerbside railing that shall be simulated using temporary metal crowd control barriers (Figure 31). These metal crowd control barriers shall constructed from a metal easily detected by RADAR. The height of the barrier shall be 1115 mm ± 5 mm. The height of the upper surface of the horizontal rail at the bottom shall be 255 mm ± 5 mm. The diameter of the vertical rail shall be no less than 10 mm and the distance between the vertical rails (from centre to centre) shall be 125 mm ± 5 mm. The feet of the railing shall extend laterally by no more than 200mm from the centre-line of the railing.

Figure 31: Example of a temporary metal crowd control railing

- **Test Service -** the organisation undertaking the testing and certification of the results to the Approval Authority.

- **Test Target** - a test dummy that accurately represents the characteristics of the relevant VRU, as seen by the relevant sensing technologies used by BSW. A range of specific test targets are defined[20]:
    a) **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.
    b) **EPTa: Euro NCAP Adult Pedestrian Target** - means the adult pedestrian target as specified in the Euro NCAP Articulated Pedestrian Target Specification document version 1.0.
    c) **EPTc: Euro NCAP Child Pedestrian Target** - means the child pedestrian target as specified in the Euro NCAP Articulated Pedestrian Target Specification document version 1.0.
- **Test Vehicle (TV)** - the vehicle under test according to this protocol.
- **Time to Collision (TTC)** - the time it would take for the vehicle to reach the point of collision if the speed and trajectory of the vehicle remained constant when calculated at any instant in time. At constant vehicle speeds, the TTC will always reduce over time. If speed is reduced, however, TTC increases and if sufficient braking is applied to avoid a collision then the TTC tends to infinity.
- **Vehicle length:** the distance in the X-axis between two points located at the foremost and rearmost aspect of the vehicle and measured in accordance with the definition contained in Commission Regulation (EU) no 1230/2012, when excluding the following components:
    a) Wiper and washer devices
    b) Front or rear marker-plates
    c) Lighting and light signalling devices
    d) Mirrors or other devices for indirect vision
    e) Watching and detection aids including RADAR
    f) Access ramps, retractable steps and lift platforms etc.
    g) Coupling and recovery towing devices for power driven vehicles
    h) Trolleybus current collection devices
    i) De-mountable spoilers
    j) Exhaust pipes
- **Vehicle width** - the distance in the Y-axis at the widest point of the vehicle and measured in accordance with the definition contained in Commission Regulation (EU) no 1230/2012, when excluding the following components:
    a) Mirrors or other devices for indirect vision
    b) Bulge in the tyre at the point of contact with the road

[20] ISO standards (ISO 19206) for these test targets are under development and once published should replace the references to the equivalent Euro NCAP standards

c) Tyre failure tell-tale devices and pressure indicators

d) Side marker lamps, service door lighting and other side mounted lamps and retroreflectors

e) Access ramps, retractable steps and lift platforms etc.

f) Watching and detection aids including RADAR

g) Flexible mudguards

h) Snow chains

4 Reference system

4.1 Global Coordinate System

4.1.1 A global coordinate system (X,Y,Z), fixed relative to the Earth, shall be defined such that the global (X,Y,Z) axes are coincident with the local (x,y,z) axes of the Test Vehicle in its initial position (T_0). These shall be defined such that the X-axis points toward the front of the Test Vehicle, the Y-axis towards the left (nearside) and the Z-axis upwards, as shown in Figure 1.

4.2 Local Coordinate System

4.2.1 Test Vehicle

The local coordinate system (x,y,z) for the Test Vehicle shall be defined such that the x-axis points toward the front of the vehicle, the y-axis towards the left (nearside) and the z-axis upwards, as shown in Figure 1. The rotation of the Test Vehicle about the x-axis shall be defined as roll, the y-axis as pitch and the z-axis as yaw. The origin of the coordinate system shall lie on the ground plane, on the longitudinal centreline of the Test Vehicle and at its foremost point.

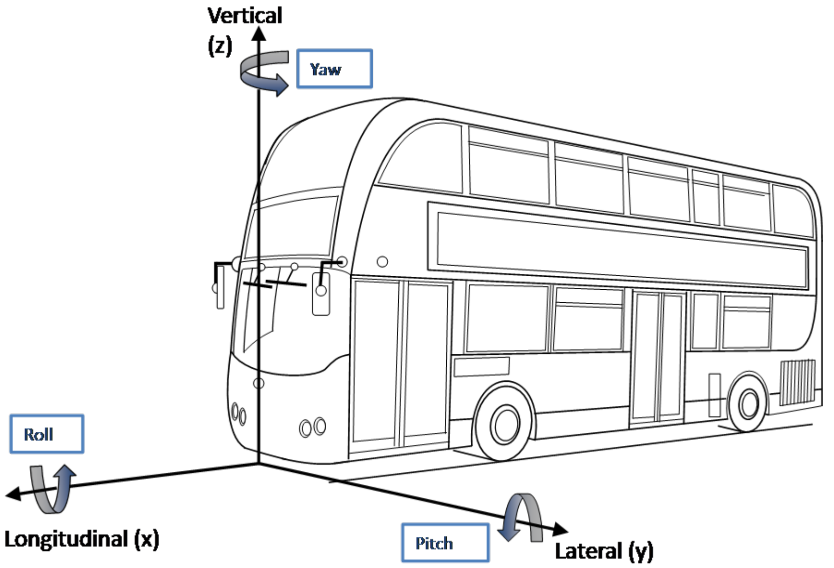

Figure 32: Local coordinate system and notation for test vehicle

4.3 Test Targets

4.3.1 The local coordinate systems (x,y,z) for the EPTa and EPTc test targets shall both be defined such that the x-axis points in the direction of walking, the y-axis towards the left and the z-axis upwards. The origin of the test target centreline and a line perpendicular to the centreline passing through the test target hip point, as shown in Figure 33.

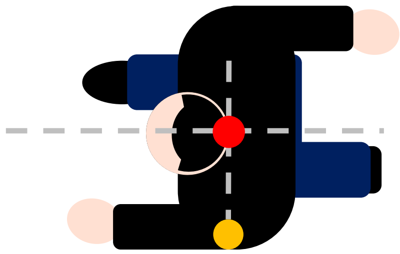

Figure 33: Origin of local coordinate systems for EPTa and EPTc test targets, illustrating test target hip point (orange), centrelines (grey) and local coordinate system origin (red)

4.3.2 The local coordinate systems (x,y,z) for the EBT test target shall be defined such that the x-axis points in the direction of travel, the y-axis towards the left and the z-axis upwards. The origin of the coordinate system shall lie on the ground plane, at the centre of the bottom bracket of the test target bicycle, as shown in Figure 34.

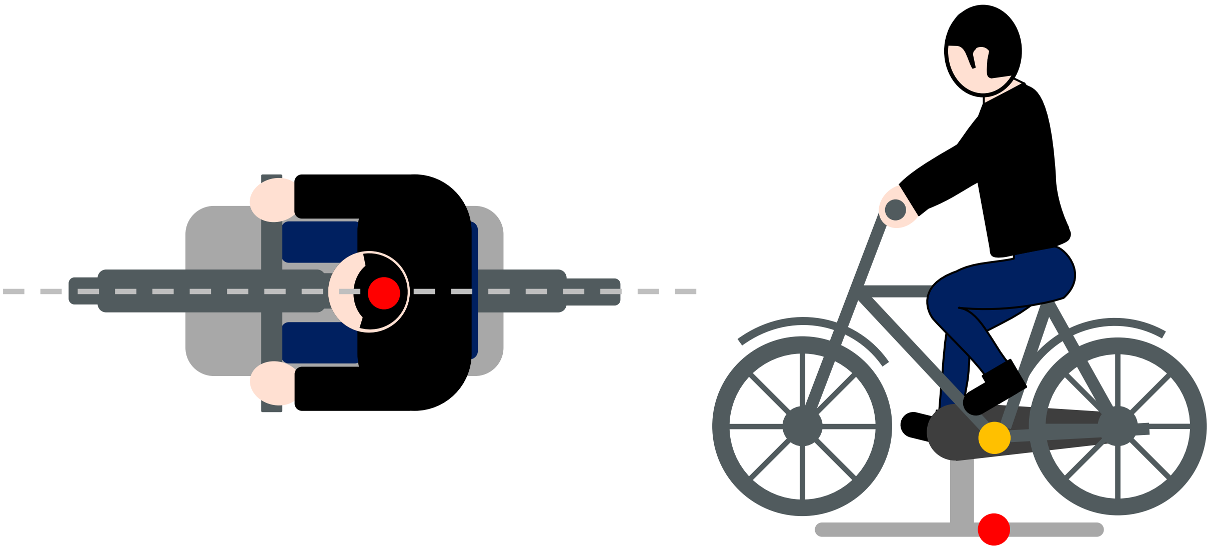

Figure 34: Origin of local coordinate systems for EBT test target, illustrating test target centreline (grey), centre of the bottom bracket (orange) and local coordinate system origin (red)

5 Measurements and variables

5.1 Variables to be measured

5.1.1 The variables which shall be measured continuously throughout testing can be seen in Table 18, along with the minimum operating ranges and measurement accuracy required.

Table 18: Variables to be measured continuously during testing with minimum operating ranges and maximum overall permitted measurement errors

Variable	Operating range (at least)	Measurement accuracy
Position (global coordinates) of test vehicle (TV_X, TV_Y)	200m in X-axis 100m in Y-axis	±0.03m
Position (global coordinates) of VRU test target (VRU_X, VRU_Y)	200m in X-axis 100m in Y-axis	±0.05m
Speed of test vehicle (V_{TV})	0 km/h to 30 km/h	0.1 km/h
Speed of VRU test target (V_{VRU})	0 km/h to 20 km/h	0.1 km/h
Heading (yaw) angle (θ) relative to global X-axis (θ_{TV}, θ_{VRU})	0˚ to 360˚	0.1˚
Test vehicle longitudinal acceleration (A_{TV})	± 15 m/s^2	0.1 m/s^2

5.1.2 Additional variables which shall be measured on a periodic basis, both before each test and at least every 30 minutes during testing, can be seen in Table 19, along with minimum operating ranges and maximum overall permitted measurement errors.

Table 19: Variables to be measured periodically during testing with minimum operating ranges and maximum overall permitted measurement errors

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

5.2 Measuring equipment

5.2.1 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 vehicle (measured relative to the local co-ordinate system for the test vehicle).

5.2.2 The default equipment to be used shall be a high-quality inertial navigation system in combination with differential GPS with data recorded at a sample rate of 100 Hz, which has been found to provide all continuously measured variables with sufficient accuracy. With such equipment, post-sampling digital filtering shall be as follows:

a) Position and speed need 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.

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

6 Test Conditions

6.1 Test Track

6.1.1 Tests shall be undertaken on a uniform, solid-paved surface with a consistent slope in any direction of between 0% and 1%. The surface must be paved and may not contain any irregularities (e.g. large dips or cracks, manhole covers or reflective studs) that may give rise to abnormal sensor measurements within a lateral distance of 3.0m to either side of the test path and within a longitudinal distance of 30m ahead of the Test Vehicle when the test ends.

6.2 Surroundings

6.2.1 Conduct testing such that only the Standardised Environmental Clutter specified in the particular test procedure is present within a lateral distance of 6.0m on the left side and 4.0m on the right side of the test vehicle path, and within a longitudinal distance of 30m ahead of the Test Vehicle when the test ends (Figure 35). No other vehicles, highway furniture, obstructions, other objects or persons protruding above the test surface that may give rise to abnormal sensor measurements are permitted in this area. Lane markings are permitted but not required.

6.2.2 The Test Vehicle must not pass under overhead signs, bridges, gantries or other significant structures during the test.

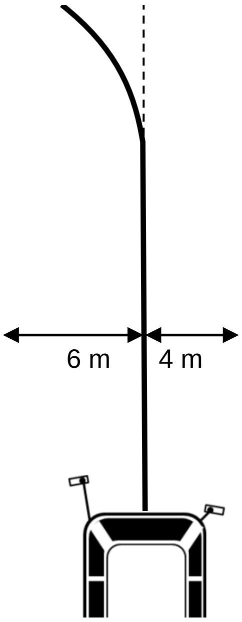

Figure 35: Area around the Test Vehicle path that must be free from all but clutter defined in the test procedure

6.2.3 The general view ahead and to either side of the test area shall comprise of a wholly plain manmade 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.

6.3 Weather Conditions

6.3.1 Tests shall be undertaken only in compliance with the following weather conditions:

a) Ambient temperatures shall be between 0°C and 45°C

b) No precipitation shall be falling during testing. The surface is permitted to be damp during testing but the quantity of water present on the surface must be less than the amount liable to cause splash or spray during the test.

c) Horizontal visibility at ground level shall be greater than 1km.

d) Wind speeds shall be below 6m/s.

e) Natural ambient illumination must be homogenous in the test area and in excess of 2000 lux with no strong shadows cast across the test area other than those caused by the Test Vehicle, VRU or standardised environmental clutter. Tests shall not be undertaken in such conditions that visual sensors are adversely affected by direct sunlight. However, if it is found that such conditions exist, it shall be recorded in the test report.

6.4 Test Targets

6.4.1 Pedestrian test targets shall be the EPTa and EPTc and the cyclist test target shall be the EBT. The relevant VRU test targets shall be moved around the test area and delivered to the point of impact with the test vehicle by a low-profile platform.

6.4.2 The system will be capable of moving the vulnerable road user at speeds of up to at least 20 km/h, to accelerate at 3 m/s^2 or more, and maintaining constant speed within a tolerance of 0.5 km/h. Lateral deviation from an intended straight path shall be no more than 0.05m.

6.4.3 The platform may be self-propelled or moved by a pulley system. However, in either case any visible parts of the combined platform and VRU mounting system shall be of a uniform colour that blends well with the test track beneath it. The default colour is grey.

6.4.4 The platform and VRU mounting system shall not influence RADAR return and RADAR absorbing material may be used at the VRU mounting points to ensure compliance with this requirement.

6.4.5 The distance between the lower edge of the VRU and the road surface shall be less than 25 mm.

7 Vehicle preparation

7.1 Aftermarket systems

7.1.1 For aftermarket systems, the system shall be installed on a standard test vehicle of category M_3[21] with the following characteristics:

a) Overall Length: 9.5 to 11 metres

b) Number of axles: 2

c) Axle configuration: 1 front (steered), 1 rear

7.1.2 Where considering the approval of aftermarket systems on vehicles that are different to this specification in terms of length, number of axles or steering configuration, then retesting with the relevant test vehicle shall be required to guarantee satisfactory performance.

7.2 OEM systems

7.2.1 For an OEM system, the rating shall apply to the vehicle as a whole and any other models that share the same critical properties. Thus, the test vehicle will be whatever vehicle is supplied by the manufacturer for test, with this recorded in the Test Report.

7.3 Dealer fit systems

7.3.1 Dealer fit systems may be tested either as integrated systems for the vehicle or as aftermarket systems fitted to a standard test vehicle. The choice shall be recorded in the Test Report.

[21] As defined by European Type Approval Framework Directive 2007/46/EC

7.4 Blind Spot Safety System

7.4.1 **Installation**

7.4.2 The blind spot safety system to be tested shall be installed on the test vehicle in accordance with the manufacturer's instructions.

7.4.3 Each blind spot safety system may enable more than one blind spot safety function. Suppliers may market such systems with a variety of optional configurations, including additional functions outside of the scope of this document. The exact configuration of the system tested must be recorded in the Test Report.

7.4.4 It is permitted to install multiple blind spot safety systems on the vehicle. This may arise where multiple separate systems, for example from different suppliers, are installed on the same test vehicle for reasons of increased efficiency. In this case, it must be ensured that no conflict, that has the potential to affect results, occurs between systems in terms of the location and field of view of the sensors, the potential for one sensor to interfere with another or the location of the user interface within the vehicle.

7.5 Settings

7.5.1 Some systems may incorporate driver configurable settings. Where those settings can influence performance, for example the sensitivity of proximity information signal or collision warnings, they shall be set to the middle setting (midpoint), or where this is not possible to the next latest possible setting. Examples are illustrated in Table 20, where a setting that would tend to make an information signal or warning later is one that would reduce the range or sensitivity of the application, whilst earlier would tend to make the application more sensitive or to detect at longer range.

Table 20: Blind spot safety system setting for testing

<table>
<tr><td rowspan="3">Early</td><td colspan="2">Setting 1</td><td colspan="2">Setting 2</td><td rowspan="3">Late</td></tr>
<tr><td>Setting 1</td><td colspan="2">Setting 2</td><td>Setting 3</td></tr>
<tr><td>Setting 1</td><td>Setting 2</td><td>Setting 3</td><td>Setting 4</td></tr>
</table>

7.5.2 In this way, a system with only two settings gets adjusted to the least sensitive setting, or latest intervention, a system with 3 possible settings gets adjusted to the midpoint and a system with four settings gets adjusted to the next latest setting from the midpoint.

7.6 Tyres

7.6.1 Perform the testing with road legal tyres of the size, speed and load rating specified by the vehicle manufacturer. Inflate tyres to the pressures recommended by the manufacturer for the least laden normal condition (unladen or lightly laden). Tyre pressures immediately before the test shall be recorded in the Test Report.

7.7 Test Vehicle Mass

7.7.1 The load space on the vehicle shall be empty (unladen condition) except for the driver, test equipment and optionally one test engineer. The fuel tank shall be filled to no less than 90% of the capacity specified by the manufacturer, whilst other fluid levels, such as lubricants etc., are set according to manufacturer recommendations. The mass of the vehicle and its distribution across the axles shall be recorded in the conditions tested.

7.7.2 All test equipment installed in the vehicle should be securely attached to it such that it cannot move under maximum braking forces.

8 Test scenarios

8.1 This section describes the methods for testing the performance of blind spot system functions. The overall approach taken is to consider tests relating to two different key collision scenarios: where a bus moves off from rest and where a bus makes a left (nearside) turn. Within each collision scenario, more than one specific test method is required to fully define blind spot system performance in that collision scenario. The method of evaluating the specific results of each individual test and assessment are therefore presented across this section.

8.2 Moving-Off Scenarios

8.2.1 General Test Scenario Configuration

8.2.1.1 The general test scenario configuration is designed to be representative of collisions where a pedestrian walks in front of a stationary bus in an urban area. The driver moves the bus off from rest, without seeing the VRU in front of the vehicle, resulting in a collision. Representative test vehicle and VRU test target starting positions and intended motions are illustrated in Figure 36, alongside positioning information for the standardised environmental clutter.

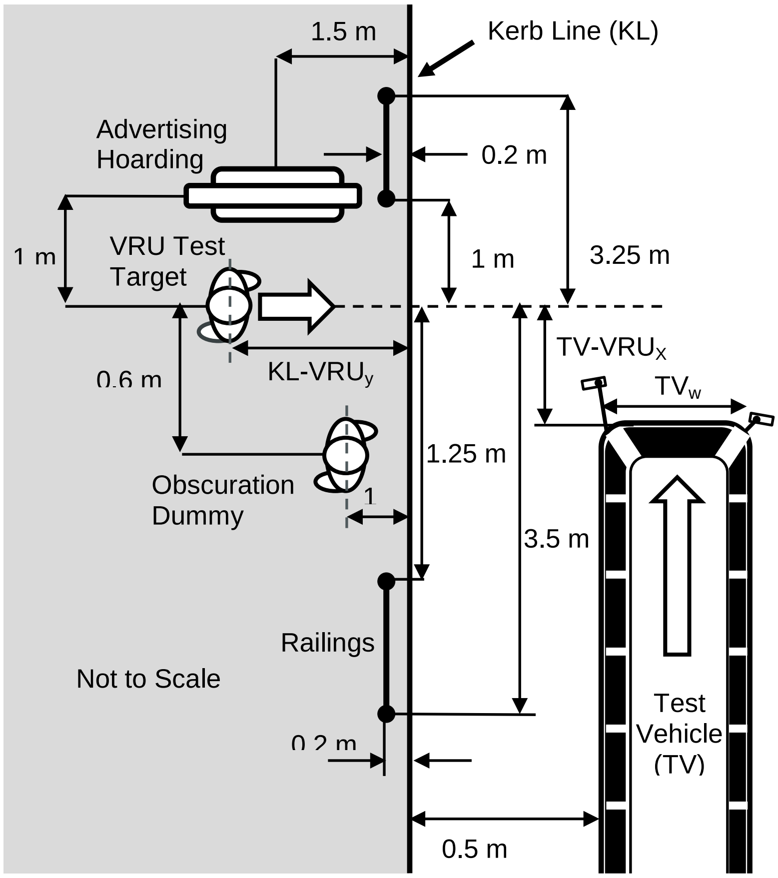

Figure 36: General test configuration for test vehicle (TV), VRU test target (VRU) and standardised environmental clutter positions at time T0 with intended motions for moving-off test scenarios

8.2.2 All test scenario configuration dimensions illustrated in Figure 36 are described in greater detail below. Fixed dimensions are enumerated, whilst dimensions that vary with each test scenario are described by their acronym:

a) Test vehicle width (TV_w)

b) Kerb Line (KL) is a line parallel to the global X-axis defining the nominal kerb edge of the road

c) Lateral distance from nearside edge of TV to KL = 0.5m

d) Lateral distance from KL to centreline of VRU ($KL\text{-}VRU_y$)

e) Longitudinal distance from front of Test Vehicle to centreline of VRU ($TV\text{-}VRU_x$)

f) Lateral distance from KL to Obscuration Dummy centreline = 1m

g) Longitudinal distance from centreline of VRU to centreline of Obscuration Dummy = 0.6m

h) Lateral distance from KL to centreline of railings = 0.2m

i) Longitudinal distance from VRU centreline to leading edge of foremost railing = 3.25m

j) Longitudinal distance from VRU centreline to trailing edge of foremost railing = 1m

k) Longitudinal distance from VRU centreline to leading edge of rearmost railing = 1.25m

l) Longitudinal distance from VRU centreline to trailing edge of rearmost railing = 2.5m

m) Lateral distance from Kerb Line to centreline of Advertising hoarding = 1.5m

n) Longitudinal distance from VRU centreline to centreline of Advertising Hoarding = 1m

8.3 Moving-Off Proximity Information signal (MOPI) Scenario

8.3.1 This test assesses the ability of a system to detect a pedestrian manoeuvring around the front end of a stationary bus and provide an effective VRU proximity information signal. The test vehicle, test targets and standardised environmental clutter shall be set up as specified in Section 8.2.1 with additional test scenario specific parameters as detailed in Table 21.

Table 21: Definition of test scenario specific parameters for the Moving-Off Proximity Information signal (MOPI) scenario

Parameter	Test Scenario		
	Adult Near (True Positive)	Child Mid (True Positive)	Adult Far (True Positive)
TV-VRU$_Y$	1.7 m	1.7 m	1.7 m
TV-VRU$_X$[22]	0.3 m	[2.5] m	[4.0] m
VRU Test Target	EPTa	EPTc	EPTa
VRU Speed (V_{VRUy})	3 km/h ± 0.2 km/h	5 km/h ± 0.2 km/h	5 km/h ± 0.2 km/h

8.3.2 For all test scenarios, a constant acceleration of 1 m/s^2 ± 0.2 m/s^2 (A_{VRUy}) shall be applied to the VRU test target in the direction of the negative Y-axis until the steady state VRU speed (V_{VRUy}) is met, at which A_{VRUy} shall drop to a nominal acceleration of 0 m/s^2 where the steady state speed shall be maintained constant until the VRU has completely passed the front of the test vehicle. The test vehicle ignition shall be switched to the fully on position with test vehicle speeds in both the x-axis and y-axis (V_{TVx}, V_{TVy}) maintained at 0 km/h through all test scenarios. The motion of the test vehicle and VRU are enumerated below:

a) A_{VRUy} = 1 m/s^2 ± 0.2 m/s^2 until V_{VRUy} is reached, thereafter nominally 0 m/s^2.

b) $V_{TVx} = V_{TVy} = 0$ km/h.

8.3.3 The start of each test (T_0) shall be taken as the point where the acceleration (A_{VRUy}) is first applied to the VRU test target. The completion of each test (T_1) shall be taken as the point at which no part of the VRU test target remains in the path of the test vehicle, defined as if the test vehicle moved purely in the x-axis.

8.3.4 The status of the blind spot information and warning signals shall be recorded, along with VRU test target position, from time T_0–1 second to T_1. The evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and T_1.

8.3.5 Each specified test scenario shall be undertaken once.

[22] Note that to achieve variation in the longitudinal separation between test vehicle and moving VRU dummy, the path of the VRU shall remain fixed and the start point of the test vehicle shall be moved backward, away from the VRU path, as required.

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8.5 Moving-Off collision Warning and motion Inhibit (MOWI) Scenario

8.5.1 This test assesses the ability of a system to detect a pedestrian located in the path of a bus moving off from rest and either intervene to inhibit the motion of the bus or to provide an effective VRU collision warning signal. The test vehicle, test targets and standardised environmental clutter shall be set up as specified in Section 8.2.1 with additional test scenario specific parameters as detailed in Table 22.

8.5.2 VRU test targets shall be positioned laterally anywhere between 25% and 75% of the width of the test vehicle (i.e. $0.25*TV_W$-$0.75*TV_W$), with the exact position determined by the Test Service on a worst-case basis.

Table 22: Definition of test scenario specific parameters for the Moving-Off collision Warning and motion Inhibit (MOWI) scenario

Parameter	Test Scenario		
	EPTa Near (Motion Inhibit)	EPTc Near (Motion Inhibit)	EPTa Far (Motion Inhibit or Collision Warning)
$TV\text{-}VRU_Y$	$0.25*TV_W$-$0.75*TV_W$	$0.25*TV_W$-$0.75*TV_W$	$0.25*TV_W$-$0.75*TV_W$
$TV\text{-}VRU_X$[23]	0.3 m	0.3 m	[4.0] m
VRU Test Target	EPTa	EPTc	EPTc

8.5.3 VRU test target speeds in the x-axis and y-axis (V_{VRUx}, V_{VRUy}) shall be maintained at 0 km/h throughout all test scenarios.

8.5.4 The test vehicle shall be driven such that it pulls away from rest in the x-axis and towards the VRU test target, before braking to a stop, using the following procedure:

a) Select an appropriate forward gear

b) Release park brake

c) Depress accelerator

d) Accelerate to no more than 10 km/h

e) Once TTC reduces to ≤0.75 seconds, decelerate to 0 km/h

8.5.5 The start of each test (T_0) shall be taken as the point where the acceleration is first applied to the test vehicle. The completion of each test (T_1) shall be taken as either the point at which the test vehicle motion inhibit function is activated, the point at which the test vehicle is automatically brought to a halt without driver intervention or the first point at which the TTC becomes 0.75 seconds.

[23] Note that to achieve variation in the longitudinal separation between test vehicle and moving VRU dummy, the path of the VRU shall remain fixed and the start point of the test vehicle shall be moved backward, away from the VRU path, as required.

8.5.6 The status of the blind spot information and warning signals and the motion inhibit system shall be recorded, along with the VRU test target and test vehicle positions, from time T_0 to T_1 + 3 seconds. The evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and T_1.

8.5.7 Each specified test scenario shall be undertaken once.

8.5.8 Should the motion inhibit function be activated, it shall be deactivated at time no earlier than T_1+ 3 seconds and no later than T_1 + 10 seconds through the motion inhibit over-ride function.

8.5.9 The motion inhibit over-ride function shall be applied manually through one of the following conditions:

a) A throttle action that requires deliberate additional force similar to kick-down actions or other defined sequence of inputs untypical of normal driving

b) A button that is held down for at least 3 seconds

c) A switch, series of switches or menu-based screen interface, where at least 3 discrete actions are required

8.5.10 A collision warning signal shall be issued whilst the motion inhibit over-ride function is applied.

8.5.11 With the motion inhibit over-ride function applied, the test vehicle shall be driven away from the test target to a finish point no further than 10 m away where no further hazards are present.

8.5.12 The motion inhibit over-ride function shall deactivate before reaching the finish point described in 8.5.11.

8.7 Nearside Turn Scenarios

8.7.1 General Test Scenario Configuration

8.7.2 The general test scenario configuration is designed to be representative of collisions with VRUs during nearside turn manoeuvres in an urban area. Two categories of test scenario are assessed: the first where a bicyclist cycles alongside the nearside of a bus about to perform a nearside turn manoeuvre and the second where a pedestrian crosses the entrance of a road on the nearside of a bus about to perform a nearside turn manoeuvre into the road. Representative test vehicle and VRU test target starting positions and intended motions are illustrated in Figure 37, alongside positioning information for the standardised environmental clutter.

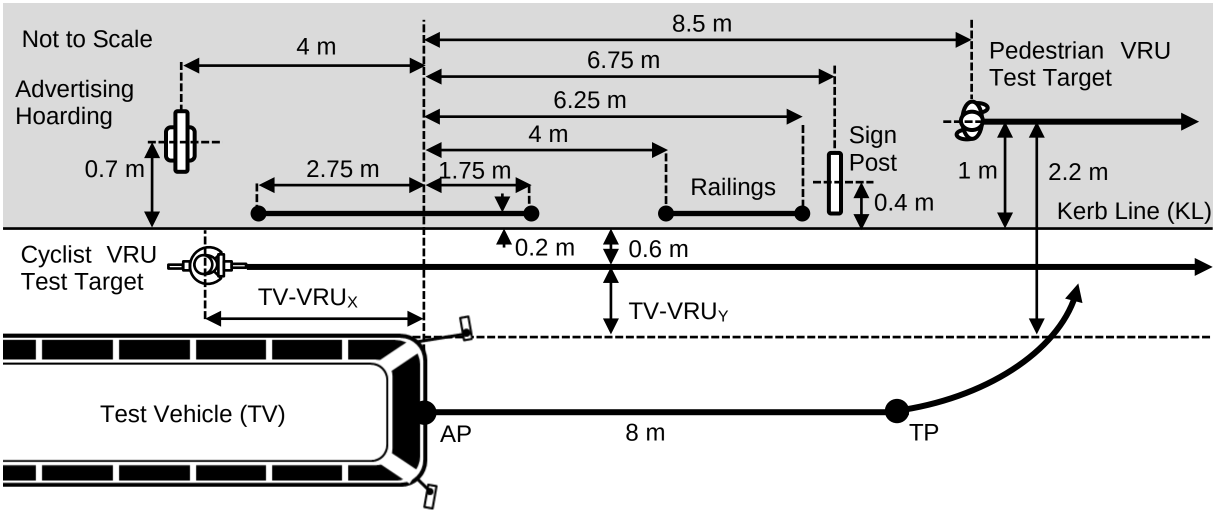

Figure 37: General test configuration for test vehicle (TV), VRU test target (VRU) and standardised environmental clutter positions at time T0 with intended motions for nearside turn test scenarios

8.7.3 All test scenario configuration dimensions illustrated in Figure 37 are described in greater detail below. Fixed dimensions are enumerated, whilst dimensions that vary with each test scenario are described by their acronym:

a) Test vehicle length (TV_L)

b) Kerb Line (KL) is a line parallel to the global X-axis defining the nominal kerb edge of the road, prior to the simulated junction.

c) Acceleration Point (AP) is the X-position of the foremost point of the test vehicle at the moment the test vehicle begins to accelerate

d) Turn Point (TP) is the X-position of the foremost point of the test vehicle at the moment that the test vehicle commences steering

e) Longitudinal distance from AP to centreline of cyclist VRU ($TV\text{-}VRU_X$)

f) Lateral distance from nearside of Test Vehicle to centreline of cyclist VRU ($TV\text{-}VRU_Y$)

g) Lateral distance from KL to centreline of cyclist VRU = 0.6 m

h) Longitudinal distance from AP to centreline of pedestrian VRU = 8.5 m

i) Lateral distance from nearside of Test Vehicle to centreline of cyclist VRU = 2.0 m

j) Lateral distance from KL to centreline of cyclist VRU = 1.0 m

k) Longitudinal distance from AP to TP = 8.0 m

l) Lateral distance from KL to centreline of railings = 0.2 m

m) Longitudinal distance from AP to leading edge of foremost railing = 6.25 m

n) Longitudinal distance from AP to trailing edge of foremost railing = 4.0 m

o) Longitudinal distance from AP to leading edge of rearmost railing = 1.75 m

p) Longitudinal distance from AP to trailing edge of rearmost railing = 2.75 m

q) Lateral distance from KL to centreline of Advertising Hoarding = 0.7m

r) Longitudinal distance from AP to centreline of Advertising Hoarding = 4.0 m

s) Lateral distance from KL to centreline of signpost = 0.4 m

t) Longitudinal distance from AP to centreline of signpost = 6.75 m

8.9 Nearside Turn Proximity Information signal (NTPI) Scenario

8.9.1 This test assesses the ability of a system to detect a cyclist manoeuvring along the nearside of a stationary bus and provide an effective VRU proximity information signal. The test vehicle, test target and standardised environmental clutter shall be set up as specified in Section 8.7.1 with additional test scenario specific parameters detailed in Figure 38 and Table 23.

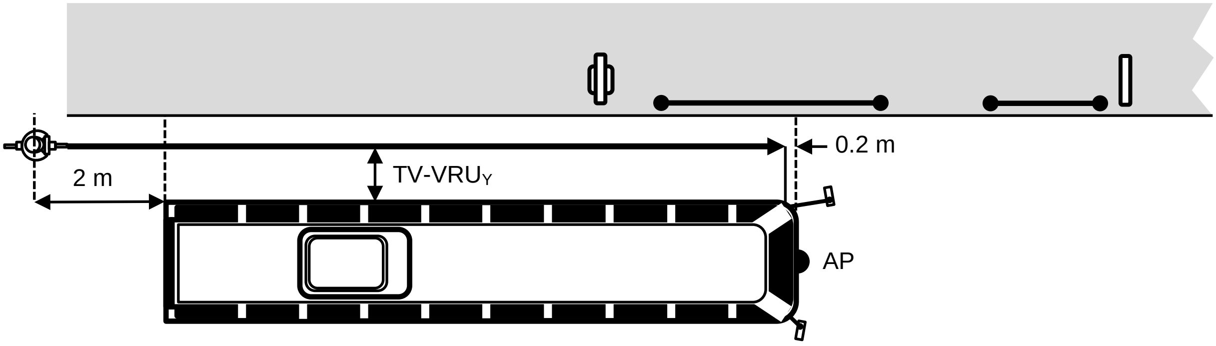

Figure 38: Test target positions at time T_0 and T_1 for Nearside Turn Proximity Information signal (NTPI) scenario whilst test vehicle is stationary

Table 23: Definition of test scenario specific parameters for the Nearside Turn Proximity Information signal (NTPI) scenario

Parameter	Test Scenario	
	Cyclist Near (True Positive)	Cyclist Far (True Positive)
TV_X	AP	AP
TV-VRU$_Y$	0.6 m	[1.5] m
TV-VRU$_X$	TV_L + 2 m	TV_L + 2 m
VRU Test Target	EBT	EBT

8.9.2 For all test scenarios, the VRU test target shall be accelerated in the direction of the positive X-axis to a steady state speed of 10 km/h ± 0.2 km/h within a distance of 2 m. The VRU test target speed shall be maintained as constant until decelerated to rest at a rate of 2 m/s^2 ± 0.5 m/s^2 such that the test target comes to rest at a position 0.2 m rearward of the AP (in the negative X-axis). The test vehicle ignition shall be switched to the fully on position with test vehicle speeds in both the x-axis and y-axis (V_{TVx}, V_{TVy}) maintained at 0 km/h throughout all test scenarios.

8.9.3 The start of each test (T_0) shall be taken as the point where the acceleration is first applied to the VRU test target. The completion of each test (T_1) shall be taken as the point at which the VRU test target comes to rest.

8.9.4 The status of the blind spot information and warning signals shall be recorded, along with VRU test target position, from time T_0–1 second to T_1. The evaluation distance shall be taken as between VRU_X = TV_L – 1 m and the VRU test target position at T_1.

8.9.5 Each specified test scenario shall be undertaken once

8.10 Nearside Turn Low relative Cyclist speed (NTLC) Scenario

8.10.1 This test assesses the ability of a system to detect a cyclist manoeuvring at a low relative speed along the nearside of a bus performing a nearside turn and provide effective VRU proximity information and collision warning signals. The test vehicle, test target and standardised environmental clutter shall be set up as specified in Section 8.7.1 with additional test scenario specific parameters as detailed in Figure 39 and Table 24.

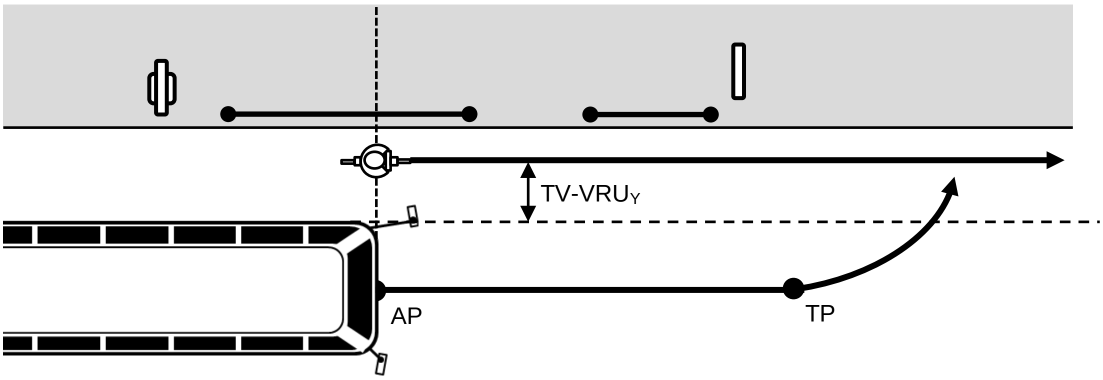

Figure 39: Test vehicle and test target position at time T_0 for Nearside Turn Low relative Cyclist speed (NTLC) scenario

Table 24: Definition of test scenario specific parameters for the Nearside Turn Low relative Cyclist speed (NTLC) scenario

Parameter	**Test Scenario**	
	Cyclist Near (True Positive)	**Cyclist Far (True Positive)**
TV_X at T_0	AP	AP
$TV\text{-}VRU_Y$ at T_0	0.6 m	[1.5] m
$TV\text{-}VRU_X$ at T_0	0 m	0 m
VRU Test Target	EBT	EBT
TV Angle of Turn (α) at T_2	27°	35°
VRU_X at T_2	AP + 10 m	AP + 11.25 m

8.10.2 For all test scenarios, the test vehicle shall be accelerated in the X-axis direction to a steady state speed of 10 km/h ± 1 km/h within a distance of 8 m. The test vehicle speed shall be maintained as constant until the completion of the test (T_1). At the turn point (TP), steering shall be applied to the test vehicle such that the foremost point of the test vehicle centreline follows the arc of a circle with a radius (R) of 10 m.

8.10.3 The VRU test target shall commence acceleration at the moment in time when the test vehicle X-axis position is 0.2m greater than that of the AP. The VRU test target shall be accelerated in the direction of the positive X-axis to a nominal steady state speed of 6.5 km/h within a distance of 2 m.

8.10.4 The moment in time at which the VRU test target path would conflict with the test vehicle path (T_2) shall be defined as the impact point. On reaching the impact point, the test vehicle shall have travelled the length of a 10 m radius arc with an angle of turn of α (where α is defined as the central angle of a circle measured in degrees, see Figure 40), whilst the VRU test target shall have reached a position VRU_X.

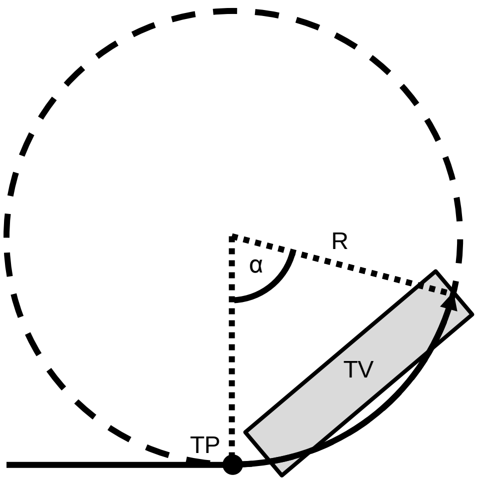

Figure 40: Illustration of central angle (α) of arc of a circle of radius (R) relating to the steering applied to the test vehicle (TV) from the turn point (TP)

8.10.5 The speed of the VRU test target may be varied in response to the actual speed and path achieved by the test vehicle to ensure compliance with the above impact point criteria. This moment approximates the moment of impact, but it should be noted that the exact point of impact on the vehicle and the exact time of impact will vary slightly depending on the steering geometry of the test vehicle.

8.10.6 The start of each test (T_0) shall be taken as the point where the acceleration is first applied to the test vehicle. The completion of each test (T_1) shall be taken as the moment in time 1 second before the impact point (i.e. $T_1 = T_2 – 1$ second).

8.10.7 To avoid unnecessary damage to the VRU test target, the test vehicle and test target shall both be decelerated to a halt between T_1 and T_2.

8.10.8 The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and test vehicle positions, from time T_0 to T_1 + 3 seconds. The proximity test evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and TP, whilst the collision test evaluation distance shall be taken as the difference between positions at TP and T_1.

8.10.9 Each specified test scenario shall be undertaken once.

8.12 Nearside Turn High relative Cyclist speed (NTHC) Scenario

8.12.1 This test assesses the ability of a system to detect a cyclist manoeuvring at a high relative speed along the nearside of a bus performing a nearside turn and provide effective VRU proximity information and collision warning signals. The test vehicle, test target and standardised environmental clutter shall be set up as specified in Section 8.7.1 with additional test scenario specific parameters as detailed in Figure 41 and Table 25.

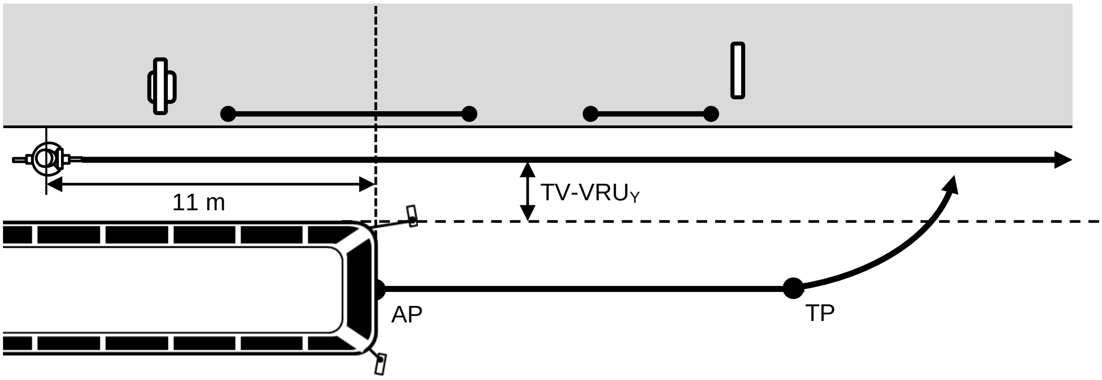

Figure 41: Test vehicle and test target position at time T_0 for Nearside Turn High relative Cyclist speed (NTHC) scenario

8.12.2 For all test scenarios, the test vehicle shall be accelerated from its start position to a steady state speed of 4 km/h and maintained as constant until the acceleration point (AP). At the AP, the test vehicle shall be accelerated in the X-axis direction to a steady state speed of 14 km/h ± 1 km/h within a distance of 8 m. The test vehicle speed shall be maintained as constant until the completion of the test (T_1). At the turn point (TP), steering shall be applied to the test vehicle such that the foremost point of the test vehicle centreline follows the arc of a circle with a radius (R) of 10 m.

8.12.3 Prior to the test vehicle reaching the AP, the VRU test target shall be accelerated from its start position to a nominal steady state speed of 18 km/h. As the test vehicle reaches the AP, the VRU shall be a distance of 11 m ± 0.5 m rearward of the AP in the negative X-axis.

8.12.4 Start positions and initial accelerations for the test vehicle and VRU test target shall be at the discretion of the Test Service to ensure compliance with these positioning requirements.

Table 25: Definition of test scenario specific parameters for the Nearside Turn High relative Cyclist speed (NTHC) scenario

Parameter	Test Scenario	
	Cyclist Near (True Positive)	Cyclist Far (True Positive)
TV_X at T_0	AP	AP m
TV-VRU_Y at T_0	0.6 m	[1.5] m
TV-VRU_X at T_0	AP – 11 m	AP – 11 m
VRU Test Target	EBT	EBT
TV Angle of Turn (α) at T_2	27°	35°
VRU_X at T_2	AP + 10 m	AP + 11.25 m

8.12.5 The moment in time at which the VRU test target path would conflict with the test vehicle path (T_2) shall be defined as the impact point. On reaching the impact point, the test vehicle shall have travelled the length of a 10 m radius arc with an angle of turn of α (Figure 40), whilst the VRU test target shall have reached a position VRU_X.

8.12.6 The speed of the VRU test target may be varied in response to the actual speed and path achieved by the test vehicle to ensure compliance with the above impact point criteria. This moment approximates the moment of impact, but it should be noted that the exact point of impact on the vehicle and the exact time of impact will vary slightly depending on the steering geometry of the test vehicle.

8.12.7 The start of each test (T_0) shall be taken as the point where the acceleration is first applied to the test vehicle. The completion of each test (T_1) shall be taken as the moment in time 1 second before the impact point (i.e. T_1=T_2–1 second).

8.12.8 To avoid unnecessary damage to the VRU test target, the test vehicle and test target shall both be decelerated to a halt between T_1 and T_2.

8.12.9 The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and test vehicle positions, from time T_0 to T_1 + 3 seconds. The proximity test evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and TP, whilst the collision test evaluation distance shall be taken as the difference between positions at TP and T_1.

8.12.10 Each specified test scenario shall be undertaken once.

8.14 Nearside Turn Crossing Pedestrian (NTCP) Scenario

8.14.1 This test assesses the ability of a system to detect a pedestrian crossing an entrance to a road whilst the bus performs a nearside turn into the road and provide effective VRU proximity information and collision warning signals. The test vehicle, test target and standardised environmental clutter shall be set up as specified in Section 8.7.1 with additional test scenario specific parameters as detailed in Figure 42.

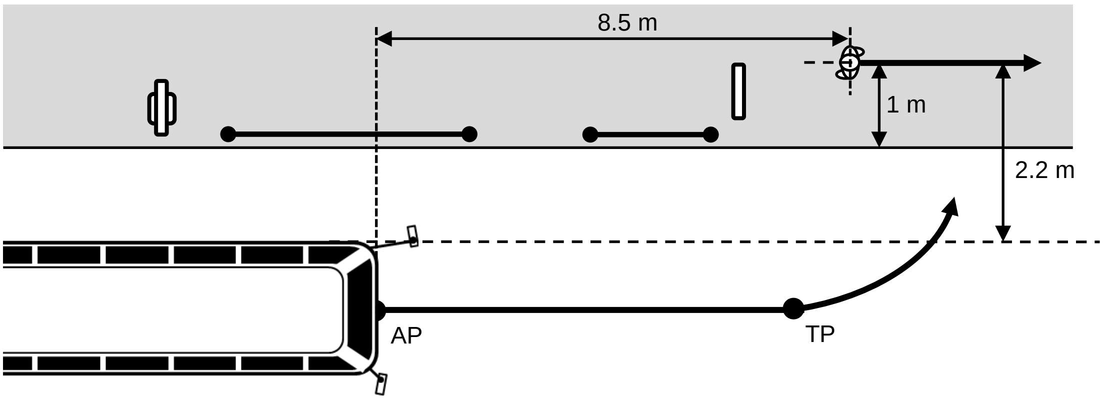

Figure 42: Test vehicle and test target position at time T_0 for Nearside Turn Crossing Pedestrian (NTCP) scenario

8.14.2 The test vehicle shall be accelerated in the X-axis direction to a steady state speed of 10 km/h ± 1 km/h within a distance of 8 m. Test vehicle speed shall be maintained as constant until the completion of the test (T_1). At the turn point (TP), steering shall be applied to the test vehicle such that the foremost point of the test vehicle centreline follows the arc of a circle with a radius (R) of 10 m.

8.14.3 The VRU test target shall be accelerated in the direction of the positive X-axis to a nominal steady state speed of 5 km/h within a distance of 2 m. The VRU test target shall commence acceleration at the moment in time such that, when the test vehicle has travelled the length of a 10 m radius arc with an angle of turn of 35° (Figure 40), the VRU test target shall have reached a position VRU_X = AP + 12.1 m. The moment in time that this point occurs shall be defined as the impact point (T_2).

8.14.4 The speed of the VRU test target may be varied in response to the actual speed and path achieved by the test vehicle to ensure compliance with the above impact point criteria. This moment approximates the moment of impact, but it should be noted that the exact point of impact on the vehicle and the exact time of impact will vary slightly depending on the steering geometry of the test vehicle.

8.14.5 The start of each test (T_0) shall be taken as the point where the acceleration is first applied to the test vehicle. The completion of each test (T_1) shall be taken as the moment in time 1 second before the impact point (i.e. T_1=T_2–1 second).

8.14.6 To avoid unnecessary damage to the VRU test target, the test vehicle and test target shall both be decelerated to a halt between T_1 and T_2.

8.14.7 The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and test vehicle positions, from time T_0 to T_1 + 3 seconds. The proximity test evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and TP, whilst the collision test evaluation distance shall be taken as the difference between positions at TP and T_1.

8.14.8 This test scenario shall be undertaken once.

8.16 Nearside Turn No test Target (NTNT) Scenario

8.16.1 This test assesses the false positive rate of a system in high levels of environmental clutter for both the VRU proximity information and collision warning signals. This may be used to evaluate the effectiveness of the system in differentiating between the at-risk VRUs and the environment. The test vehicle and standardised environmental clutter shall be set up as specified in Section 8.7.1, with additional test scenario specific parameters as detailed in Figure 43.

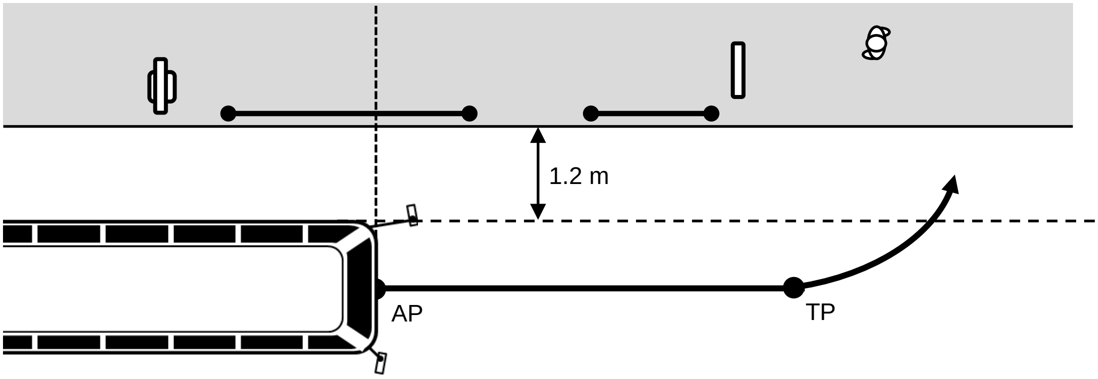

Figure 43: Test vehicle and test target position at time T_0 for Nearside Turn No test Target (NTNT) scenario

8.16.2 The test vehicle shall be accelerated in the X-axis direction to a steady state speed of 10 km/h ± 1 km/h within a distance of 8 m. Test vehicle speed shall be maintained as constant until the completion of the test (T_1). At the turn point (TP), steering shall be applied to the test vehicle such that the foremost point of the test vehicle centreline follows the arc of a circle with a radius (R) of 10 m.

8.16.3 The start of each test (T_0) shall be taken as the point where the acceleration is first applied to the test vehicle. The completion of each test (T_1) shall be taken as the moment in time that the test vehicle has traversed the arc of the circle for an angle of turn (α) of 75°.

8.16.4 The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and test vehicle position, from time T_0-1 second to T_1. The evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and T_1.

8.16.5 This test scenario shall be undertaken once.

9 Assessment of results

9.1 Moving-Off Proximity Information signal (MOPI) Scenario

9.1.1 Test Scenario Performance Evaluation

9.1.1.1 The evaluation of the blind spot system performance during the Moving-Off Proximity Information signal (MOPI) test scenarios shall be assessed according to Table 26.

Table 26: Evaluation of test performance for the Moving-Off Proximity Information signal (MOPI) test scenarios

Test Scenario	Points Available	Result Criteria	Result Metric	Score
All Scenarios (False Positive)	-2 to 0	Proximity information signal status before T_0 in any test condition	Inactive [0] Active [-2]	
Adult Near (True Positive)	0 to 1	Proximity of evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Child Mid (True Positive)	0 to 1		100% Active [1] 100% Inactive [0]	
Adult Far (False Positive)	-1 to 0		100% Inactive [0] 100% Active [-1]	
All Scenarios (False Positive)	-2 to 0	Collision warning status in any test scenario	Inactive [0] Active [-2]	
Max. Points	**2**		**Total Score**	
			Total Score/Max. Points	

9.1.2 **HMI Performance Evaluation**

9.1.3 The evaluation of the performance of the blind spot system HMI across all Moving-Off Proximity Information signal (MOPI) test scenarios shall be assessed according to Table 27.

Table 27: Evaluation of human-machine interface (HMI) performance for the Moving-Off Proximity Information signal (MOPI) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual [3] Tonal or Haptic or Speech [0]	
Visual proximity information signal is located within a horizontal field of view angle of between ±30°, without causing an obstruction to direct or indirect vision	0 to 1	In zone [1] Out of zone [0]	
Visual proximity information signal is amber in colour	0 to 1	Amber [1] Other colour [0]	
Visual proximity information signal ceases automatically within [1] second of the VRU moving out of vehicle path	0 to 1	Ceases within [1] sec [1] Does not cease/ceases in ≥1s [0]	
Max. Points	**6**	**Total Score**	
		Total Score/Max. Points	

9.2 Moving-Off collision Warning and motion Inhibit (MOWI) Scenario

9.2.1 Test Scenario Performance Evaluation

9.2.1.1 The evaluation of the blind spot system performance during the Moving-Off collision Warning and motion Inhibit (MOWI) test scenarios shall be assessed in accordance with Table 28.

Table 28: Evaluation of test performance for the Moving-Off collision Warning and motion Inhibit (MOWI) test scenarios

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Adult Near (Motion Inhibit)	0 to 1	The vehicle remains stationary despite the driver actions	Stationary [1] Motion [0]	
Child Near (Motion Inhibit)	0 to 1		Stationary [1] Motion [0]	
Child Far (Motion Inhibit or Collision Warning)	0 to 1	The vehicle remains stationary despite the driver actions, or is automatically brought to a halt without driver intervention before the point of collision	Stationary [1] Halted: No Driver Intervention [1] Halted: With Driver Intervention [0]	
	0 to 1	Proportion of evaluation distance for which collision warning was active	100% Active [1] 100% Inactive [0]	
Max. Points	**3**		**Total Score**	
			Total Score/Max. Points	

9.2.2 HMI Performance Evaluation

9.2.2.1 The evaluation of the performance of the blind spot system HMI across all Moving-Off collision Warning and motion Inhibit (MOWI) test scenarios shall be assessed in accordance with Table 29.

Table 29: Evaluation of human-machine interface (HMI) performance for the Moving-Off collision Warning and motion Inhibit (MOWI) test scenarios

HMI Criteria	Points Available	Result criteria	Score
Collision warning signal is transmitted over at least two modes	0 to 1	Multi-mode [1] Single mode [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Includes Audible/Haptic Mode [1] No Audible/Haptic Modes [0]	
Collision warning signal uses a different mode to the proximity information signal or is distinctly different in presentation	0 to 1	Different [1] Similar [0]	
Visual collision warning signal is located within a horizontal field of view angle of between ±30°, without causing an obstruction to direct or indirect vision	0 to 1	In zone [1] Out of zone [0]	
Visual collision warning signal is red in colour	0 to 1	Red [1] Other colour [0]	
Visual collision warning signal displayed on windscreen via a head-up display that does not obstruct driver vision	0 to 1	HUD [1] No HUD [0]	
Audible collision warning signal does not use speech coding	0 to 1	Tonal [1] Speech Coding [0]	
Tonal collision warnings are distinct from other sounds used within the vehicle	0 to 1	Distinct [1] Similar [0]	
Tonal collision warnings have a signal to ambient noise ratio of greater than 1.3 between relevant loudness spectra	0 to 1	>1.3 [1] ≤1.3 [0]	
Collision warning signal automatically ceases in less than [1] second after T_1	0 to 1	Ceases within 1 sec [1] Does not cease/ceases in ≥1s [0]	
Max. Points	**10**	**Total Score**	
		Total Score/Max. Points	

9.3 Nearside Turn Proximity Information signal (NTPI) Scenario

9.3.1 Test Scenario Performance Evaluation

9.3.1.1 The evaluation of the performance of the blind spot system during the Nearside Turn Proximity Information signal (NTPI) test scenarios shall be assessed in accordance with Table 30.

Table 30: Evaluation of test performance for the Nearside Turn Proximity Information signal (NTPI) test scenarios

Test Scenario	Points Available	Result Criteria	Result Metric	Score
All Scenarios (False Positive)	-2 to 0	Proximity information signal status before T_0 in any test scenario	Inactive [0] Active [-2]	
Cyclist Near (True Positive)	0 to 1	Proportion of evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Cyclist Far (True Positive)	0 to 1	Proportion of evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
All Scenarios (False Positive)	-2 to 0	Collision warning status in any test scenario	Inactive [0] Active [-2]	
Max. Points	**2**		**Total Score**	
			Total Score/Max. Points	

9.4 HMI Performance Evaluation

9.4.1.1 The evaluation of the performance of the blind spot system HMI across all Nearside Turn Proximity Information signal (NTPI) test scenarios shall be assessed according to Table 31.

Table 31: Evaluation of human-machine interface (HMI) performance for the Nearside Turn Proximity Information signal (NTPI) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual [3] Tonal or Haptic or Speech [0]	
Visual proximity information signal is located within a horizontal field of view angle of 30°-60° towards the nearside of the vehicle, without causing an obstruction to direct or indirect vision	0 to 1	In zone [1] Out of zone [0]	
Visual proximity information signal is amber in colour	0 to 1	Amber [1] Other colour [0]	
Max. Points	**5**	**Total Score**	
		Total Score/Max. Points	

9.5 Nearside Turn Low relative Cyclist speed (NTLC) Scenario

9.5.1 Test Scenario Performance Evaluation

9.5.1.1 The evaluation of the performance of the blind spot system during the Nearside Turn Low relative Cyclist speed (NTLC) test scenarios shall be assessed in accordance with Table 32.

Table 32: Evaluation of test performance for the Nearside Turn Low relative Cyclist speed (NTLC) test scenarios

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Cyclist Near (Proximity Information Signal)	0 to 1	Proportion of proximity test evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Cyclist Near (Collision Warning)	0 to 2	Proportion of collision test evaluation distance for which collision warning was active	100% Active [2] 100% Inactive [0]	
Cyclist Near (Premature Collision Warning)	-2 to 0	Collision warning status before TP in any test scenario	Inactive [0] Active [-2]	
Cyclist Far (Proximity Information Signal)	0 to 1	Proportion of proximity test evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Cyclist Far (Collision Warning)	0 to 2	Proportion of collision test evaluation distance for which collision warning was active	100% Active [2] 100% Inactive [0]	
Cyclist Far (Premature Collision Warning)	-2 to 0	Collision warning status before TP in any test scenario	Inactive [0] Active [-2]	
Max. Points	**6**		**Total Score**	
			Total Score/Max. Points	

9.5.2 HMI Performance Evaluation

9.5.2.1 The evaluation of the performance of the blind spot system HMI across all Nearside Turn Low relative Cyclist speed (NTLC) test scenarios shall be assessed according to Table 33.

Table 33: Evaluation of human-machine interface (HMI) performance for the Nearside Turn Low relative Cyclist speed (NTLC) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual [3] Tonal or Haptic or Speech [0]	
Visual proximity information signal is located within a horizontal field of view angle of 30°-60° towards the nearside of the vehicle, without causing an obstruction to direct or indirect vision	0 to 1	In zone [1] Out of zone [0]	
Visual proximity information signal is amber in colour	0 to 1	Amber [1] Other colour [0]	
Visual proximity information signal ceases automatically on activation of the collision warning signal	0 to 1	Ceases on Activation [1] Does not cease on Activation [0]	
Collision warning signal is transmitted over at least two modes	0 to 1	Multi-mode [1] Single mode [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Includes Audible/Haptic Mode [1] No Audible/Haptic Modes [0]	
Collision warning signal uses a different mode to the proximity information signal or is distinctly different in presentation	0 to 1	Different [1] Similar [0]	
Visual collision warning signal is located within a horizontal field of view angle of 30°-60°	0 to 1	In zone [1] Out of zone [0]	

towards the nearside of the vehicle, without causing an obstruction to direct or indirect vision			
Visual collision warning signal is red in colour	0 to 1	Red [1] Other colour [0]	
Audible collision warning signal does not use speech coding	0 to 1	Tonal [1] Speech Coding [0]	
Tonal collision warnings are distinct from other sounds used within the vehicle	0 to 1	Distinct [1] Similar [0]	
Tonal collision warnings have a signal to ambient noise ratio of greater than 1.3 between relevant loudness spectra	0 to 1	>1.3 [1] ≤1.3 [0]	
Collision warning signal automatically ceases in less than [2] seconds after T_1	0 to 1	Ceases within 2 secs [1] Does not cease/ceases in ≥2s [0]	
Max. Points	**15**	**Total Score**	
		Total Score/Max. Points	

9.6 Nearside Turn High relative Cyclist speed (NTHC) Scenario

9.6.1 Test Scenario Performance Evaluation

9.6.1.1 The evaluation of the performance of the blind spot system during the Nearside Turn High relative Cyclist speed (NTHC) test scenarios shall be assessed in accordance with Table 34.

Table 34: Evaluation of test performance for the Nearside Turn High relative Cyclist speed (NTHC) test scenarios

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Cyclist Near (Proximity Information Signal)	0 to 1	Proportion of proximity test evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Cyclist Near (Collision Warning)	0 to 2	Proportion of collision test evaluation distance for which collision warning was active	100% Active [2] 100% Inactive [0]	
Cyclist Near (Premature Collision Warning)	-2 to 0	Collision warning status before TP in any test scenario	Inactive [0] Active [-2]	
Cyclist Far (Proximity Information Signal)	0 to 1	Proportion of proximity test evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Cyclist Far (Collision Warning)	0 to 2	Proportion of collision test evaluation distance for which collision warning was active	100% Active [2] 100% Inactive [0]	
Cyclist Far (Premature Collision Warning)	-2 to 0	Collision warning status before TP in any test scenario	Inactive [0] Active [-2]	
Max. Points	**6**		**Total Score**	
			Total Score/Max. Points	

9.6.2 HMI Performance Evaluation

9.6.2.1 The evaluation of the performance of the blind spot system HMI across all Nearside Turn Low relative Cyclist speed (NTLC) test scenarios shall be assessed according to Table 35.

Table 35: Evaluation of human-machine interface (HMI) performance for the Nearside Turn Low relative Cyclist speed (NTLC) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual [3] Tonal or Haptic or Speech [0]	
Visual proximity information signal is located within a horizontal field of view angle of 30°-60° towards the nearside of the vehicle, without causing an obstruction to direct or indirect vision	0 to 1	In zone [1] Out of zone [0]	
Visual proximity information signal is amber in colour	0 to 1	Amber [1] Other colour [0]	
Visual proximity information signal ceases automatically on activation of the collision warning signal	0 to 1	Ceases on Activation [1] Does not cease on Activation [0]	
Collision warning signal is transmitted over at least two modes	0 to 1	Multi-mode [1] Single mode [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Includes Audible/Haptic Mode [1] No Audible/Haptic Modes [0]	
Collision warning signal uses a different mode to the proximity information signal or is distinctly different in presentation	0 to 1	Different [1] Similar [0]	
Visual collision warning signal is located within a horizontal field of view angle of 30°-60° towards the nearside of the	0 to 1	In zone [1] Out of zone [0]	

an obstruction to direct or indirect vision			
Visual collision warning signal is red in colour	0 to 1	Red [1] Other colour [0]	
Audible collision warning signal does not use speech coding	0 to 1	Tonal [1] Speech Coding [0]	
Tonal collision warnings are distinct from other sounds used within the vehicle	0 to 1	Distinct [1] Similar [0]	
Tonal collision warnings have a signal to ambient noise ratio of greater than 1.3 between relevant loudness spectra	0 to 1	>1.3 [1] ≤1.3 [0]	
Collision warning signal automatically ceases in less than [2] seconds after T_1	0 to 1	Ceases within 2 secs [1] Does not cease/ceases in ≥2s [0]	
Max. Points	**15**	**Total Score**	
		Total Score/Max. Points	

9.7 Nearside Turn Crossing Pedestrian (NTCP) Scenario

9.7.1 Test Scenario Performance Evaluation

9.7.1.1 The evaluation of the performance of the blind spot system during the Nearside Turn Crossing Pedestrian (NTCP) test scenario shall be assessed according to Table 36.

Table 36: Evaluation of test performance for the Nearside Turn Crossing Pedestrian (NTCP) test scenario

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Pedestrian (Proximity Information Signal)	0 to 1	Proportion of proximity test evaluation distance for which proximity information signal was active	100% Active [1] 100% Inactive [0]	
Pedestrian (Collision Warning)	0 to 2	Proportion of collision test evaluation distance for which collision warning was active	100% Active [2] 100% Inactive [0]	
Pedestrian (Premature Collision Warning)	-2 to 0	Collision warning status before TP in any test scenario	Inactive [0] Active [-2]	
Max. Points	**3**		**Total Score**	
			Total Score/Max. Points	

9.7.2 HMI Performance Evaluation

9.7.2.1 The evaluation of the performance of the blind spot system HMI across all Nearside Turn Low relative Cyclist speed (NTLC) test scenarios shall be assessed according to Table 37.

Table 37: Evaluation of human-machine interface (HMI) performance for the Nearside Turn Crossing Pedestrian (NTCP) test scenario

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual [3] Tonal or Haptic or Speech [0]	
Visual proximity information signal is located within a horizontal field of view angle of 30°-60° towards the nearside of the vehicle, without causing an obstruction to direct or indirect vision	0 to 1	In zone [1] Out of zone [0]	
Visual proximity information signal is amber in colour	0 to 1	Amber [1] Other colour [0]	
Visual proximity information signal ceases automatically on activation of the collision warning signal	0 to 1	Ceases on Activation [1] Does not cease on Activation [0]	
Collision warning signal is transmitted over at least two modes	0 to 1	Multi-mode [1] Single mode [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Includes Audible/Haptic Mode [1] No Audible/Haptic Modes [0]	
Collision warning signal uses a different mode to the proximity information signal or is distinctly different in presentation	0 to 1	Different [1] Similar [0]	
Visual collision warning signal is located within a horizontal field of view angle of 30°-60°	0 to 1	In zone [1] Out of zone [0]	

towards the nearside of the vehicle, without causing an obstruction to direct or indirect vision			
Visual collision warning signal is red in colour	0 to 1	Red [1] Other colour [0]	
Audible collision warning signal does not use speech coding	0 to 1	Tonal [1] Speech Coding [0]	
Tonal collision warnings are distinct from other sounds used within the vehicle	0 to 1	Distinct [1] Similar [0]	
Tonal collision warnings have a signal to ambient noise ratio of greater than 1.3 between relevant loudness spectra	0 to 1	>1.3 [1] ≤1.3 [0]	
Collision warning signal automatically ceases in less than [2] seconds after T_1	0 to 1	Ceases within 2 secs [1] Does not cease/ceases in ≥2s [0]	
Max. Points	**15**	**Total Score**	
		Total Score/Max. Points	

9.8 Nearside Turn No test Target (NTNT) Scenario

9.8.1 Test Scenario Performance Evaluation

9.8.1.1 The evaluation of the performance of the blind spot system during the Nearside Turn No test Target (NTNT) test scenario shall be assessed in accordance with Table 38. No assessment of the HMI performance shall be performed for the Nearside Turn No test Target (NTNT) test scenario.

Table 38: Evaluation of test performance for the Nearside Turn No test Target (NTNT) test scenario

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Proximity Information Signal (False Positive)	-1 to 0	Proximity information signal status in any test scenario	Inactive [0] Active [-1]	
Collision Warning (False Positive)	-2 to 0	Collision warning status in any test scenario	Inactive [0] Active [-2]	
Max. Points	**0 (min -3)**		**Total Score**	
			Total Score/Max. Points	

9.9 General HMI Evaluation

9.9.1 Formal independent tests need not be undertaken in respect of the additional HMI requirements specified in Table 39. Assessment may be based on documentary evidence provided by the system supplier and demonstration of functionality. The general HMI parameters that attract additional credit are identified in Table 39.

Table 39: Requirements for warning systems

HMI Criteria	Points Available	Result criteria	Score
The device automatically switches off above a speed of 30 km/h	0 to 1	Switches Off [1] Does Not Switch Off [0]	
The operational status of the device is communicated to the driver	0 to 1	Status Communicated [1] Status Not Communicated [0]	
Visual displays use colour combinations recommended by ISO 15008:2009	0 to 1	Recommended [1] Not recommended [0]	
Visual displays shall have a brightness of ≥6000 cd/m^2 in daylight conditions	0 to 1	≥6000 cd/m^2 [1] <6000 cd/m^2 [0]	
Visual displays have a (manually or automatically) adjustable brightness to compensate for ambient conditions	0 to 1	Adjustable [1] Fixed [0]	
Visual displays are of sufficient size with minimum dimensions of 12 mm x 12 mm on driver side and 20 mm x 20 mm on passenger side of vehicle	0 to 1	Sufficient Size [1] Insufficient Size [0]	
Max. Points	**6**	**Total Score**	
		Total Score/Max. Points	

9.9.2 Motion inhibit systems shall be over-rideable by the driver to continue making progress in the event of a false positive

9.10 Quality, Durability and Installation Requirements

9.10.1 Additional score will be awarded if the system or vehicle supplier can demonstrate documentary evidence of compliance with the requirements in Table 40.

Table 40: Requirements for Quality, Durability and Installation

Criteria	Points Available	Result criteria	Score
Complies with EN50498 for Electro-Magnetic Compatibility	0 to 1	Compliant [1] Not Compliant [0]	
Complies with UNECE Regulation 10.04 for immunity to radio frequency interference (RFI)	0 to 1	Compliant [1] Not Compliant [0]	
Complies with ISO 11452-9 or ISO 11451-3	0 to 1	Compliant [1] Not Compliant [0]	
Complies with the Mechanical Test aspects of ISO 16001	0 to 1	Compliant [1] Not Compliant [0]	
Complies with the Mechanical Test aspects of ISO 15998	0 to 1	Compliant [1] Not Compliant [0]	
Max. Points	**5**	**Total Score**	
		Total Score/Max. Points	

9.11 Overall Rating

9.11.1 Each of the individual assessments defined across the previous sections will provide a normalised performance score between 0 and 1. Due to the characteristics of the London collision landscape, however, some test scenarios are deemed to be more important than others for preventing bus-to-VRU collisions. These individual scores are, therefore, weighted by importance then summed together to produce an overall Blind Spot information signal, Warning and intervention (BSW) performance score between 0% and 100%, as shown in Table 41.

Table 41: Weightings for overall Blind Spot information signal, Warning and intervention (BSW) performance rating score

Scenario	Evaluation Method	Evaluation Score (E)	Scenario Weighting	Collision Population Weighting	Scenario Weighting	Evaluation Method Weighting	Overall Weighting (W)	Weighted Score (W*E)
Moving-Off Proximity Information signal (MOPI)	Performance		90%	57%	45%	75%	0.173	
	HMI					25%	0.058	
Moving-Off collision Warning and motion Inhibit (MOWI)	Performance		90%	57%	55%	95%	0.268	
	HMI					5%	0.014	
Nearside Turn Proximity Information signal (NTPI)	Performance		90%	15%	20%	75%	0.020	
	HMI					25%	0.007	
Nearside Turn Low relative Cyclist speed (NTLC)	Performance		90%	15%	30%	75%	0.030	
	HMI					25%	0.010	
Nearside Turn High relative Cyclist speed (NTHC)	Performance		90%	15%	30%	75%	0.030	
	HMI					25%	0.010	
Nearside Turn Crossing Pedestrian (NTCP)	Performance		90%	28%	100%	75%	0.189	
	HMI					25%	0.063	
Nearside Turn No test Target (NTNT)	Performance		90%	15%	20%	75%	0.020	
	HMI					25%	0.007	
Additional HMI Requirements			5%				0.050	
Quality, Durability & Installation			5%				0.050	
						Overall BSW Performance Rating Score (%)		

10 Test Report

10.1 The Test Service shall provide a comprehensive Test Report that will be made available to TfL. The test report shall consist of three distinct sections:

a) Performance data

b) Confirmation of protocol compliance

c) Reference information

10.2 The minimum performance data required is the completion of each table of results listed in this document.

10.3 In order to confirm protocol compliance, the Test Service shall:

a) include in the report processed data (e.g. graphs, tables etc.) that show that each test was compliant with its associated variables and tolerances

b) provide data on environmental validity criteria, including temperature, weather and lighting measurements, demonstrating compliance with respective limit values.

10.4 The reference information required includes as a minimum:

a) Vehicle Make

b) Vehicle Model

c) Vehicle Model Variant

d) BSW Hardware version (e.g. sensor types, ECU references)

e) BSW Software version

Attachment 25: Blind Spot Warning Guidance Notes

1 Introduction

Separate requirements are intended to ensure that drivers have a good field of view from a bus in respect to vulnerable road users (VRUs) in close proximity to the bus. The aim of the Blind Spot information signal, Warning and intervention (BSW) safety measure is to recognise that good vision alone will not guarantee that drivers will successfully avoid all collisions with VRUs in close proximity to buses performing low speed manoeuvres. Information signals, warnings and interventions based on the detection of vulnerable road users through electronic sensing systems can, therefore, still have a significant potential benefit in these circumstances.

This document sets out the guidance notes related to the testing and assessment of the safety performance of BSW systems. These guidance notes are aimed at bus operators and manufacturers 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, guidance provided by the manufacturer of a bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The blind spot information warning and intervention (BSW) requirements may be assessed against a new build bus with functions integrated in the factory by the bus OEM, or against a vehicle fitted with a system supplied by an organisation other than a bus OEM either for dealer fit or as an aftermarket fitment.

2.1 Compliance and warranty

A bus operator should seek evidence from the system supplier and/or bus manufacturer that a dealer fit or aftermarket fitted device does not create any warranty problems for the bus OEM. Operators should also be aware that a regulation governing the technical standards of systems with some of the functionality described in the assessment is in development and will be applied to HGVs. It is possible that this may be extended to buses, but any regulatory requirements will only apply to new buses first registered from the relevant future date. It will not render devices fitted before that time illegal, even if they do not comply with the new requirements.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

In order to recognise a potentially dangerous situation during low speed manoeuvres and successfully avoid a collision, then the following elements are required:

- **Available to be seen:** The hazard (pedestrian, cyclist, other vehicle etc.) needs to be available to be seen by the driver sufficiently ahead of time to allow avoiding action to be taken. That is, the hazard needs to be in view at least around 2 seconds before collision.
- **Alert and attentive:** The driver needs to be attentive to the road and traffic environment and alert to the possible need to react.
- **Looking in the right direction**: In complex driving situations, the driving task can demand attention in multiple different directions; the driver needs to be looking in the right direction at the right time to see the hazard. In dynamic moving environments this is not guaranteed even if the driver is alert and attentive.
- **Recognition:** Once the hazard is seen, then the driver must recognise the hazard and the risk that it poses.
- **Reaction:** Once the risk is recognised, the driver must react quickly and correctly to the risk. In some circumstances this may be steering around the hazard, in many it will be braking the vehicle to a stop and in others it might simply be to remain stationary instead of moving off from rest.

Thus, the ability to avoid a collision in the low speed manoeuvring circumstances envisaged for BSW systems is also strongly related to the vision performance of the bus and so the two safety measures should be considered together so that they are complementary and work in synergy.

BSW systems can supplement the vision requirements in circumstances where the hazard is still unavailable to be seen by the driver. However, the main benefit is likely to be in drawing the drivers attention to the presence of the hazard when, either for legitimate reasons of driver workload or for reasons of distraction or fatigue, the driver is not looking in the direction of the hazard at the exact time needed to avoid collision. In these circumstances the BSW can draw the driver attention to the right spot at the right time where the hazard will be visible in direct or indirect vision such that it maximises the chance of prompt recognition and correct reactions.

In order to achieve this, the way that the systems interact with the driver to inform them, warn them or intervene on their behalf is considered critical to the likely success of the system. This aspect of system design is known as the human-machine interface, or HMI. Measures are in place to encourage good HMI in the test and assessment protocol and are based on established industry standards (e.g. ISO standards). They are typically related to the criticality of the driving situation (is a collision likely in the next couple of seconds, in a longer period or not necessarily likely at all) and the urgency of the warning. However, HMI has inevitable subjective elements and can be difficult to measure objectively so there will still be room for substantial variation in the systems available on the market. The guidance below provides both the rationale for the protocol requirements and information to help operators choose systems that they believe will work well with their vehicles, in the operating environments the vehicles will be used in and by their drivers.

2.3 Proximity information signals

Proximity information signals are systems that will inform the driver any time a vulnerable road user is in close proximity to the vehicle. In London traffic these will be issued very frequently. In the vast majority of these situations, the situation will not be critical i.e. a collision will not be imminent in the next couple of seconds and the driver may well already be well aware of the presence of the hazard. Thus, reaction to non-critical situations should be discouraged and the warning should not be urgent or intrusive. In these circumstances an urgent, intrusive warning such as a loud tonal sound, a buzzer etc. can be annoying to the driver. They may subconsciously tune the warning out such that they ignore it when it is really needed or they may even find ways of disabling the system. Thus, examples of amber visual warnings may be much more acceptable to the driver in the many cases where the situation is not critical and/or they were already aware, while still providing useful information about the presence of hazards, when they are hidden or the driver has not seen them.

2.4 Collision warnings

Collision warnings should be issued only when the driving situation is critical i.e. the system has calculated that a collision is imminent in the next few seconds. Thus, even in London traffic they should go off far less frequently than proximity warnings. In this case, it is necessary for the warnings to be urgent and intrusive because they must quickly grab the attention of the driver and provoke rapid action to prevent a collision. These intrusive warnings are far less likely to annoy the driver, firstly because they should be far less frequent than proximity warnings and secondly because if they are working well it should be possible for the driver to see the reason for the warning in the majority of instances. False or premature activations when either the system has misdiagnosed the situation or reacted too soon will undermine driver confidence in the system and should be minimised, though what constitutes ‘too soon’ or even ‘false’ is to some degree subjective and driver dependent.

As such warnings issued over more than one channel (e.g. audible and visual and/or haptic warnings that are felt such as vibrations) are desirable, and speech warnings are undesirable because they take a finite time to complete and the drivers take a finite amount of time to process and understand the warning. Visual warnings should be red and audible warnings sufficiently loud to be heard against the backdrop of engine/passenger noise etc.

2.5 Other alert/warning signals

It should be noted that the test and assessment protocol only considers information signals and collision warnings in relation to close proximity manoeuvring but system suppliers may offer such signals in other driving circumstances, for example in relation to lane departure or imminent collision with a vehicle ahead. The requirements of the Bus Vehicle Specification and the test and assessment protocol do not apply to these other functions but also do not prohibit them. You can have other functions on the vehicle if considered beneficial. However, operators should consider the same HMI principles in relation to these other warnings and consider driver workload, recognition and reaction issues in terms of how well the system quick and correct response and avoids driver confusion. Having very similar anonymous bleeps in reaction to multiple different undesirable traffic situations is unlikely to maximise driver effectiveness in collision avoidance.

2.6 Signal directionality and workload

Systems that draw the driver’s attention in the direction of the hazard are considered more desirable than those that do not. For example, a system detecting the proximity of a cyclist to the left of the bus might illuminate an amber visual warning at the left side of the bus. By contrast a system that issues an audible and visual collision warning at a point low down in the dashboard near the driver, actually draws driver attention away from the hazard and may well be less effective as a consequence and generally increase driver workload.

2.7 Intervention systems

Even with the best vision and a high quality warning, successful collision avoidance will still rely on the driver taking the correct course of action sufficiently quickly and is, therefore, not guaranteed. Intervention systems will act in the event that the driver does not make the correct avoidance action or makes it insufficiently quickly. There are also clear risks with intervention systems if, for example, they misdiagnose the situation and intervene when they should not.

At the time of drafting requirements, it should be noted that automated emergency braking systems that are active in low speed manoeuvres (i.e. <10 km/h), particularly during left or right turns, were not available for any vehicle type. Although it is known that prototypes are in development, technical challenges remain around sensor accuracy, sensor fields of view and brake build up times, so it is not clear when they would be available. These have therefore not been included in the bus safety standard. However, such systems are not prohibited and if they become available should be analysed, assessed and considered.

Collisions where the vehicle moves off from rest and hits a pedestrian immediately in front of the vehicle present a particular challenge. In HGVs they are thought to occur because of blind spots. Buses typically do not suffer from such blind spots but collisions do still occur, albeit relatively less frequently. One possible explanation for this is that the driver is legitimately looking over their shoulder to check it is clear to move out from a bus stop into traffic at the time they move off. A non-intrusive visual warning may or may not be sufficient to draw the attention of the driver to the hazard given how far away from the relevant direction they may be looking.

By definition, a collision warning can only activate once the vehicle first moves such that it is on a collision course. If the pedestrian is close to the front, this would be issued too late for the driver to react and stop before the collision, though it may still prevent runover by the wheels.

However, a system that detected the presence of a pedestrian and, for example, disabled the throttle, then a driver that had not seen the pedestrian would remain unable to move the vehicle. Given that the vehicle would at this time be stationary, and probably would have been for some time, then the risks of such an intervention are relatively low. In the event of a spurious activation, the procedure allows for a driver over-ride to prevent the vehicle being ‘marooned’. The aim is that it should not be so easy to activate that it could be done accidentally but not so complicated that the driver would forget how to do it. Driver over-ride should only be activated when the driver is absolutely confident there is no hazard immediately in front of the vehicle. The over-ride function should deactivate once the system determines that the detected hazard has been avoided.

3 Training

3.1 For test houses

Test houses accredited to undertake Euro NCAP AEB tests will have the skills and equipment required for these tests. Test houses without such accreditation will be required to demonstrate to TfL at their expense that they can achieve the same standard of testing as an accredited organisation.

3.2 Bus drivers

Drivers should be familiarised with the system such that they know what any warnings mean and, where applicable, how to over-ride an intervention system and when to do so. They should also be trained to understand the circumstances where the system can help them and those where it can’t, for example, if a system does not perform at night or in adverse weather.

3.3 Shift Supervisors

Supervisors should also be familiar with systems such that they can answer any questions from drivers and recognise any problems that may require maintenance.

3.4 Bus maintenance engineers

The engineers carrying out general bus maintenance should be aware of the location and details of the sensors and warning displays/tell tales. They should be trained in any routine maintenance required (e.g. keeping sensors clean, free from obstruction etc.) and how to fault find and repair the system.

4 Maintenance

Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs.

5 Repair

If the driver or anyone else reports a failure or a problem with the system this should be investigated and, if confirmed, repaired.

Attachment 26: Pedal Application Error Assessment Protocol

1 Introduction

This document presents a procedure for objectively assessing the performance of systems designed to stop incidents of pedal application error from occurring and to aid recovery from pedal application error.

1.1 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, Class II.

The pedal acoustic feedback assessment shall only apply to quiet running buses with a hybrid (HEV), pure electric (PEV), electrified vehicle (EV), fuel cell vehicle (FCV) or a fuel cell hybrid vehicle (FCHV) drivetrain.

1.2 Purpose

The purpose of this assessment is to provide data from a controlled and repeatable test that can be used to assess the potential benefits (reduced casualties and damage) of a system to minimise pedal application error incidents, namely:

- The misapplication of the accelerator pedal; or
- The failure of the drivers to realise that they have applied the incorrect pedal.

In addition to measuring aspects of vehicle dynamics, the protocol provides a method for measuring how the system affects driver performance and how drivers interact with and understand the system.

2 Normative references

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

- UNECE Regulation No, 121 - Uniform Provisions Concerning the Approval of: Vehicles with Regard to the Location and Identification of Hand Controls, Tell-tales and Indicators
- ISO 2575:2004 – Road Vehicles – Symbols for controls, indicators and tell-tales.
- NHTSA Human Factors Design Guidance for Driver-Vehicle Interfaces (DOT HS 812 360).

3 Definitions

For the purpose of this Protocol:

- **Approval Authority** – 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.
- **BTS: Brake Toggle System** – a system that requires an extra brake press in order to release the halt brake after the bus doors have opened or the passenger ramp has been lowered.
- **ALS: Accelerator Light System** – a light system to inform the driver which pedal is currently being pressed.
- **CAN bus: Controller Area Network bus** – a vehicle bus standard to allow communication between microcontrollers and devices in applications without a host computer.
- **Halt Brake** – an automated braking system that prevents a bus from moving under certain conditions (e.g. when the bus doors are open or the bus ramp is lowered).
- **New Build** – a vehicle that has been built by the Vehicle Manufacturer with the system to be assessed fitted during the assembly process prior to first registration of the vehicle.
- **Pedal Application Error** – an incident where a driver mistakenly presses the accelerator pedal instead of the brake pedal.
- **Pedal Acoustic Feedback System** – a system fitted on quiet running buses that provides an acoustic feedback to the driver as to the acceleration and change of acceleration of the bus as determined by pedal usage, in order to help the driver recover from pedal confusion incident.
- **Retrofit** – fitment of the system to be assessed after the first registration of the vehicle. Installation is may be completed by the Vehicle Manufacturer or an authorised fitter.
- **Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority.
- **VUT: Vehicle Under Test** – means a vehicle that is being tested to this protocol.

4 Test conditions

4.1 Test Track

4.1.1 Testing shall be conducted on solid-paved road surfaces, with only a small amount of surface moisture, ice or other environmental factors that could reduce surface adhesion permitted.

4.1.2 The road surface shall not contain any major irregularities such as large pot holes or cracks in the road surface that may affect the behaviour of the driver (e.g. forcing them to take avoiding action) or have a physical impact on them (e.g. disturbing their foot and body position by causing them to move around excessively in their seat).

4.1.3 There shall be no obstructions in front of or behind the VUT for a distance of 10m. There shall be an area of free space of 3m to either side of the VUT.

4.2 Weather and lighting

4.2.1 Testing shall be conducted in clear and dry weather conditions with no precipitation falling and temperatures no lower than 5°C and not higher than 40°C.

4.2.2 Testing shall be conducted in both daytime and night time lighting conditions:

a) For daytime testing, natural ambient illumination shall be homogenous in the test area and in excess of 2000 lux. Testing shall not be performed driving towards, or away from the sun when there is direct sunlight.

b) For night-time testing, natural ambient illumination shall be homogenous in the test area and should not be in excess of 20 lux.

5 Vehicle preparation

5.1 The VUT shall be prepared according to the following requirements:

5.1.1 The pedal application error systems shall have been installed during manufacture in the case of a new-build vehicle or retrofitted by qualified fitter authorised by the Vehicle Manufacturer; and

5.1.2 The VUT shall:

a) Have passed a DVSA approved Periodic Technical Inspection within the last 12 months (if the vehicle is more than 12 months old) or passed an equivalent inspection if unregistered;

b) Be within its scheduled maintenance period (unless it is a new vehicle that has not yet been required to have its first service);

c) Have no faults or damage that could interfere with the testing protocol;

d) Have a halt brake system the engages when the bus doors are opened and when the passenger ramp is lowered;

e) Be driven by a qualified driver; and

f) Be empty of passengers or any persons other than the driver.

6 Test procedure

6.1 BTS

6.1.1 Apply the BTS checklist as defined in Annex 1 in the following sequence:

a) Put the VUT into the specified state;

b) Observe the result;

c) Compare the observed result to required result; and

d) Record if observed result matches required result (“Pass” or “Fail”).

6.2 ALS

6.2.1 Apply the ALS checklist as defined in Annex 1 in the following sequence:

a) Put the VUT into the specified state;

b) Observe the result;

c) Compare observed result to required result; and

d) Record if observed result matches required result (“Pass” or “Fail”).

6.2.2 The assessment of the ALS shall be completed under the following lighting conditions:

a) Daylight; and

b) Night time.

See section 4.2 for definition of lighting conditions.

6.2.3 Apply the lamp installation/illumination checklist as defined in Annex 2

6.2.3.1 The speed of activation of the lamps shall be assessed using high speed video analysis.

a) The frame rate for the video shall be at least 1000 frames per second.

b) The high speed video shall be synchronised with the CAN signal from the pedals.

6.2.3.2 The delay between the first movement of the pedal and the lamp achieving 90% of its steady state output shall be recorded.

6.3 Pedal acoustic feedback

6.3.1 Apply the pedal acoustic feedback checklist as defined in Annex 3.

6.3.1.1 This test shall only apply for quiet running vehicles including a hybrid (HEV), pure electric (PEV), electrified vehicle (EV), fuel cell vehicle (FCV) or a fuel cell hybrid vehicle (FCHV) drivetrain.

7 Assessment of results

7.1 The following criteria will be used to asses if the BTS and ALS have passed or failed the assessment.

7.1.1 BTS

7.1.1.1 In order to receive a “Pass” certification the system must receive a “Pass” grade for each of the requirements on the assessment checklist.

7.1.1.2 The system shall be deemed to have failed the assessment if it received a single “Fail” grade on the BTS assessment checklist.

7.1.2 ALS

7.1.2.1 In order to receive a “Pass” certification the system must receive a “Pass” grade for each of the requirements on the assessment checklist.

7.1.2.2 The system shall be deemed to have failed the assessment if it received a single “Fail” grade on the ALS assessment checklist.

7.1.3 Lamp installation/illumination checklist

7.1.3.1 In order to receive a “Pass” certification the system must receive a “Pass” grade for each of the requirements on the assessment checklist.

7.1.3.2 The system shall be deemed to have failed the assessment if it received a single “Fail” grade on the assessment checklist.

7.1.3.3 The lamp activation time shall be 100ms or less.

7.1.4 Pedal acoustic feedback checklist

7.1.4.1 Evidence shall be submitted by the bus manufacturer, or a bus inspected. The test engineer shall assess whether the bus passes or fails each check.

7.1.5 Overall Assessment

7.1.5.1 In order to receive an overall “Pass” certification the system must receive a “Pass” grade for each of the above sections on the checklist and have a lamp activation time of 100ms or less.

7.1.5.2 The system shall receive an overall “Fail” grade in the assessment if a single “Fail” grade was awarded on any section of the assessment checklist or if the lamp activation time is more than 100ms.

7.1.5.3 To integrate this pass/fail test into the overall bus safety score an overall Pass will be deemed as a score of 100% and a fail will be deemed a score of 0%

8 Test report

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

a) Completed BTS checklist;

b) Completed ALS checklist;

c) Completed lamp installation/illumination checklist;

d) Lamp activation assessment;

e) Pedal acoustic feedback checklist; and

f) Reference information.

8.2 The reference information required shall include as a minimum:

a) Vehicle make;

b) Vehicle model;

c) Vehicle model variant;

d) Pedal application error system installed (New-build/Retrofit);

e) Evidence of meeting vehicle preparation requirements (e.g. MOT certificate, service history);

f) Details of the Test Service; and

g) Test date(s).

Annex 1 Brake toggle system checklist

Brake Toggle System Checklist

Step	Bus State (On/Off)	Gear	Park Brake	Bus Doors	Action	Required Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
1	On	Drive	On	Closed	Open all bus doors	Halt brake engages		
2	On	Drive	Off	Closed	Apply accelerator	Halt brake remains engaged and bus does not move		
3	On	Drive	Off	Closed	Depress brake pedal to level that triggers brake lights on, and then release brake pedal	Halt brake releases		
4	On	Drive	Off	Closed	Apply accelerator	Bus moves forward		
5	On	Drive	On	Closed	Open all bus doors	Halt brake engages		
6	On	Drive	Off	Closed	Depress brake pedal to level that triggers brake lights on, and then release brake pedal	Delay of no more than 500ms before halt brake releases		

Total	
Required Score	6
Outcome	

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Annex 2 Accelerator light system checklist

Accelerator Light System Checklist

Step	Bus State (On/Off)	Gear	Park Brake	Bus Doors	Action	Required Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
1	On	Drive	Off	Closed	Neither pedal pressed	Light is unlit when neither pedal is pressed		
2	On	Drive	Off	Closed	Brake pedal pressed	Light is unlit when brake pedal is pressed		
3	On	Drive	Off	Closed	Accelerator pedal pressed <80%	Light unlit		
4	On	Drive	Off	Closed	Accelerator pedal pressed >80%	No noticable delay in light turning on		
5	On	Drive	Off	Closed	Accelerator pedal pressed >80%	Light illuminated		
6	On	Drive	Off	Closed	Accelerator pedal pressed <80%	No noticable delay in light turning off		
7	On	Drive	Off	Closed	Accelerator pedal pressed >80%	No visible flickering of lights		
8	On	Drive	Off	Closed	Brake pedal pressed	No noticable delay in light turning off		
9	Pn	Drive	Off	Closed	Accelerator pedal pressed	No noticable delay in light illuminating		
						Total Required Score		9
						Outcome		

Annex 3 Lamp installation/illumination checklist

Lamp installation/illumination Checklist

Step	Bus State (On/Off)	Gear	Park Brake	Bus Doors	Action	Required Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
1	On	Neutral	On	Closed	Accelerator pedal pressed	Lights meet requirements of UN Regulation 121 Sections 5.2.2 5.2.4 5.4.2 and 5.4.3		
2	On	Neutral	On	Closed	Accelerator pedal pressed	Lights meet requirements of ISO 2575:2004 Section 4 and Section 5		
3	On	Neutral	On	Closed	Accelerator pedal pressed	Lights meet UN ECE Regulation 121		
						Total		
						Required Score		3
						Outcome		

Annex 4 Pedal acoustic feedback checklist

Pedal Acoustic Feedback checklist

Acoustic feedback	Expected Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
The feedback system shall have a master volume control that can only be set by the bus manufacturer to prevent increasing the noise levels inside the saloon of the bus	Pass		
The level set by the manufacturer shall be audible by the driver and not cause undue annoyance. (Levels to be defined by testing using ISO 5128 -1980 (E); Acoustics - Measurement of Noise inside Motor Vehicle).	Pass		
A local Driver volume control shall also be incorporated that will allow the driver to reduce the volume of the system to a pre set minimum level (not to switch off) and also not increase the volume beyond the manufacturers pre-set point.	Pass		
The feedback speaker(s) should be mounted behind the drivers head area at ear height.	Pass		
When installing/positioning the feedback speaker(s) care must be taken as to not have a detrimental effect on head movement during the operation of the bus and in the case of a collision the head being able to strike hard objects.	Pass		
	Total		
	Required Score		5
	Outcome		

Attachment 27: Pedal Application Error Guidance Notes

1 Introduction

This document sets out the guidance notes related to pedal application error. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The Bus Safety Standard contains several systems intended to reduce the likelihood and consequence of errors in pedal choice between the brake and accelerator:

- Pedal toggling – a system in which the brake pedal must be fully depressed and released before moving off after closing the doors
- Accelerator light indicator– a system that gives the driver a visual indication of the accelerator pedal being pressed via a light on the dashboard
- Pedal acoustic feedback system – a system that gives the driver an audible cue as to the use of pedals and the change of acceleration of the bus, in order to help with recovery from a pedal confuscial incident.

2.1 Brake toggling

2.1.1 *Bus selection*

In order for this system to be retrofitted onto buses, the buses must have a halt brake system that operates when the bus doors are opened (as well as when the passenger ramp is lowered). Therefore, vehicles with such a system should be procured.

2.1.2 *System Selection*

A brake toggling system that requires the driver to press the brake pedal in order to release the halt brake should be selected. The halt brake should only engage after the bus doors have been opened or the passenger ramp has been lowered, with the brake press to release the halt brake only intended to operate when drivers are leaving bus stops or starting their shift. A comparison between the task order for the brake reminder system and standard bus operation is detailed in Table 1 below.

Table 1. Comparison of task order between standard operation and the brake toggle system

Standard Bus Task Order	Brake Toggle Task Order
Press brake	Press brake
Change gear to "D"	Change gear to "D"
Release brake	Release brake
-	Press brake
-	Release brake
Release park brake	Release park brake
Apply accelerator	Apply accelerator

2.2 Brake/accelerator indicator lights

2.2.1 Bus selection

It may be easier to integrate the accelerator light into buses with LCD screens on the dashboard.

2.2.2 System selection

The accelerator indicator light system should be designed in such a way that it conforms to UN ECE Regulation 121. This makes reference to ISO 2575:2004, which should be used as additional guidance if needed. If further guidance is still needed then the guidance set out in the NHTSA Human Factors Design Guidance For Driver Vehicle Interfaces (DOT HS 812 360) may be referenced as a third option. UN ECE Regulation 121 takes precedence in all cases.

The requirements for the design and installation of the accelerator light system are contained within the requirements of the EC Whole Vehicle Type Approval for any tell-tale or indicator fitted to passenger or goods vehicles. These are provided in UN ECE Regulation 121 - Uniform Provisions Concerning the Approval of: Vehicles with Regard to the Location and Identification of Hand Controls, Tell-tales and Indicators. Regulation 121 prescribes the location, identification, colour, and illumination of common controls as well as the requirements for access and visibility

The visual indicator showing the driver when the accelerator is pressed is not included within the list of common items or controls covered by the Regulation. Where a tell-tale or indicator for which the Regulation does not provide specific provisions is installed on a vehicle certain requirements shall be adhered to. These requirements, taken from Sections 5 and 6 of Regulation 121, are summarised below:

2.2.2.1 Identification:

a) Where possible a symbol designated for the purpose in ISO 2575:2010 - Road vehicles — Symbols for controls, indicators and tell-tales, shall

b) To identify a tell-tale or indicator not included in the Regulation or ISO 2575:2004 the manufacturer may use a symbol of its own conception. Such symbols may include internationally recognised alphabetic or numeric indications.

c) Where a symbol is designed by a manufacturer the principles of Paragraph 4 of ISO 2575:2010 shall be followed.

d) Any additional symbol used by the manufacturer shall not cause confusion with any symbol specified in the Regulation.

2.2.2.2 Colour:

a) Indicators and tell-tales not included in the Regulation or ISO 2575:2010 may be of any colour chosen by the manufacturer, however, such colour shall not interfere with or mask the identification of any tell-tale, control, or indicator specified in the Regulation.

b) The colour to be selected shall follow the guidelines specified in Paragraph 5 of ISO 2575:2010.

c) Each symbol used for identification of tell-tale or indicator shall stand out clearly against the background.

d) The accelerator light system selected must adhere to these criteria.

2.3 Pedal acoustic feedback

2.3.1 Bus selection

This system is only required on quiet running buses with a hybrid (HEV), pure electric (PEV), electrified vehicle (EV), fuel cell vehicle (FCV) or a fuel cell hybrid vehicle (FCHV) drivetrain.

2.3.2 System Selection

No prototype or production versions of this system yet exist. Consultation with the bus manufacturers and TfL is needed before selecting buses.

3 Training

Usage of the pedal confusion solutions will require the creation of a training course to teach drivers about the solutions and how they operate. If feasible schedules should minimise drivers experience of mix of vehicles with and without the system. The determination for whether or not a driver is able to safely use the systems shall be up to the discretion of the bus operator and any assessment criteria they decide upon.

3.1 Brake Toggle

As the brake toggle solution involves a change to the driving tasks that drivers will have been trained to undertake and may have used for extended periods of time, some form of training with the system will be necessary.

In order to train drivers to use the brake toggle solution, it is recommended that drivers are first given a set of written instructions that explain how the system operates. The drivers shall then be given an oral explanation of how the system works from an instructor who is experienced at using the system. The driver shall then be given the opportunity to practise driving the bus on a private road. The driver shall first practice moving the bus from a standstill, imitating letting passengers on and off the bus by opening the bus doors and lowering the passenger ramp. Once the driver is comfortable using the system, they shall be given the opportunity to drive the bus on public roads. Ideally they will drive their normal bus route, stopping at bus stops along the way to practise moving off with the new brake interlock.

The instructor shall be responsible for determining if the driver is able to use the system based on how many errors they make and how long it takes them to deactivate the halt brake and drive away from the bus stops. There shall also be a small written examination that asks the driver basic questions regarding the brake toggle system, what the driver needs to do to operate the system and how their driving tasks will differ from what they are used to as a result of the system.

3.2 Accelerator Light System

Drivers are to be trained with the accelerator light system in conjunction with the brake toggle system, with the same training protocol applied. As with the brake toggle system, written and oral instructions will be provided to drivers, who will then drive the bus on private and public roads in order to familiarise themselves with the system. The instructor will then determine if the driver is able to safely use the system based on the number of errors they make and the time it takes them to move off from bus stops. A short written examination will also be employed to determine how well the driver understands the system.

3.3 Pedal acoustic feedback

The training for this system can be integrated with the other systems as above, with the same training protocol applied.

4 Maintenance

Maintenance shall only be undertaken by authorised and qualified individuals using OEM approved procedures. Maintenance of the systems should be incorporated into the regular servicing schedules for the bus.

4.1 Brake Toggle

Maintenance of the brake toggle system consists of maintaining the software that controls the bus interlock system as well as the halt brake system.

The software that is responsible for operating the bus interlock system must be regularly checked as part of the regular vehicle service schedule. The software must be checked in order to see that the halt brake is only activated upon the opening of the bus doors or the lowering of the passenger ramp, and that the halt brake can only be released after the brake has been fully depressed. It must also be ensured interlock system by allowing the halt brake to activate and deactivate in an incorrect manner. In order to ensure that the brake toggle system works as intended, the halt brake itself must undergo regular checks as part of the service schedule for the bus.

A maintenance check for the brake toggle system should consist of checking that opening the bus doors and lowering the passenger ramp activates the halt brake, and that the halt brake cannot be deactivated without the brake pedal being fully depressed. A software check should also be carried out in order to ensure that the system is operating correctly.

4.2 Accelerator Light System

Maintenance of the accelerator light system should form part of the regular service schedule for the vehicle.

The light must be checked to see that there is no visible flicker when it illuminates and that there is no perceptible delay between the accelerator pedal being pressed and the corresponding lights activating. The light should also be checked to make sure that the correct colour is associated with the accelerator pedal press. A check should also be made to see that the light does not illuminate when neither of the pedals are being pressed. If the light is built into an LCD display then the software that operates the screen must be regularly checked. Visual inspections must also be carried out in order to ensure that there are no dead pixels or artefacts.

A maintenance check for the accelerator light system should consist of a visual inspection of the lights while the accelerator pedal is being pressed. A software check should also be carried out.

4.3 Pedal acoustic feedback system

Maintenance of the pedal acoustic feedback system should form part of the regular service schedule for the vehicle.

The speakers must be checked to see that there is no obscuration or damage, and to check that there is no perceptible delay between the accelerator pedal being pressed and the corresponding sound changing frequency. A check should also be made to listen for the sound changing frequency as the accelerator pedal is released, and that the sound remains constant if the pedal pressure is also constant.

5 Repair

Repairs shall only be undertaken by authorised and qualified individuals using OEM approved parts and procedures. If the systems were retrofitted then the guidelines set out by the post-homologation manufacturer shall be followed.

Advice should be sought from the manufacturers of the specific systems fitted to buses in service regarding precautions to be taken in the event of a system failure. However, as these systems are safety aids rather than safety critical systems for the bus, the failure of these systems should not normally render the bus unroadworthy. Repairs to the systems should be made as soon as operationally possible.

5.1 Brake Toggle

If a failure occurs to the brake toggle system due to a software error, then an appropriate software fix shall be implemented. The bus OEM (or post-homologation parts manufacturer in the case that the systems were retrofitted) should be consulted to diagnose the software fault and they shall then issue a fix to resolve the fault. The bus operator should not attempt to diagnose and fix the issue without consulting the bus OEM and seeking their assistance as incorrect software changes could affect the functioning of the halt brake.

Any faults that occur with halt brake system shall be repaired following the normal repair guidelines set out by the bus OEM.

5.2 Accelerator Light System

In the event that the accelerator light system becomes faulty due to a software issue then the bus OEM (or post-homologation parts manufacturer) should be consulted to diagnose the software fault and they shall then issue a fix to resolve the fault. Any physical issues with the lights shall be resolved by replacing the lights with approved parts. If the operation of dashboard lights fitted within an LCD screen is compromised due to some fault with the screen itself, e.g. dead pixels, poor contrast or brightness, then the bus OEM or supplier of the screen should be consulted for repair instructions.

5.3 Pedal acoustic feedback system

In the event that the pedal acoustic feedback system becomes faulty due to a software issue then the bus OEM (or post-homologation parts manufacturer) should be consulted to diagnose the software fault and they shall then issue a fix to resolve the fault. Any physical issues with the speakers shall be resolved by replacing the speakers with approved parts.

Attachment 28: Runaway Bus Prevention Assessment Protocol

1 Introduction

This document presents a procedure for objectively assessing the performance of systems installed on a bus to prevent the bus rolling in an uncontrolled manner without input from a driver; the occurrence of which would be known as a “runaway event” or “runaway bus”.

1.1 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, Class II.

1.2 Purpose

The purpose of this assessment is to provide an expected level of performance for systems that claim to prevent runaway bus occurrences.

2 Normative References

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

- London Bus Services Limited Guidance Notes: Runaway Bus Prevention

3 Definitions

For the purpose of this Protocol:

- **Approval Authority** – 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.
- **Halt Brake** – an automated braking system that prevents a bus from moving under certain conditions (e.g. when the bus doors are open or the bus ramp is lowered).
- **New Build** – a vehicle that has been built by the Vehicle Manufacturer with the system to be assessed fitted during the assembly process prior to first registration of the vehicle.
- **Park Brake** – brake system that is intended to keep the vehicle stationary when parked.
- **RaB: Runaway Bus** – a bus without the park brake engaged that moves in any direction in an uncontrolled manner without any input from a driver
- **Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority.
- **VUT: Vehicle Under Test** – means a vehicle that is being tested to this protocol.

4 Test conditions

4.1 Test track

4.1.1 Testing shall be conducted on dry (no surface moisture, ice or other environmental factors that could reduce surface adhesion) and solid-paved road surfaces.

4.1.2 The test track shall have a gradient of between 1% and a 5%.

4.1.3 There shall be clear zone around the VUT. The clear zone shall extend at least one bus length in front of and behind the VUT, and one bus width to either side of the VUT, to give the required room for any rolling that occurs as a result of the testing.

4.2 Weather and lighting

4.2.1 Testing shall be conducted in clear and dry weather conditions with no precipitation falling and temperatures no lower than 5°C and not higher than 40°C. As an alternative the tests may be conducted indoors.

4.2.2 The test track shall have a level of ambient light that will allow the driver and assessor to see if any people or objects move into positions where they could be a risk of being hit by the bus during testing.

5 Vehicle preparation

5.1 The RaB bus preventions system shall:

a) Have been installed during manufacture in the case of a new-build vehicle; and

b) Interact with the park brake and not the halt brake to ensure system functionality in the event that the halt brake has no air pressure in it (whether through a malfunction or because the bus is switched off and the brake pressure has released).

5.1.1 **The VUT shall:**

a) Have passed its mandatory Periodic Technical Inspection at a DVSA approved facility within the last 12 months (if the vehicle is more than 12 months old), with the exception of prototype vehicles;

b) Be within its scheduled maintenance period (unless it is a new vehicle that has not yet been required to have its first service);

c) Have no faults or damage that could interfere with the testing protocol. The brakes shall have been checked by the driver to ensure that the bus can be stopped manually during testing in the event that the bus does roll;

d) Have a halt brake system the engages when the bus doors are opened and when the passenger ramp is lowered;

e) Have checked all passenger doors on the ground floor to ensure they are all fully operational;

f) Be positioned on the test track of defined gradient to ensure that if the bus is not being held stationary by any mechanisms it will visibly roll in a way that is obvious to the assessor;

g) Have no obstructions in front or behind any of its wheels;

h) Be driven by a qualified driver. In the instances where the test procedure requires there be no seat pressure the driver shall remain within the drivers cabin to apply the brakes when the bus rolls; and

i) Be empty of passengers or any persons other than the driver.

6 Test procedure

6.1 The assessment of the RaB prevention system is carried out in two stages. The bus safety system checklist shall be completed prior to commencing the RaB prevention system checklist.

6.2 Bus safety system checklist

6.2.1 Apply the bus safety system checklist as defined in Annex 1 in the following sequence:

a) Put the VUT into the specified state;

b) Observe the result;

c) Compare the observed result to the required result;

d) Record if observed result matches required result (“Pass” or “Fail”);

e) Reset the position of the VUT if it has moved during the test; and

f) Reset the gear to neutral.

6.3 RaB prevention system checklist

6.3.1 If all requirements of the bus safety system checklist are satisfied, apply the RaB prevention system checklist as defined in Annex 2 in the following sequence:

a) Put the VUT into the specified state;

b) Observe the result;

c) Compare the observed result to the required result;

d) Record if observed result matches required result (“Pass” or “Fail”);

e) Reset the position of the VUT if it has moved during the test; and

f) Reset the gear to neutral.

7 Assessment of results

7.1 The following criteria will be used to asses if the RaB prevention system has passed or failed the assessment.

7.1.1 Pre-requisites

a) In order to receive a “Pass” certification, the system must meet the expected outcome for each of the requirements on the bus safety system assessment checklist.

b) The system shall be deemed to have failed the assessment if it does not meet a single expected outcome on the bus safety assessment checklist. A system that fails to meet these pre-requisites shall not be recommended.

7.1.2 Assessment of the RaB prevention system

a) In order to receive a “Pass” certification the system must meet the expected outcome for each of the requirements on the RaB prevention system checklist.

b) The system shall be deemed to have failed the assessment if it does not meet a single expected outcome on the RaB prevention system checklist.

7.1.3 Overall Assessment

a) In order to receive an overall “Pass” certification the system must receive a “Pass” grade for each if the above sections on the checklist

b) The system shall receive an overall “Fail” grade in the assessment if a single “Fail” grade was awarded on any section of the assessment checklist.

c) To integrate this pass/fail test into the overall bus safety score an overall Pass will be deemed as a score of 100% and a fail will be deemed a score of 0%.

8 Test report

8.1 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) Completed bus safety system checklist;

b) Completed RaB prevention system checklist; and

8.2 Reference information.

8.3 The reference information required shall include as a minimum:

a) Vehicle Make;

b) Vehicle Model;

c) Vehicle Model Variant;

d) RaB system installed;

e) Evidence of meeting vehicle preparation requirements (e.g. MOT certificate, service history);

f) Details of the Test Service; and

g) Test date(s).

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Annex 1 Runaway bus safety system checklist

Runaway Bus Prevention			General Braking Mechanisms		Break Down			
Drive enabled (Is the bus "on"?)	Gear	Seat Pressure / Driver Input	Park Brake	Passenger Door	Kill Switch	Expected Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
No	Neutral	Yes	Off	Closed	Disengaged	Roll		
No	Neutral	Yes	On	Closed	Disengaged	No roll		
No	**Neutral**	**No**	**Off**	**Closed**	**Engage**	**Roll**		
Yes	Neutral	Yes	Off	Closed	Disengaged	Roll		
Yes	Neutral	Yes	On	Closed	Disengaged	No roll		
Yes	**Neutral**	**No**	**Off**	**Closed**	**Engage**	**Roll**		
Yes	Reverse	Yes	Off	Closed	Disengaged	Roll		
Yes	Reverse	Yes	On	Closed	Disengaged	No roll		
Yes	**Reverse**	**No**	**Off**	**Closed**	**Engage**	**Roll**		
Yes	Drive	Yes	Off	Closed	Disengaged	Roll		
Yes	Drive	Yes	On	Closed	Disengaged	No roll		
Yes	**Drive**	**No**	**Off**	**Closed**	**Engage**	**Roll**		
						Total		
						Required Score		12
						Outcome		

Transport for London
London Buses

Annex 2 Runaway bus prevention system checklist

Runaway Bus Prevention			General Braking Mechanisms		Expected Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
Drive enabled (Is the bus "on"?)	**Gear**	**Seat Pressure / Driver Input**	**Park Brake**	**Passenger Door**			
No	Neutral	Yes	Off	Open	No roll		
No	Neutral	No	Off	Closed	No roll		
No	Neutral	Yes	Off	Closed	Roll		
Yes	Neutral	Yes	Off	Open	No roll		
Yes	Neutral	No	Off	Closed	No roll		
Yes	Neutral	Yes	Off	Closed	Roll		
Yes	Reverse	Yes	Off	Open	No roll		
Yes	Reverse	No	Off	Closed	No roll		
Yes	Reverse	Yes	Off	Closed	Roll		
Yes	Drive	Yes	Off	Open	No roll		
Yes	Drive	No	Off	Closed	No roll		
Yes	Drive	Yes	Off	Closed	Roll		
					Total		
					Required Score		12
					Outcome		

Attachment 29: Runaway Bus Prevention Guidance Notes

1 Introduction

This document sets out the guidance notes related to runaway bus prevention. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems/ testhouse

Any bus that meets the TfL Bus Vehicle Specification.

A runaway bus prevention system may be provided as a new build bus

The testing of the runaway prevention should be carried out by a TfL approved testhouse. In the case that testing is to be carried out by a test house that does not fall into the aformentioned category prior approval must be gained from TfL.

2.1 Compliance and warranty

A bus operator should ask to see compliance certificates for UNECE Regulation 13 and warranty information for the brake system from both the bus manufacturer and/or the 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, and that the bus will not brake unexpectedly whilst in motion.

A bus manufacturer should work with any brake or runaway bus prevention system suppliers to ensure that UNECE Regulation 13 requirements are met, and that warranty on the brake system is maintained. The bus manufacturer must be able to present certificates to TfL as evidence that the bus brake system will continue to operate safely, and that the bus will not brake unexpectedly whilst in motion.

In the case that there are any functional changes made to the bus the vehicle should be re-tested (at the discretion of TfL) to make sure it still complies with the runaway bus assessment protocol.

2.2 Towing and recovery

The runaway bus prevention system is designed to keep the bus brakes on. Towing and recovery are the exceptions to this requirement and the bus needs to be able to roll without the driver in the seat.

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UNECE Regulation 13 requires an auxiliary release system for the brakes to allow towing. These are often mechanical. Obviously, this should only be undertaken when the vehicle is held stationary by some other external means, e.g. wheel chocks or recovery vehicles etc., and is only intended for use in full breakdown/recovery circumstances. The Regulation permits powered auxiliary release systems but only if the energy source is different to that used by the brakes, e.g., it can't be operated from the same air supply such that the loss causing the problem also causes the release not to work. Bus drivers should be trained on how to use the auxiliary release.

3 Training

3.1 Bus drivers

The runaway bus prevention systems are only aimed at preventing rare occurrences where the handbrake has not been applied. The drivers don't necessarily need to be trained in exactly how the system works but do need to be informed that it will trigger in instances where the bus has been left vulnerable to rolling (without the park brake engaged). Drivers do however need to be trained in how to release the system once they have rectified the issue by engaging the park brake.

3.2 Shift Supervisors

Shift supervisors should be trained in how the system works and know the code/ sequence of actions to activate the system's auxiliary release. In the event that one of their drivers or engineers has engaged the system and doesn't understand how to disengage it, or require the code for the runaway prevention systems auxiliary release (for what the supervisor deems to be a legitimate reason) they will have the ability to facilitate the rectification of the situation.

3.3 Bus maintenance engineers

The engineers carrying out general bus maintenance should be aware of how to activate the auxiliary release on the runaway prevention system should the maintenance they are carrying out requiring the bus to roll in a state where the runaway prevention system would otherwise inhibit that movement.

4 Maintenance

One system supplier requires daily checks of the runaway bus prevention system and the sensors that the system makes use of. Operators are encouraged to establish what (if any) daily checks are required, and to plan for these additional operational costs.

5 Repair

If during system maintenance checks (section 4) any of the sensors are deemed to be faulty or failing they should be replaced immediately. The runaway prevention

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system's effectiveness and reliability is completely contingent on the performance of the sensors the system is connected to.

Attachment 30: Acoustic Conspicuity Assessment Protocol

1 Introduction

This document presents a procedure for objectively assessing the performance of Acoustic Vehicle Alerting Systems (AVAS) installed on a bus. The aim of these systems is to make a quiet running vehicle (e.g. hybrid or electric) as conspicuous to a pedestrian as a typical diesel engine.

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, Class II.

3 Purpose

The purpose of this assessment is to provide an expected level of performance for AVAS.

4 Normative References

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

- London Bus Services Limited Guidance Notes: Acoustic Conspicuity
- UN ECE Regulation 138; Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility

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5 Definitions

For the purpose of this Protocol:

- **Approval Authority** – 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.
- **AVAS** – Acoustic Vehicle Alerting System, as per Regulation 138.
- **New Build** – a vehicle that has been built by the Vehicle Manufacturer with the system to be assessed fitted during the assembly process prior to first registration of the vehicle.
- **Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority.
- **VUT: Vehicle Under Test** – means a vehicle that is being tested to this protocol.

6 Test conditions

6.1 Test track

6.2 Testing shall be conducted on dry (no surface moisture, ice, snow or other environmental factors that could affect acoustic performance..

6.3 The test **track** shall meet the requirements of ISO 10844.

6.4 Weather and lighting

6.5 Testing shall be conducted in clear and dry weather conditions with no precipitation falling and temperatures no lower than 5°C and not higher than 40°C. Wind speed shall be less than 5 m/s. As an alternative the tests may be conducted indoors.

6.6 The test track shall have a level of ambient light that will allow the driver and assessor to see if any people or objects move into positions where they could be a risk of being hit by the bus during testing.

7 Vehicle preparation

7.1 The AVAS shall have been installed during manufacture in the case of a new-build vehicle.

7.2 The VUT shall:

7.3 Have passed an annual MOT test at a DVSA test station within the last 12 months (if the vehicle is more than 12 months old), with the exception of prototype vehicles;

a) Be within its scheduled maintenance period (unless it is a new vehicle that has not yet been required to have its first service);

b) Have no faults or damage that could interfere with the testing protocol;

c) Be driven by a qualified driver. In the instances where the test procedure requires there be no seat pressure the driver shall remain within the drivers cabin to apply the brakes when the bus rolls; and

d) Be empty of passengers or any persons other than the driver.

8 Test procedure

8.1 The assessment of the AVAS is carried out using a checklist.

8.2 The AVAS checklist shall be assessed based on documentation submitted by the bus manufacturer.

8.3 Compare the observed result to the required result;

8.4 Record if observed result matches required result (“Pass” or “Fail”);

9 Assessment of results

9.1 The following criteria will be used to asses if the AVAS system has passed or failed the assessment.

9.2 In order to receive a “Pass” certification, the system must meet the expected outcome for each of the requirements on the assessment checklist.

9.3 The system shall be deemed to have failed the assessment if it does not meet a single expected outcome on the AVAS assessment checklist. A system that fails to meet these pre-requisites shall not be recommended.

11 Test report

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

a) Completed AVAS checklist;

b) Reference information.

11.2 The reference information required shall include as a minimum:

a) Vehicle Make;

b) Vehicle Model;

c) Vehicle Model Variant;

d) AVAS system installed;

e) Evidence of meeting vehicle preparation requirements (e.g. technical inspection, service history);

f) Details of the Test Service; and

g) Test date(s).

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Annex 1 **AVAS checklist**

Acoustic Vehicle Alerting System (AVAS)	**Expected Outcome**	**Actual Outcome**	**Outcome match? (Yes=1, No=0)**
2 channel directional system	Pass		
Speaker mounted with horizontal plane - up to a maximum [0.6] m either side of the centre line of the bus	Pass		
Speaker mounted with vertical plane - between [0.5 m] to [1.0 m] (Normally [0.8 m])	Pass		
The speaker(s) must have an unobstructed sound path.	Pass		
The speakers are mounted one on each side of the bus front	Pass		
Each speaker has a horizontal beamwidth/directivity pattern in the range [120° to 140°] and a vertical beamwidth/directivity pattern in the range [70° to 110°]	Pass		
The centre line of the speakers shall be aligned towards the nearside kerb at an angle of 20° to 30° from the front surface of the bus	Pass		
If the two speakers are playing the same sound, the sounds shall be incoherent to avoid interference patterns affecting conspicuity.	Pass		
AVAS sound is Regulation 138 compliant and a valid test certificate submitted	Pass		
TfL Urban bus sound, version 1.0 installed	Pass		
AVAS shall be capable of receiving an updated sound file in the future, e.g. as a minimum locally via USB, or optionally via telematics (mass update).	Pass		
A USB device must also be incorporated in to the AVAS to allow for local updates.	Pass		
The system shall have the capability to have at least 3 sounds stored on the system (one sound at installation / entry into service, then a further two additional sounds)	3 or more		

Total	
Required Score	13
Outcome	

Attachment 31: Acoustic Conspicuity Guidance Notes

1 Introduction

This document sets out the guidance notes related to Acoustic Conspicuity. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

2.1 Buses requiring Acoustic Conspicuity measures

Regulatory requirements are coming in to force for Whole Vehicle Type Approval (WVTA), in the form of Regulation 138[24]. This requires:

- From September 2019 all new bus models (new designs requiring type approval) in vehicle category M2 or M3 and fitted with either a hybrid (HEV), pure electric (PEV), electrified vehicle (EV), fuel cell vehicle (FCV) or a fuel cell hybrid vehicle (FCHV) drivetrain will be subject to having acoustic conspicuity measures installed.
- From September 2022 all new registered buses with drivetrains listed above will also be subject to having acoustic conspicuity measures installed.

TfL are requiring that all its new buses meet Regulation 138 from 2019, whether they go through WVTA or National Small Series Type Approval (NSSTA) or Individual Vehicle Approval (IVA).

TfL requires all new buses to have an Acoustic Vehicle Alerting System (AVAS) installed in accordance with Regulation 138. In particular the AVAS shall additionally meet some extra requirements, mainly around ability to emit the urban bus sound being designed by TfL, and that the noise should be updatable in the future.

2.2 Acoustic Conspicuity measure

2.2.1 AVAS (Acoustic Vehicle Alerting System)

[24] UN ECE Regulation 138; Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility.

A solution has been defined as 'added sound'; or what is currently referred to as an AVAS (Acoustic Vehicle Alerting System). This is an audible warning, active at low speed, indicating steady state, acceleration and deceleration conditions. Currently, systems are only active at speeds between 0 km/h to 30 km/h inclusive (the maximum speed within Europe is 20 km/h and 30 km/h for the US only), and are intended to replace engine noise cues to pedestrians and vulnerable road users (VRUs) that a vehicle is approaching.

A two channel AVAS should be selected; this will enable the sound sources to provide a fuller directional component towards the kerbside. The sound sources should be installed at the front of the bus (see specification for details of source height and direction). This should also be done in conjunction with the manufacturer of the AVAS equipment

Any AVAS chosen should be compliant with UNECE Regulation 138 (Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility - QRTV). Regulation 138 lays out the requirements for the minimum sound and defines the testing protocol. This document can be found at the following web address:
www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2017/R138r1e.pdf

Thought will need to be given to the actual sound generated by the AVAS, as it is a balance between brand signature, enhancing detection and reducing environmental noise. Therefore, consultation with TfL is advised during the process of specifying any AVAS equipment.

TfL will be developing an urban bus sound for use on all buses across London. Partners are invited to collaborate on the development of this sound. The purpose is to minimise any risk of confusion that might arise if different bus models had different sounds. The sound will be made available to other urban areas and its use will not be restricted to London.

3 Training

Once AVAS equipment is installed, there should be very little training required as the system is automatic and will operate between set speeds and adjust the sound for acceleration and deceleration via inputs from the CAN-Bus. However, individual manufacturers of the equipment will advise if any training is required.

4 Maintenance

Once AVAS equipment is installed, there should be minimal maintenance required. However, as the system will be fitted within the front of the bus, regular inspection of the sound sources is recommended to keep them free of debris and to ensure that no damage has occurred.

Individual manufacturers of the equipment will advise if and what maintenance is required and will specify maintenance intervals.

5 Repair

Any repairs that are required to the AVAS will need to be done in conjunction with the manufacturer of the equipment.

Attachment 32: Slip Protection Assessment Protocol

1 Introduction

This document presents a procedure for the characterisation of the slip resistance properties of flooring materials for buses.

1.1 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, Class II.

1.2 Purpose

The purpose of this assessment is to characterise the slip risk associated with bus flooring materials by measuring and assessing the slip resistance of those materials. This is achieved by using a method adapted from the United Kingdom Slip Resistance Group (UKSRG) guidelines (The UK Slip Resistance Group, 2016) which uses the Portable Slip Resistance Tester (PSRT) as the measurement device.

2 Normative References

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

British Standards Institution. (2002). *BS 7976-2:2002 Pendulum testers - Part 2: Method of operation.* London: BSi.

British Standards Institution. (2011). *BS EN 13036-4. Road and airfield surface characteristics. Test methods. Method for measurement of slip/skid resistance of a surface. The pendulum test.* London: BSi.

British Standards Institution. (2013). *BS 7976-1:2002+A1:2013 Pendum testers - Part 1: Specification.* London: BSi.

British Standards Institution. (2013). *BS 7976-3:2002+A1:2013 Pendulum testers - method of calibration.* London: BSi.

The UK Slip Resistance Group. (2016). *The assessment of floor slip resistance - The UK slip resistance group guidelines.* UKSRG.

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3 Definitions

For the purpose of this Protocol:

- **Approval Authority –** 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.
- **IHRD: International Rubber Hardness Degrees –** method for measuring the hardness of rubber.
- **PSRT: Portable Slip Resistance Tester –** standard laboratory testing device for measuring slip resistance in the UK, defined by British Standards.
- **PTV: Pendulum Test Value –** measurement recorded by the PSRT
- **UKAS: United Kingdom Accreditation Service –** the UK's national accreditation body**.**
- **UKSRG: United Kingdom Slip Resistance Group –** independent authority of slip resistance.
- **Test Service –** The organisation undertaking the testing and certifying the results to the Approval Authority**.**
- **VUT: Vehicle Under Test –** means a vehicle that is being tested to this protocol.

4 Test equipment and conditions

4.1 Test equipment

4.1.1 The measurement device used in this protocol is the PSRT as defined by the following British Standards:

- BS 7976-1:2002+A1:2013 (British Standards Institution, 2013)
- BS 7976-2:2002 (British Standards Institution, 2002)
- BS 7976-1:2003+A1:2013 (British Standards Institution, 2013)

4.2 Test conditions

4.2.1 All tests shall be completed in a test environment where the temperature is between 5°C to 40°C. This requirement is in addition to UKSRG guidelines (The UK Slip Resistance Group, 2016))

4.2.2 Tests shall only be made under wet conditions. This requirement supersedes Section 3.6 of the UKSRG guidelines (The UK Slip Resistance Group, 2016))

5 Test procedure

5.1 Apply the UKSRG guidelines for measuring slip resistance using the PSRT, with the following amendments:

5.2 Test shall be carried out in a test environment with a temperature range of 5°C to 40°C. (Addition to UKSRG guidelines (The UK Slip Resistance Group, 2016))

5.3 Tests shall only be made under wet conditions. (Supersedes Section 3.6 of the UKSRG guidelines (The UK Slip Resistance Group, 2016))

5.4 During one test sequence, repeat measurements shall be made until the difference between the smallest and largest of five consecutive measurements is less than or equal to 3 (i.e. $PTV_{Max}-PTV_{MIN} \leq 3$). The mean of these 5 consecutive measurements is the average PTV.(Supersedes Section 3.6, Point 9 and 10 of the UKSRG guidelines (The UK Slip Resistance Group, 2016)).

5.5 For each test specimen, sequence of tests shall be completed for each of the following directions, note 0° is defined as the main direction of travel of passengers:

a) 0°;

b) 45°; and

c) 90°

5.6 For clarity, Table 1 shows a test matrix that defines the minimum testing requirement.

Test sequence / location	**Test direction (degrees)**	**PTV for test number:**										**Mean PTV**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**…**	**n**	
1	0											
	45											
	90											
2	0											
	45											
	90											
3	0											
	45											
	90											
…	0											
	45											
	90											
X	0											
	45											
	90											

Table 42: Example test matrix for supplied specimens

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6 Assessment of results

6.1 For all test sequences / locations the mean Pendulum Test Values (PTV) measured in all directions shall exceed the minimum values required. These are detailed in the London Bus technical specification document available from TfL.

7 Test report

7.1 The Test Service shall provide a comprehensive test report which contains UKAS test certificates for testing performed and presents the following:

a) Test conditions;

b) Mean PTV;

c) The number of passengers transported by the vehicle at each assessment stage;

d) The amount of time that the flooring material type was in service for at each assessment stage.

e) Slip potential characterisation; and

f) Reference information:

   i. Material type being assessed;

   ii. The vehicle details on which the assessed material was installed.

or London
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Attachment 33: Slip Protection Guidance Notes

1 Introduction

This document sets out the guidance notes related to flooring materials. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

Slip resistance testing should be carried out on all bus flooring materials in an as-new condition. The test protocol should be followed for the characterisation and acceptance of materials.

3 Training

Slip resistance testing should be carried out by a United Kingdom Accreditation Service (UKAS) accredited operator. Training may be provided by UKAS or another suitable training body if required.

Training for flooring installation should be provided by the flooring supplier.

4 Certification of flooring materials

Flooring material types[25] fitted to buses shall be supplied with a certification documentation pack that the slip resistance performance required by the 'London Bus Technical Specification' is met. The performance required is:

- At installation i.e. "as new", a PTV of least 36.
- After 100,000 persons have accessed the material, or after 6 months in service, whichever is sooner, a PTV of at least 40.
- Thereafter, for a period of 7 years from new, a PTV of at least 40, (based on an annual assessment).

[25] For the purposes of this document a flooring material type is considered as materials that share the same trade name and are constructed from using the same component parts and manufacturing processes.

Assessment of the skid resistance of the materials must be carried out in accordance with the test protocol. The assessment of materials must be carried by persons accredited by the United Kingdom Accreditation Service (UKAS) for the operation of the Portable Skid Resistance Tested (PSRT). This includes individuals working for the material manufacturer, bus manufacturer, bus operator or third party test house.

The certification of materials should, where appropriate take into account possible variations in material performance between manufactured batches. This may require the assessment of materials installed in a number of different vehicles.

For a material to be certified for use documentary evidence of the performance of flooring material types should be submitted in the form of (United Kingdom Accreditation Service) UKAS certificates which present as a minimum:

- The material type being assessed
- The vehicle details on which the assessed material was installed,
- The PTV of the material at each assessment stage,
- The number of passengers transported by the vehicle at each assessment stage,
- The amount of time that the flooring material type was in service for at each assessment stage.

This certification documentation pack should be based on one of the following options depending on whether the material is an existing or new material:

- Performance measured on in-service buses, for ‘existing’ materials
- Performance measured on in-service buses, for ‘new’ materials
- Performance measured in the laboratory, for ‘existing’ or ‘new’ materials

Each of these options is described in more detail below.

4.1 Performance measured on in-service buses, for ‘existing’ materials

Existing flooring materials may be certified by assessing the performance of those materials on currently in-service buses. For certification to be achieved the performance of the materials should be assessed on flooring materials meeting the temporal requirements specified in the specification document. Evidence for the certification of materials in this way could therefore be gathered quickly assuming that materials of the requisite ages could be identified.

4.2 Performance measured on in-service buses, for ‘new’ materials

If the option to certify new materials through laboratory testing is not invoked then new materials may also be assessed on in-service buses as per section 4.1. In this case the performance of the material, following its installation, must be reported at each assessment stage and the material replaced if the measurements of PTV at any of the assessments falls below the threshold stated in the specification. It would be expected that the floor material manufacturer would bear the costs of replacing the material.

4.3 Performance measured in the laboratory, for 'new' or 'existing' materials

Ideally the assessment of materials will be carried out on in-service vehicles which meet the requirements of the specification. However, to encourage innovation, laboratory accelerated wear protocols may also be used to simulate the amount of footfall experienced by the flooring materials at the required intervals. If this option is invoked then additional evidence showing a strong correlation between the accelerated wear test, and in-service wear must be presented. This correlation should be demonstrated by showing the change in slip resistance as a result of wear testing with that of in-service wear on buses for typical bus flooring materials.

5 Replacement or repair of flooring materials

5.1 Inspection

The bus flooring material shall be inspected using the standard intervals and protocols specific to the bus operating company. It is recommended however that inspections are carried out every 5 - 7 years'. The flooring material shall be visually inspected for any obvious defects following the standard inspection regimes used by the bus operating company and areas containing defects (as defined by the operating companies inspection regime) noted.

5.2 Replacement

If defects are identified the affected section of the surface should be completely replaced with one characterised as providing a low slip potential and the appropriate wear resistance (as defined in the test protocol). A section of the surface is defined as an area of the surface which can be independently defined by its use. For example, a bus may consist of the following surfacing sections:

- Entrance ways,
- Aisles,
- Stairwells and landings,
- Seating areas,
- Disabled reservation areas,
- Etc…

If therefore a defect was identified in the aisle of a bus, then the entire width of flooring between the seats should be replaced.

Persons replacing bus flooring materials should be trained and competent to do so. The manufacturer's installation instructions should be followed precisely when replacing materials and, if available, training by the material manufacturer should be given. Particular care should be taken when welding material joints in order to protect the underlying materials.

5.3 Inspection and repair of the underlying materials

After the removal of defective material (and the surrounding area), the underlying materials should be inspected for damage and repaired as necessary. Conducting repairs at this stage will lengthen the life of the flooring materials and the bus.

6 Cleaning of bus flooring materials

The selection of bus flooring materials should take into account their cleaning and maintenance procedures. It is advised that materials with high levels of texture, or materials that are very coarse are not used. These materials are likely to provide high levels of PTV but will also be very hard to clean and could trap dirt and contaminants that could ultimate reduce their PTV characteristics.

Bus flooring materials should be cleaned regularly following the manufacturers recommended procedures. In cases where there are no manufacturer recommended procedures the following should be carried out:

1. Daily:
    a. Vacuum the surface to remove dust and debris,
    b. Use a mop to clean floor with clean water and a 2-5% neutral detergent solute as per manufacturer's instructions,
    c. Rinse surface with a thoroughly cleaned mop and clean water to remove detergent residue.
    d. Vacuum dry.
2. Once per month or after heavy soilage:
    a. Vacuum the surface to remove dust and debris,
    b. Scrub grease or oil spots only with a medium stiff bristled hand brush, rotocleaner or dingle brush machine with alkaline detergent
    c. Use a mop to clean floor with clean water and a 2-5% neutral detergent solute as per manufacturer's instructions,
    d. Rinse surface with copious amounts of clean water using a thoroughly cleaned mop to remove detergent residue.
    e. Vacuum dry.
3. Never:
    a. Use an electric scrubber with abrasive discs,
    b. Use solvents,
    c. Use industrial stain removers without first testing on a discrete area out of natural corridors,
    d. Leave detergent residue on the floor,
    e. Apply any surface treatment,
    f. Use high pressure devices,
    g. Place any form of rubber on the flooring.

7 Considerations of flooring colouring and patterns

It should be noted that the use of darker colours for bus floorings is preferential to lighter colours as dirt and detritus is less contrasting with darker colours and so is less visible.

There is a potential that flooring which is reflective or has reflective elements can look “sparkly” or “shiny”. There is the potential for some bus passengers to sub-consciously associate these features with flooring that is wet and therefore slippery. In these cases it is likely that these users will adjust their gait to compensate for the perceived lack of slip resistance. This is undesirable as it increases the risk to the passenger who may become off balanced or even fall as a result. With this in mind the use of materials with a matt hue are preferred to those with satin or gloss hues.

Attachment 34: Occupant Friendly Interiors Assessment Protocol

1 Introduction

This document presents a protocol for:

- The inspection of a bus interior to identify potential injury hazards; and
- The assessment and rating of hazards identified.

The categories of potential hazards included in this protocol are:

- Handrails;
- Restraints – partitions and inadequately constrained seated passengers; and
- General/other hazards, such as sharp corners and protrusions.

1.1 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 in the Consolidated Resolution on the Construction of Vehicles (R.E.3) as M_3; Class I, Class II.

1.2 Purpose

The purpose of this assessment is to identify potential injury hazards present in the vehicle design. The protocol assesses and rates the identified hazards with the objective of encouraging safer vehicle designs, with minimal constraints for the vehicle designers. The protocol has been written to enable assessment using drawings or CAD models of the vehicle at the design stage.

2 Definitions

For the purpose of this Protocol:

- **3D:** Three dimensional, components in the x, y and z axes.
- **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.
- **Computer-Aided Design (CAD):** The use of computer systems to aid in the creation, modification, analysis, or optimization of a design.
- **Floor:** Vehicle floor where a passenger's feet will rest when seated or standing.
- **Head impact zone:** Height range in which a standing or seated passenger's is usually positioned.
- **'High occupancy / PRM' seats:** Seats with high occupancy rate and / or used by Persons with Reduced Mobility (PRM)—These seats include nominated priority / preferential seats, all seats on the main floor level and any seats immediately adjacent to a door. "Immediately adjacent to a door" means any seat in a row of seats near a door, even if only accessible via a step. Example of these seats behind the middle doors and wheelchair area with step to access are shown below.

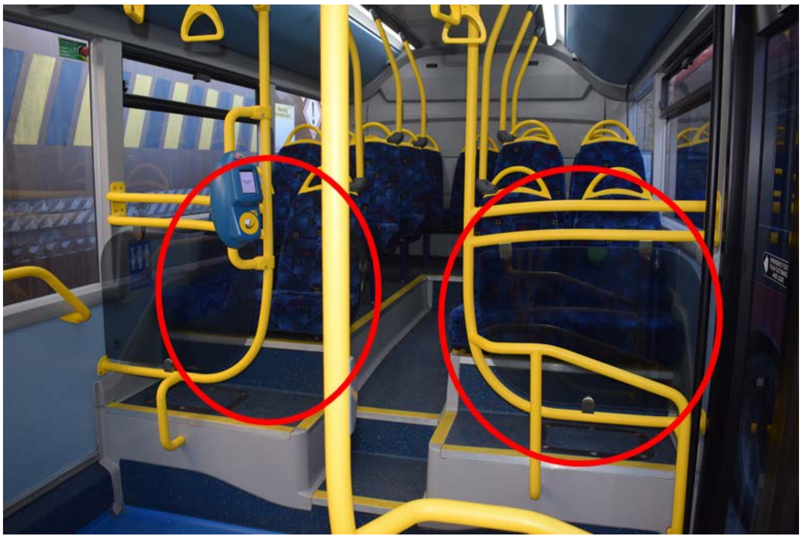

Figure 44: Examples of seats with high occupancy rate immediately adjacent to a door and only accessible via a step.

- **Partition-like structure**: Note that a partition like structure is defined as a continuous structure with apertures no greater than 50 mm and a lower edge not more than 100 mm above the floor where the passenger's feet rest.
- **Passenger trajectory plane (PTP)**: vertical plane extending from the longitudinal centre of each box within the vertical handrail assessment space envelope to the vertical centreline of the primary handrail

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- **Position line (PL)**: Line representing a position from which a passenger could leave the confines of the box within the space envelope while being thrown towards the handrail
- **Primary handrail**: The handrail being assessed
- **Secondary handrail**: A handrail that can be used by a passenger to prevent a collision with the primary handrail.
- **Test Service:** The organisation undertaking the testing and certifying the results to the Approval Authority
- **Vehicle Manufacturer:** the business responsible for the manufacture of the bus being assessed.
- **Vehicle under Test (VuT)**: means the vehicle assessed according to this protocol.

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3 Test conditions

This protocol has been developed to be applied during the design of buses. This protocol shall be applied to CAD models or drawings of the VuT.

4 Test preparation

4.1 The following assessment envelopes/zones shall be defined by the Test Service in a universally compatible 3D CAD format e.g. .IGES or .STEP.

4.1.1 Standing passenger vertical handrail assessment space envelope. A plan view of the envelope is shown in Figure 45. The envelope shall extend from the ground plane of the VuT to a height of 1870mm. The ground plane of the space envelope shall follow the profile of the vehicle floor.

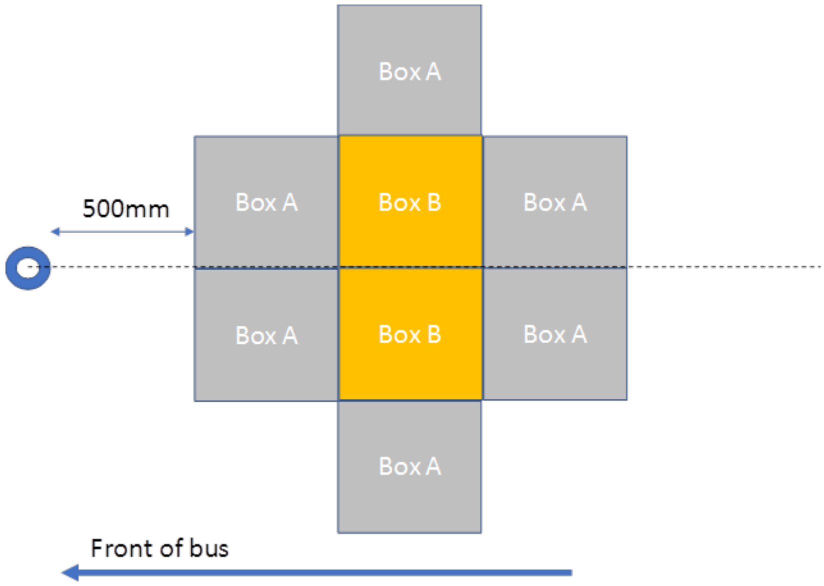

Figure 45: Plan view of the vertical handrail assessment space envelope.

4.1.2 Seated passenger handrail assessment zone. A side view of this zone relative to the seat being assessed is shown in Figure 46. The zone shall extend for the width of the seat being assessed.

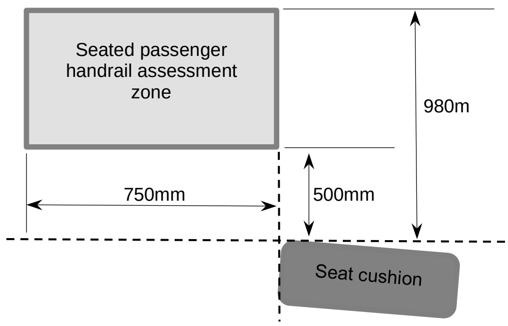

Figure 46: Side view of seated passenger handrail assessment zone

5 Test procedure

5.1 Standing passengers

5.1.1 This test only applies to the lower deck of the VuT on the basis that standing (for substantial periods) is prohibited on the upper deck.

5.1.2 Handrails

5.1.2.1 This procedure considers vertical and horizontal handrails separately.

5.1.2.2 Vertical handrails

5.1.2.2.1 A vertical handrail is a vertical structure which passes through two horizontal planes; 1310 mm and 1870 mm above the floor of the VuT at the location where the structure is installed. The diameter or width of the vertical structure in the vehicle's lateral plane shall be less than 45 mm. Attachments to the hand rails such as Oyster Card readers shall not be included in the definition of the structures diameter/width. All vertical handrails shall be identified.

5.1.2.2.2 Apply the Vertical Handrail Assessment Space Envelope to each of the vertical handrails identified. The centre of the handrail being assessed is the reference point for the template.

5.1.2.2.3 Identify the boxes in which a passenger is likely to stand by applying the following criteria:

5.1.2.2.4 Identify encroaching structures for each of the boxes within the space envelope.

5.1.2.2.5 There shall be at least space to fit a circle of 250 mm diameter touching the edge of the box that does not have any permanent structure encroaching within it for the box to be assessed that a passenger is likely to stand in it.

5.1.2.2.6 Determine if a passenger has an unobstructed path from a box to fall against the primary handrail. There shall be an unobstructed corridor at least 250 mm wide from the box to the primary handrail, defined using the following method:

a) Along the forward edge of the box, draw three position lines (PL) each 250 mm long, one from each of two box corners to the edge's centre point, and one with the edge's centre point at its mid-point (see Figure 47 top picture lines in black, blue and red).

b) For each PL, draw potential trajectory corridors by extending a vertical plane from each end of the position line to the edge of the handrail (so that the edge of the handrail is just touching the boundary of each corridor). The plane extending from the end of the PL farthest away from the primary handrail shall contact the handrail at the farthest point and the plane extending from the end of the PL nearest the handrail shall contact the handrail at its nearest point. Add two other planes parallel to each of these lines as illustrated in Figure 47 bottom picture. When complete this will give 6 corridors; two corridors for each PL.

5.1.2.2.7 If one or more of these corridors does not have a structure encroaching into it (at a height less than 1870 mm above bus floor level), it is deemed that a passenger has an unobstructed path to the primary handrail. Note that structures less than 300 mm from the primary handrail which do not shield it completely in the head impact zone (1420 mm to 1755 mm above bus floor) should not be counted as obstructions.

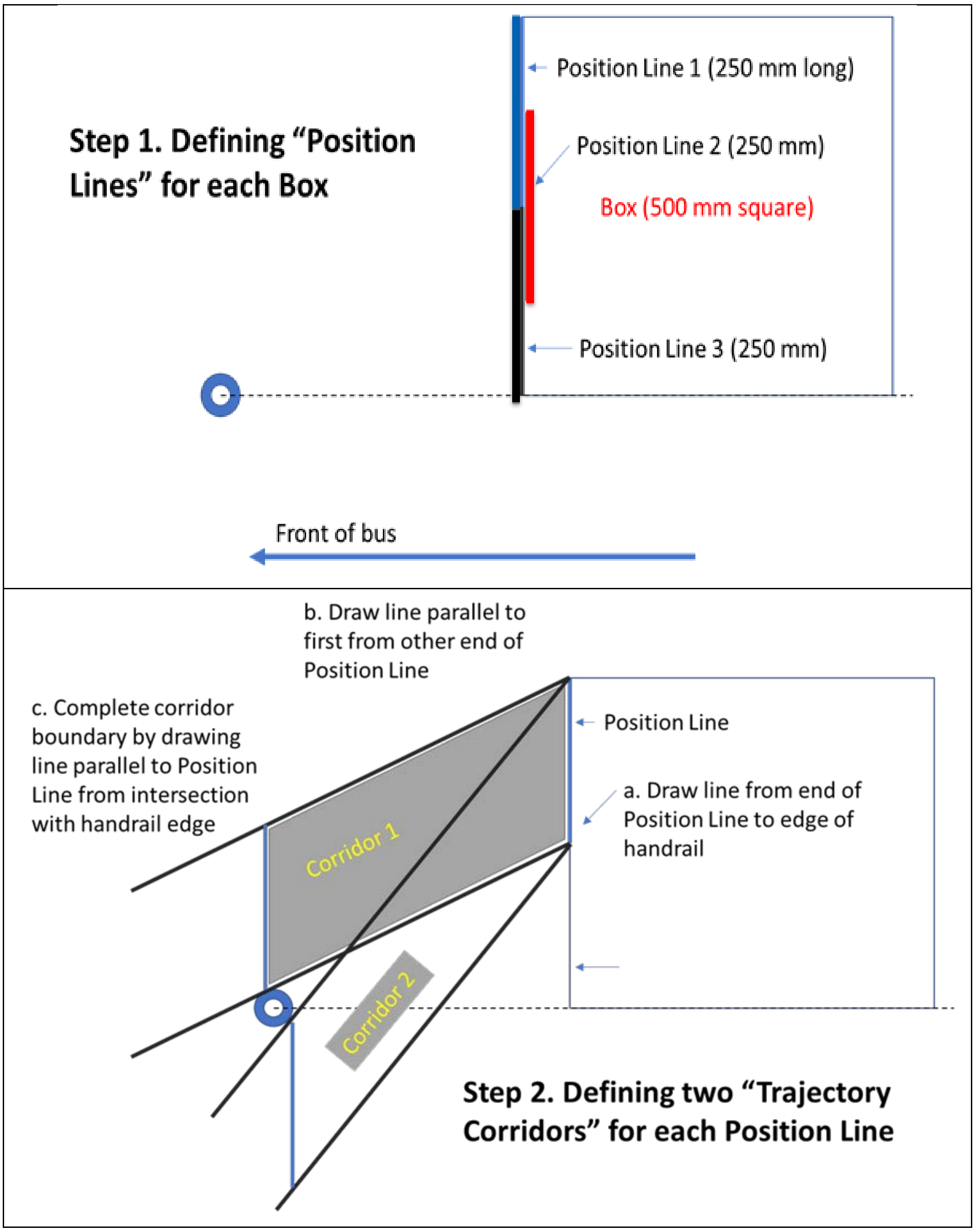

Figure 47: Procedure to assess presence of unobstructed corridor to vertical handrail.

5.1.2.2.8 Determine whether passengers have an opportunity to grab another handrail (secondary handrail) to prevent a collision with the primary handrail using the following method:

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a) The Passenger Trajectory Plane (PTP) shall be drawn from the centre of the front of each box to the centre of the primary handrail.

b) A secondary handrail is defined as one positioned at least 500 mm longitudinally from the primary handrail and within a corridor extending 250 mm either side of the PTP.

5.1.2.2.9 Figure 48 shows an example of a seat back handrail (secondary handrail) positioned to give an opportunity to a passenger standing in the indicated boxes to prevent a collision with the primary handrail.

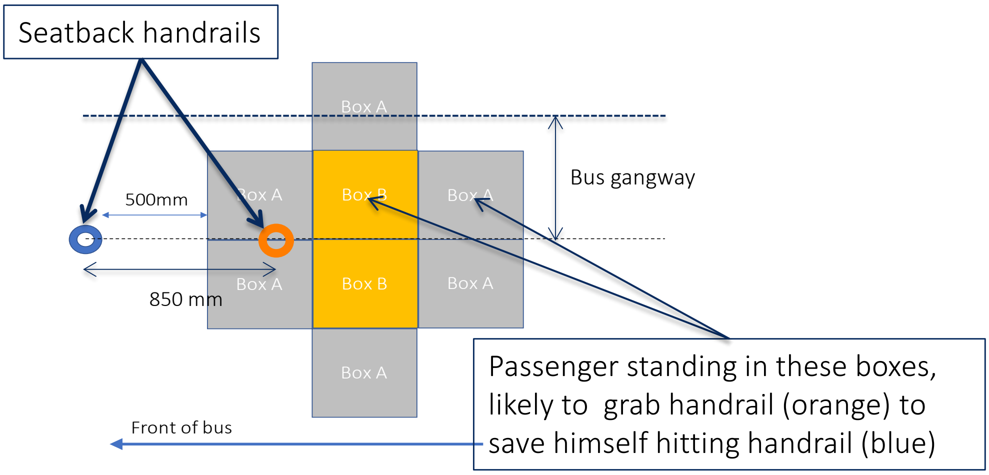

Figure 48: Example of a seat back handrail positioned to give standing passenger opportunity to prevent a collision with the primary handrail.

5.1.2.3 Horizontal handrails

5.1.2.3.10 All horizontal handrails shall be identified.

5.1.2.3.11 The height of the middle of each handrail above the bus floor shall be measured. The length of each handrail shall also be measured.

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5.1.3 Restraint

5.1.3.1 Partitions that a passenger can stand behind shall be identified. These are defined as partitions which have a space extending at least 500 mm rearward across the width of the partition and to a height of 1870 mm.

5.1.3.2 The width of the partitions identified shall be measured.

5.1.3.3 For partitions with a width greater than 500 mm, the height of the partition above the VuT floor shall be measured:

5.1.3.4 Where the partition consists of more than one structure, the height of the highest structure shall be measured, e.g. the height of the seat backs for the partition illustrated in Figure 49.

5.1.3.5 Where the height of the partition above the floor varies, an average height shall be measured.

Figure 49: Example of partition consisting of multiple structures

5.1.4 General/other hazards

5.1.4.1 General hazards meeting the following criteria shall be identified:

a) Within the head impact zone – features with a shore hardness[26] rating greater than 60 with a radius less than 20mm.

b) Outside the head impact zone – features with a shore hardness rating greater than 60 with a radius less than 5mm.

5.1.4.2 Examples include step corners, corners of Passenger Information Systems (PIS) and ceiling mounted mirrors which are mounted within the head impact zone (Figure 50).

5.1.4.3 Items that move when impacted such as grab handles on straps attached to structures above 1870mm from the VuT floor shall not be identified as a hazard.

[26] Shore hardness is *defined* as a material's resistance to indentation when a static load is applied.

Figure 50: Examples of general hazards for standing passengers, corner of step (left) and mirror in head impact zone (right).

5.2 Seated passengers

5.2.1 The assessment shall be completed for both the lower and upper decks for forward facing seats.

5.2.2 Handrails

5.2.2.1 Identify handrails positioned within the seated passenger handrail assessment zone. Examples of handrails in this zone are shown in Figure 51. Handrails can be vertical or horizontal.

5.2.2.2 For each of the handrails identified, take the following measurements relative to the longitudinal centreline of the seat:

a) Lateral (y-axis) distance from boundary (edge) of the handrail nearest to the seat centreline to the outer edge of the seat (d).

b) The maximum width of the seat (w).

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5.2.2.3 Identify whether or not the handrails assessed are associated with ‘high occupancy / PRM’ seats.

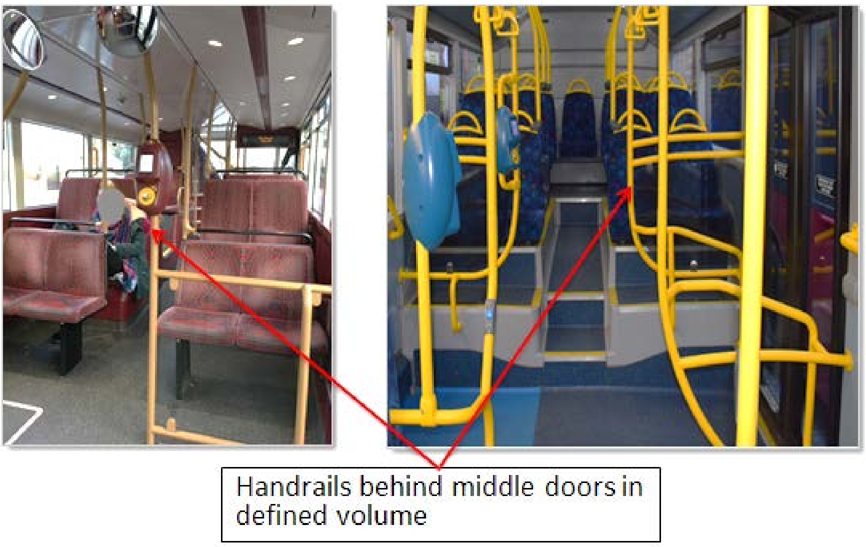

Figure 51: Examples of handrails positioned behind middle doors in trajectory of seated occupant that shall be identified for further assessment.

5.2.3 **Restraint**

5.2.3.1 For each seat, identify the level of restraint present using the following categories:

a) No partition-like structure or other seats in front;

b) Bay seat arrangement; or

c) Some structure within a longitudinal distance of 1200 mm from seat back.

5.2.3.2 Where a seat has some structure in front of it, take the following measurements;

a) The average height above the floor on which the passenger’s feet rest for the seating position being assessed.

b) The maximum width of the seat (w).

c) Define effective seat width (we) as 75% of the maximum width positioned around the seat centreline. Project edges of effective seat width longitudinally forward to restraint structure. Measure effective seat width not covered by restraint structure (d). See Figure 58.

5.2.3.3 Identify whether or not the restraints assessed are associated with PRM seats.

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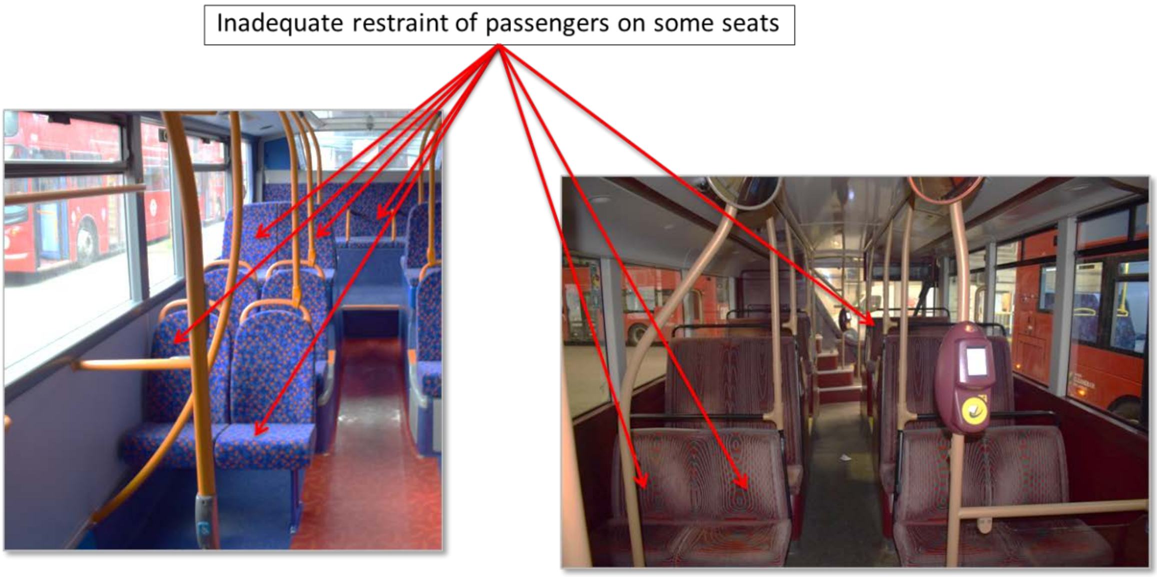

Figure 52: Examples of seats where there is inadequate restraint of seated passengers.

5.2.4 General hazards

5.2.4.1 Hazards meeting the following criteria shall be identified:

a) Within the head impact zone – features with a shore hardness[27] rating greater than 60 with a radius less than 20mm.

b) Outside the head impact zone – features with a shore hardness rating greater than 60 with a radius less than 5mm.

5.2.4.2 Examples include bolt heads, corners of Passenger Information Systems (PIS) and luggage racks which are mounted within the head impact zone (Figure 53). Note the full height glass partition in front of seated passenger is considered a hazard because it is likely to cause a head injury to a passenger if impacted and the risk of an impact is high.

[27] Shore hardness is *defined* as a material's resistance to indentation when a static load is applied.

Protruding bolt heads in lower body impact area:

Injury potential – low

Risk of impact - low

Sharp corner on PIS in head impact area:

Injury potential – high

Risk of impact - low

Luggage rack rail behind rear facing seats in head impact zone:

Injury potential – high

Risk of impact - high

Full height glass partition in front of forward facing seats covering head impact zone:

Injury potential – high

Risk of impact - high

Figure 53: Examples of general hazards for seated passengers

6 Assessment of results

6.1 Standing passengers

6.1.1 Handrails

6.1.1.1 Vertical

6.1.1.1.1 The boxes in the assessment template are scored as follows:

a) A score of 0.1 is given for each Box A that a passenger could stand in and which:

i. Has an unobstructed path to the handrail; and

ii. Presents no opportunity for the passenger to grab a secondary handrail.

iii. If any of these criteria are not met, the box is scored 0.

b) A score of 0.2 is given for each Box B that a passenger could stand in and which:

i. Has an unobstructed path to the handrail; and

ii. Presents no opportunity for the passenger to grab a secondary handrail.

iii. If any of these criteria are not met, the box is scored 0.

c) This results in maximum score of 1 for a handrail.

6.1.1.1.2 In the following situations this score is factored:

a) In the case that a handrail does not have a length of 560 mm between the lower boundary of 1310 mm and upper boundary of 1870 mm, e.g. it is not vertical. In this case the length of the handrail projected into the Y plane (i.e. plane transverse across the bus) should be measured and a factor of (handrail length)/560 applied.

b) In the case of handrails that curve away behind an obstruction (e.g. going further behind a row of seats), only those parts of the handrail within 250 mm of a longitudinal of the obstructing structure’s outermost edge shall be considered within the zone. The length of handrail within the zone shall be measured and a factor of (handrail length)/560 applied.

6.1.1.2 Horizontal

6.1.1.2.3 Using the data collected, each handrail shall be assessed as follows:

a) For handrail height below 1130 mm score 0.

b) For handrail height greater than 1130 mm and less than 1420 mm, linearly score between 0 and 1 by application of formula below:

c) Score = (‘handrail height (mm)’ – 1130 mm)/(1420 mm – 1130 mm)

d) For handrail height greater than 1420 mm and less than 1755 mm, score 1

e) For handrail height greater than 1755 mm and less than 1870 mm, linearly score between 1 and 0 by application of formula below:

f) Score = (1870 mm - ‘handrail height (mm)’)/(1870 mm – 1755 mm)

g) For handrail height above 1870 mm score 0.

Figure 54: Illustration of assessment for horizontal handrail based on its height above the bus floor.

6.1.1.2.4 The score for each handrail shall be factored per 500 mm length by application of the formula below:

Score = (‘handrail score’)*(handrail length mm)/500 mm

6.1.2 Restraint

6.1.2.1 The partition is scored based on its height and width as below:

a) ‘Partition height’ less than 770 mm score 1

b) ‘Partition height’ greater than 770 mm and less than 1060 mm apply formula below:

Score = (1060 mm - ‘Partition height (mm)’)/290 mm) * (‘Partition length (mm)’/500 mm)

c) Partition height greater than 1060 mm score 0

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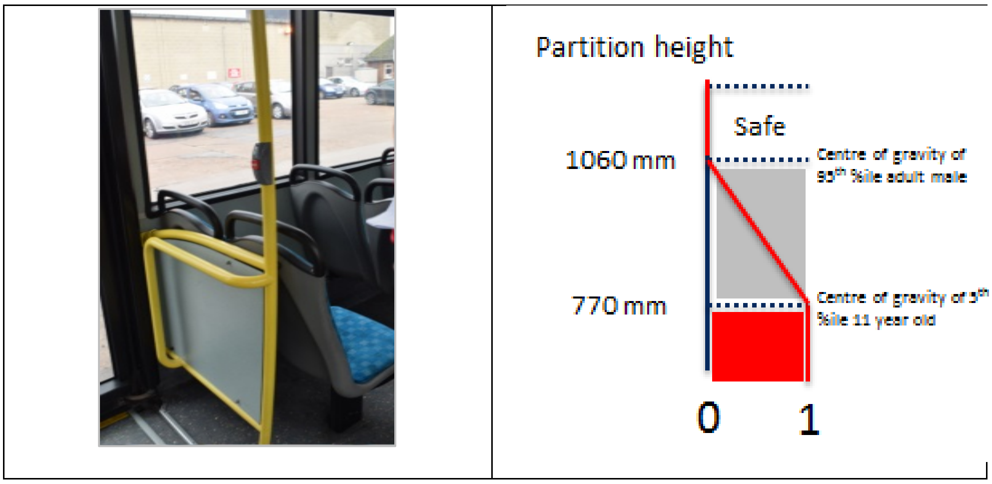

Figure 55: Illustration of assessment of restraint (partitions) for standing passengers.

6.1.2.2 The score for each partition shall be factored per 500 mm length by application of the formula below:

Score = (‘Partition score’)*(partition length mm)/500 mm

6.1.3 General/other hazards

6.1.3.1 A score of 1 shall be given to any such hazard identified, or group of such hazards if they fall within the area of a 100 mm sided square area.

6.1.4 Weighting of hazards for standing passengers

6.1.4.1 The following weightings shall be applied to the scores for standing passengers:

a) Handrails – multiply by 5

b) Restraint – multiply by 4

c) General / other hazards – multiply by 3

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6.2 Seated passengers

6.2.1 Handrails

6.2.2 The handrail shall be scored as illustrated in Figure 56 as follows:

a) If distance (d) from the edge of the rail closest to the seat centre to the outer edge of the seat in the vehicles y-axis is less than 100 mm, handrail scores 0;

b) If distance (d) from the edge of the rail closest to the seat centre to the outer edge of the seat in the vehicles y-axis is greater than (half the seat width (w/2) – 90 mm), handrail scores 1; and

c) For distances in between those defined above, use the formula below to calculate a score between 0 and 1:

$$\text{Score} = (d - 100\text{ mm})/(w/2 - 190\text{ mm})$$

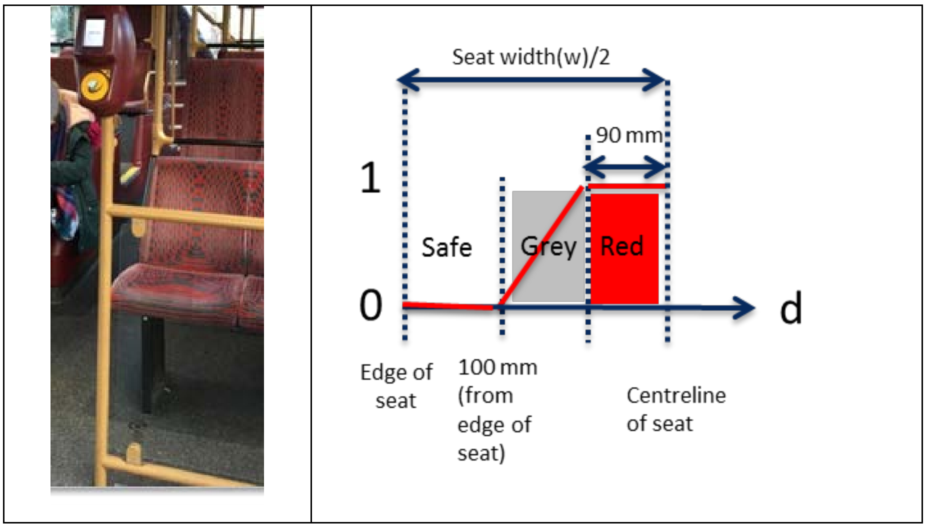

Figure 56: Procedure for assessment for handrails identified as a potential hazard for seated occupants.

6.2.3 **Restraint**

6.2.3.1 The seats identified shall be assessed as follows:

a) Seats with no or little structure in front of them (i.e. no partition like structure or other seats) shall be scored 1;

b) Bay seat arrangements shall be scored 0.75;

c) Seats with some structure (partition line structure or other seats) in front of them shall be assessed as follows;

i. The proportion of the effective seat width projected forward not covered by the restraint structure shall be calculated using the formula below (see Figure 58):

ii. Proportion not covered (Pwe) = ‘distance not covered in mm’ (d) / ‘Effective seat width mm’ (we)

iii. If the height of the structure is 800 mm or greater, score (1*Pwe).

iv. If the height of the structure is 700 mm or less, the structure’s height is in red zone, score 1.

v. If height of structure is between 700 mm and 800 mm, the formula below shall be applied to calculate score between 0 and 1:

Score = (P_{we})+(800 mm - Structure’s height mm)/100 mm

Note: Scores calculated to be greater than 1 should be capped at 1.

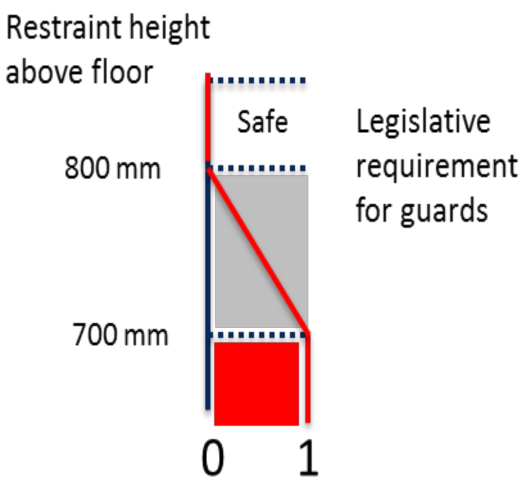

Figure 57: Illustration of safe, grey and red zones for height of restraint assessment.

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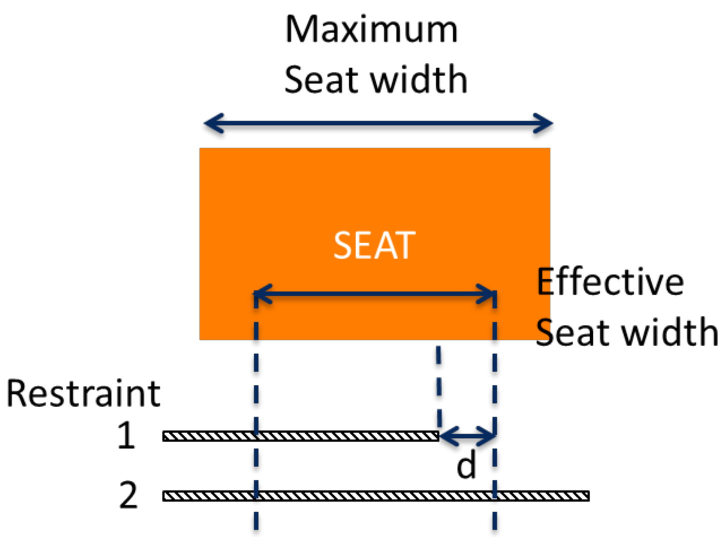

Figure 58: Illustration of effective seat width not covered by restraint structure, distance d for Restraint No 1, all covered by Restraint No 2, i.e. d = 0.

6.2.4 **General/other hazards**

6.2.4.1 For each seat position, an assessment of the injury potential and risk of impact shall be made for the hazards identified and a score of up to 1.0 given, in accordance with the following criteria:

a) Injury potential:
   i. For head impact categorise as high
   ii. For impact of other body regions categorise as low
b) Risk of impact:
   iii. For small sized hazard such as single bolt head (or single group of hazards within 100 mm of each other) categorise as low
   iv. For hazard covering area likely to be impacted by body region e.g. multiple small sized hazards (e.g. > 4) or single hazard covering area in good alignment with head trajectory categorise as high
c) Score:
   v. Injury potential low, risk of impact low; score 0.3
   vi. Injury potential high, risk of impact low and vice versa; score 0.6
   vii. Injury potential high, risk of impact high; score 1.0

6.2.5 **Weighting of hazards for seated passengers**

6.2.5.1 The following weightings shall be applied to hazards not associated with ‘high occupancy / PRM’ seats:

a) Handrails – multiply by 5
b) Restraint – multiply by 4
c) General / other hazards – multiply by 4

6.2.5.2 For ‘High occupancy / PRM’ seats, the following weighting shall be applied:

a) Handrails – multiply by 10
b) Restraint – multiply by 8
c) General / other hazards – multiply by 8

7 Assessment template

7.1 Each of the scores shall be entered into an assessment template made up of the tables shown in Appendix 1: Assessment Template.

7.2 The Total Actual Score is the sum of the weighted score for each assessment section, which are highlighted yellow. A separate value shall be calculated for the lower saloon, the upper saloon and the vehicle as a whole.

8 Normalising the score

8.1 The basic score system above produces a higher score the greater the number of hazards identified and, theoretically, there is no upper limit to the score. Ideally the score would be zero with no identified hazards.

8.2 In order to incorporate the interiors score within an overall bus safety score, it is necessary to ‘normalise’ this score to a value between 0% and 100%, where 0% represents the worst vehicles and 100% the best.

8.3 In order to do this a maximum points ceiling shall be set at 120 points for the lower saloon and 12 points for the upper saloon. Thus the overall maximum points is 120 points for a single deck vehicle and 132 points for a double deck vehicle.

8.4 A Total Limited Score shall be defined for the lower saloon, the upper saloon and the vehicle as a whole and shall be the lesser of the Total Actual Score and the Maximum score.

8.5 The Normalised Score for lower saloon, upper saloon and whole vehicle shall be calculated according to the formula 1-(Total Limited Score/Maximum Score) and expressed as a percentage.

9 Test report

9.1 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) Confirmation of protocol compliance; and

b) Reference information.

9.2 To confirm protocol compliance, the Test Service shall include in the report the completed Occupant Friendly Interiors Assessment worksheet

9.3 The reference information required includes as a minimum:

a) Vehicle make;

b) Vehicle model;

c) Vehicle model variant;

d) Details of the Test Service; and

e) Test date(s).

10 Appendix 1: Assessment Template

Note: Values entered in the tables below are fictional values for illustrative purposes only.

Section 1. Standing Passengers											Weighted
Vertical (& near) Handrails	**Length factor**	**Box A's (Max 0.1 each)**						**Box B's (Max 0.2 each)**		**Total**	**15.04**
		Score	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**		
Handrail 1	1.00	0.10	0.10					0.20		**0.40**	
Handrail 2	1.00	0.10								**0.10**	
Handrail 3	1.16	0.10	0.10	0.10				0.20		**0.58**	
Handrail 4	0.00									**0.00**	
Handrail 5	1.00	0.10	0.10	0.09	0.09			0.20	0.20	**0.78**	
Handrail 6	0.86	0.10	0.10					0.20		**0.34**	
Handrail 7	0.86	0.10	0.10					0.20		**0.34**	
Handrail 8	0.86	0.10	0.10					0.20		**0.34**	
Handrail 9	0.71	0.10								**0.07**	
Handrail 10	0.45	0.10								**0.05**	
Handrail 11										**0.00**	
Handrail 12										**0.00**	
Handrail 13										**0.00**	
Handrail 14										**0.00**	
Handrail 15										**0.00**	
Handrail 16										**0.00**	
Handrail 17										**0.00**	
Handrails 18 or more										**0.00**	

For handrail curved in bus Y plane: Length Factor = (Length in mm between 1310 mm and 1870 mm from floor)/560;
For straight handrails Length Factor = 1.0
For handrail that curves behind obstruction: Length Factor = (Length in mm between 1310 mm and 1870 mm from floor AND < 250 mm from edge of obstruction)/560

Horizontal (& near) Handrails	**Length Factor**	**Red/Grey/Safe Zone factor**		**Total**	**13.00**
Handrail 1	2.60	1.00		**2.60**	
Handrail 2				**0.00**	
Handrail 3				**0.00**	
Handrail 4				**0.00**	
Handrail 5				**0.00**	
Handrail 6 or more				**0.00**	

Length Factor = (Length in mm)/500
Red Zone Factor (IF rail > 1420 mm from floor AND rail < 1755 mm) = 1
Grey Zone Factor (if rail between 1755 mm and 1870 mm from floor) = (1870 - 'height of rail from floor in mm') /115
Grey Zone Factor (if rail between 1130 mm and 1420 mm from floor) = ('height of rail from floor in mm' - 1130)/290
Safe Zone Factor (if rail > 1870 mm from floor OR < 1130 mm from floor) = 0

Restraint	**Length factor**	**Red/Grey/Safe Zone factor**		**Total**	**0.00**
Restraint 1	0.00	1.00		**0.00**	
Restraint 2				**0.00**	
Restraint 3				**0.00**	
Restraint 4				**0.00**	
Restraint 5				**0.00**	
Restraint 6 or more				**0.00**	

Length Factor = (Length in mm)/500
Red Zone Factor (IF partition height < 770 mm from floor) = 1
Grey Zone Factor (if partition height between 770 mm and 1060 mm from floor) = (1060 - 'partition height from floor in mm')/290
Safe Zone Factor (if partition height > 1060 mm from floor) = 0

General/Other Hazards	**Score (0 or 1)**			**Total**	**9.00**
Hazard 1	1.00			**1.00**	
Hazard 2	1.00			**1.00**	
Hazard 3	1.00			**1.00**	
Hazard 4				**0.00**	
Hazard 5				**0.00**	
Hazard 6				**0.00**	
Hazard 7				**0.00**	
Hazard 8				**0.00**	
Hazard 9				**0.00**	
Hazard 10 or more				**0.00**	

Section 2. Seated Passengers (Lower Deck)						
Handrails	**ed/Grey/Safe Zone Fact**	**No. identical (seats)**	**PRM seat? (Y/N)**		**Total**	**40.71**
Handrail 1	1.00	1.00	Y		**2.00**	
Handrail 2	0.86	2.00	Y		**3.43**	
Handrail 3	0.86	2.00	N		**1.71**	
Handrail 4	1.00	1.00	N		**1.00**	
Handrail 5					**0.00**	
Handrail 6					**0.00**	
Handrail 7					**0.00**	
Handrail 8					**0.00**	
Handrail 9					**0.00**	
Handrail 10					**0.00**	
Handrail 11					**0.00**	
Handrail 12 or more					**0.00**	

Red Zone Factor (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (d) > ('half seat width in mm' (w/2) - 90) = 1
Safe Zone Factor (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (d) < 100) = 0
Grey Zone Factor (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (d) > 100 AND < ('half seat width in mm' (w/2) - 90) = (d – 100)/(w/2 – 190)

Restraint Hazards	ed/Grey/Safe Zone Fact	Proportion not covered factor	PRM seat? (Y/N)		Total	12.00
Restraint 1	1.00	1.00	N		1.00	
Restraint 2	0.75	1.00	N		1.00	
Restraint 3	0.75	1.00	N		1.00	
Restraint 4					0.00	
Restraint 5					0.00	
Restraint 6 or more					0.00	

Score 1 if seat facing directly into aisle or other empty space. Score 0.75 for pair of front-facing bay seats
Red zone factor (IF height of restraint above floor in mm (h) < 700 mm) = 1
Safe zone factor (IF height of restraint above floor in mm (h) > 800 mm) = 0
Grey zone factor (IF height of restraint above floor in mm (h) > 700 mm and < 800 mm) = (800 - h)/100
Proportion (of effective seat width) not covered factor (Pwe) = 'distance not covered in mm' (d) / 'Effective seat width mm' (we)
For safe zone score add Pwe
For grey zone score add Pwe and if score > 1, cap score of 1

General/Other Hazards	Score (0.3, 0.6 or 1)	No. identical (seats)	PRM seat? (Y/N)		Total	0.00
Hazard 1					0.00	
Hazard 2					0.00	
Hazard 3					0.00	
Hazard 4					0.00	
Hazard 5					0.00	
Hazard 6					0.00	
Hazard 7					0.00	
Hazard 8 or more					0.00	

Injury potential: Head impact high; Other body regions low
Risk of impact:
i. For small sized hazard such as single bolt head (or single group of hazards within 100 mm of each other) categorise as low;
ii. For hazard covering area likely to be impacted by body region e.g. multiple small sized hazards (e.g. > 4) or single hazard covering area in good alignment with head trajectory categorise as high
Score:
i. Injury potential low, risk of impact low; score 0.3
ii. Injury potential high, risk of impact low and vice versa; score 0.6
iii. Injury potential high, risk of impact high; score 1.0

Section 3. Seated Passengers (Upper Deck)

Handrails	Red/Grey Zone Factor	No. identical (seats)	PRM seat? (Y/N)		Total	45.00
Handrail 1	1.00	8.00	N		8.00	
Handrail 2	1.00	1.00	N		1.00	
Handrail 3			N		0.00	
Handrail 4			N		0.00	
Handrail 5			N		0.00	
Handrail 6			N		0.00	
Handrail 7			N		0.00	
Handrail 8			N		0.00	
Handrail 9			N		0.00	
Handrail 10			N		0.00	
Handrail 11			N		0.00	
Handrail 12 or more			N		0.00	

Red Zone Factor (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (d) > ('half seat width in mm' (w/2) - 90) = 1
Safe Zone Factor (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (d) < 100) = 0
Grey Zone Factor (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (d) > 100 AND < ('half seat width in mm' (w/2) - 90) = (d – 100)/(w/2 – 190)

Restraint Hazards	Restraint height factor	Seat width factor	PRM seat? (Y/N)		Total	4.00
Restraint 1	1.00	1.00	N		1.00	
Restraint 2			N		0.00	
Restraint 3			N		0.00	
Restraint 4			N		0.00	
Restraint 5			N		0.00	
Restraint 6 or more			N		0.00	

Score 1 if seat facing directly into aisle or other empty space. Score 0.75 for pair of front-facing bay seats
Red zone factor (IF height of restraint above floor in mm (h) < 700 mm) = 1
Safe zone factor (IF height of restraint above floor in mm (h) > 800 mm) = 0
Grey zone factor (IF height of restraint above floor in mm (h) > 700 mm and < 800 mm) = (800 - h)/100
Proportion (of effective seat width) not covered factor (Pwe) = 'distance not covered in mm' (d) / 'Effective seat width mm' (we)
For safe zone score add Pwe
For grey zone score add Pwe and if score > 1, cap score of 1

General/Other Hazards	Score (0.3, 0.6 or 1)	No. identical (seats)	PRM seat? (Y/N)		Total	0.00
Hazard 1			N		0.00	
Hazard 2			N		0.00	
Hazard 3			N		0.00	
Hazard 4			N		0.00	
Hazard 5			N		0.00	
Hazard 6			N		0.00	
Hazard 7			N		0.00	
Hazard 8			N		0.00	
Hazard 9			N		0.00	
Hazard 10 or more			N		0.00	

Injury potential: Head impact high; Other body regions low
Risk of impact:
i. For small sized hazard such as single bolt head (or single group of hazards within 100 mm of each other) categorise as low;
ii. For hazard covering area likely to be impacted by body region e.g. multiple small sized hazards (e.g. > 4) or single hazard covering area in good alignment with head trajectory categorise as high
Score:
i. Injury potential low, risk of impact low; score 0.3
ii. Injury potential high, risk of impact low and vice versa; score 0.6
iii. Injury potential high, risk of impact high; score 1.0

Attachment 35: Occupant Friendly Interiors Guidance Notes

1 Introduction

This document sets out the guidance notes related to occupant friendly interiors and the bus interior safety assessment protocol. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Explanation of approach for assessment protocol

The bus interior safety assessment protocol involves the identification and assessment of bus interior potential hazards (i.e. features that have injury causing potential) present in three categories; handrail, restraint and general (for standing and seated passengers), as shown diagrammatically in Figure 59. The assessment gives points for each potential hazard identified. More points are given for hazards which have greater injury causing potential and greater exposure (e.g. hazards associated with seats that are likely to be used more often). The aim is to encourage manufacturers to have as few potential hazards as possible and therefore score the minimum number of points, i.e. a lower score correlates with a better assessment.

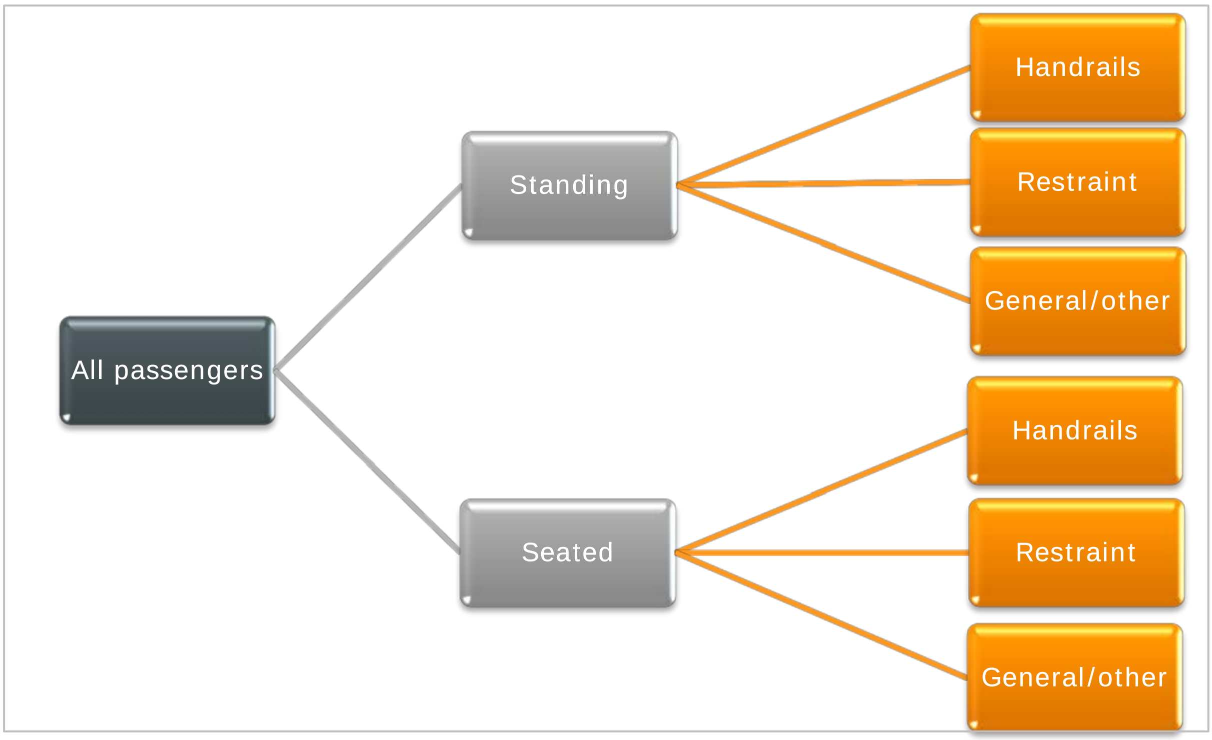

Figure 59. Visual inspection hazard categories

The approach to perform an inspection and assessment is as follows:

- Identify and count potential hazards in each category for standing and seated passengers.
- Scale individual potential hazards according to passenger exposure. This step is also used to avoid discontinuities in the assessment system. To help understanding of this step, an example of the scaling for horizontal handrails (for standing passengers) is given in *italics* on the page below.
- Further weight the points for each potential hazard identified in each of the six categories (handrail, restraint and general for standing and seated passengers) and sum them to give overall point scores for the lower deck and upper deck (if appropriate). Weightings are applied to reflect the following:

  (a) The injury potential of the hazard, e.g. if the hazard is likely to cause a head injury as opposed to a lower limb injury, a higher weighting is given.

  (b) Exposure of the hazard, e.g. if the hazard is in an area of the bus with a higher occupancy rate, a higher weighting is given. Also, additional weighting is applied to hazards to which persons with reduced mobility (PRM) are likely to be exposed. This is because, generally, PRM have slower reaction times and are less tolerant to injury, which can increase their likelihood of impacting a hazard and being injured.

Horizontal handrails can be positioned where they may be hit by a standing passenger's head, when that passenger falls. The likelihood of this occurring depends on the position height of the rail. The more the rail is in alignment with a passenger's head, the more likely it is that it will be hit. To account for this and to avoid discontinuities, a sliding scale scoring system has been developed that gives a score ranging from 0 to 1. This results in red, grey and safe zones as illustrated in the left hand side of Figure 60 below.

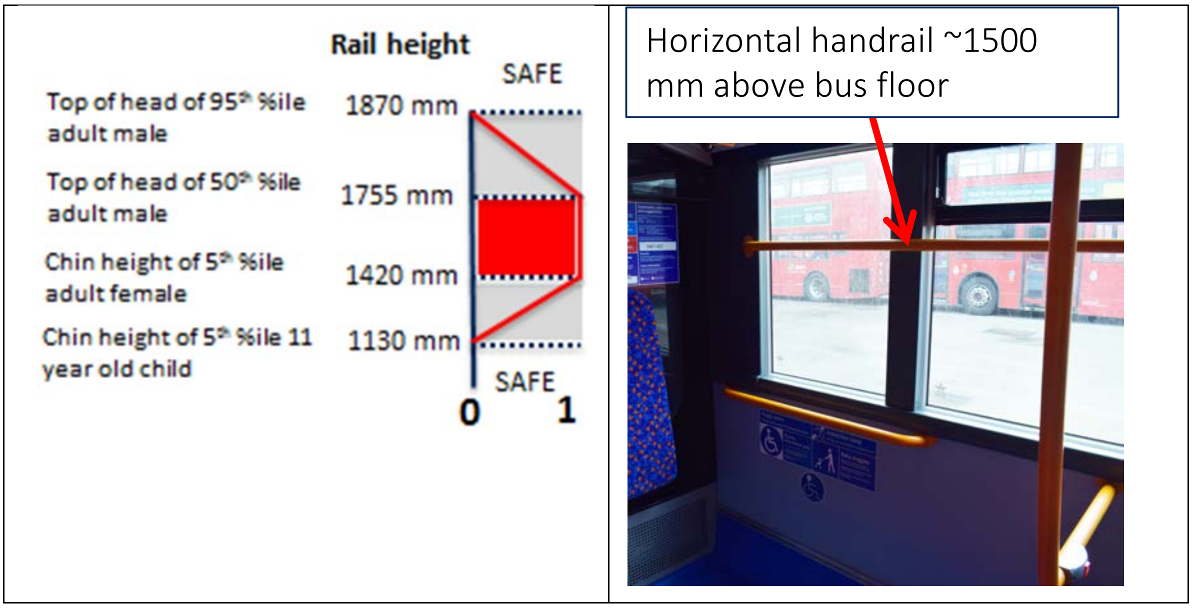

Figure 60: Illustration of concept. Top rail in picture is about 1500 mm above the bus floor and in the red zone (and scores 1) whereas the bottom rail is about 1000 mm above the bus floor and in the safe zone (and scores 0). Grey zones, in which the score is scaled linearly from 1 to zero depending on the height of the rail above the bus floor, are positioned between the red and safe zones.

- The red zone is positioned between 1420 mm (height of chin of 5^{th} percentile female) and 1755 mm (height of top of head of 50^{th} percentile male). The head height of a substantial proportion of the population will be in this zone. Therefore a passenger is likely to hit their head on a rail positioned at this height. Hence, a score of 1 (per unit length) is given for a horizontal rail positioned within this zone. The unit length chosen was 500 mm on the basis that this is approximately the space taken up by one passenger stood or leaning against the side of the bus.
- The grey zones are positioned above and below the red zone. The top grey zone is positioned between 1755 mm (height of top of head of 50^{th} percentile male) and 1870 mm (height of top of head of 95^{th} percentile male). The head height of a large proportion of the population will be in this zone, with the proportion reducing to about 5 % as the height becomes closer to 1870 mm. Hence, a score linearly reducing from 1 to 0 (per unit length) is given for a rail positioned in this zone depending on the precise height of its centre. For example a rail with a top edge height of 1800 mm would be scored (1870 – 1800)/(1870 -1755) = 0.61 per unit length. The bottom grey zone is positioned between 1420 mm (height of chin of 5^{th} percentile female) and 1130 mm (height of chin of 5^{th} percentile 11 year old child). A similar argument applies and approach is taken for this zone as for the top grey zone.
- The safe zones are positioned above and below the grey zones. These zones are above 1870 mm (top safe zone) and below 1130 mm (bottom

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safe zone). The head height of a small proportion of the population will be in these zones. Therefore a score of zero is given for rails positioned in these zones.

Note: It can be seen that if a manufacturer decides to change the height of a horizontal handrail by a small amount, say 10 mm, then the score will only change a small amount to reflect this, i.e. there are no discontinuities in the assessment system with the sliding scale approach.

3 Selection of buses/systems

A bus interior safety assessment should be carried out on each different bus model and variant in a 'ready for service' condition, i.e. with additional items such as TfL iBUS modules fitted. This assessment should be carried out by a TfL nominated supplier.

It is expected that manufacturers will wish to achieve given interior safety assessment values as targets for new bus designs. Therefore, they will need to be able to estimate the assessment values for potential designs throughout the design process. For these reasons, the assessment protocol has been kept as simple as possible (it is based mainly on simple measurements), so that it should be easily possible to perform an assessment based on 3D CAD information.

4 Training

Training and consultancy related to carrying out a bus interior assessment should be provided by a TfL nominated supplier.

5 Retro-fitment of additional items

Following the assessment of a bus model / variant in a 'service ready' condition by a TfL nominated supplier, additional items which alter the assessment should not be fitted to the bus (e.g. by operators). If it is necessary to fit items, which may alter the assessment, TfL should be consulted.

Attachment 36: Bus Impact Test Standard Assessment Protocol

1 Introduction

This document presents a procedure, hereon referred to as the Bus VRU Impact Test Standard (BITS), for objectively measuring the impact protection provided by the front end of a bus in the event of a collision with a vulnerable road user (VRU); in particular, when striking their head.

1.1 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, Class II.

1.2 Purpose

The purpose of this test and assessment protocol is to bring about an improvement in the construction of certain components of the front end of buses which have been identified as causing injury when in collision with a pedestrian's, or other vulnerable road user's, head.

The vehicles that will be tested under the Bus VRU Impact Test Standard (BITS) are representative of the majority of buses in circulation in the urban environment, where there is a significant potential for bus collisions with pedestrians and other vulnerable road users.

2 Normative References

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

- 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.
- International Standard ISO 384:1976. Road vehicles – Measurement of impact velocity in collision tests
- International Standard ISO 6487:2015. Road vehicles – Measurement techniques in impact tests – Instrumentation
- 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.
- UN Regulation No. 107. Uniform provisions concerning the approval of category M_2 or M_3 vehicles with regard to their general construction.
- UN Regulation No. 127. Uniform provisions concerning the approval of motor vehicles with regard to their pedestrian safety performance.

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3 Definitions

For the purpose of this protocol:

3.1 **Adult headform -** is the test tool used to represent the head of an adult in these impact tests. It is identical to those used in UN Regulation No. 127 and GTR No. 9 and is defined specifically in Test impactor specifications.

3.2 **Adult headform test area -** is an area on the outer surfaces of the front structure. The area is bounded:

3.3 At the lower edge, by a Wrap Around Distance (WAD) of [1,500]mm from the ground reference plane (with the vehicle at its nominal ride attitude) (WAD1500);

3.4 At the upper edge, by a WAD of [1,850] mm from the ground reference plane (with the vehicle at its minimum ride attitude) (WAD1850); and

3.5 At each side, by a line 82.5 mm inside the side reference line. The distance of 82.5 mm is to be set with a flexible tape held tautly parallel to the horizontal plane of the vehicle and along the outer surface of the vehicle.

3.6 **A-pillar -** means the foremost and outermost roof support extending from the chassis to the roof of the vehicle.

3.7 **Bus front end -** means all outer structures of the front end of the vehicle exposed to a potential collision with a VRU. It may therefore include, but is not limited to, the bumper, the bonnet or grille, scuttle, wiper spindles, lower windscreen frame, the windscreen, the windscreen header and the A-pillars.

3.8 **Child headform -** is the test tool used to represent the head of a child in these impact tests. It is identical to those used in UN Regulation No. 127 and GTR No. 9 and is defined specifically in Test impactor specifications.

3.9 **Child headform test area -** is an area on the outer surfaces of the front structure. The area is bounded:

3.10 At the lower edge, by a WAD of [1,115] mm from the ground reference plane (with the vehicle at its maximum ride attitude) (WAD1115);

3.11 At the upper edge, by a WAD [1,500] mm from the ground reference plane (with the vehicle at its nominal ride attitude) (WAD1500); and

3.12 At each side, by a line 82.5 mm inside the side reference line. The distance of 82.5 mm is to be set with a flexible tape held tautly parallel to the horizontal plane of the vehicle and along the outer surface of the vehicle.

3.13 **Driver mass -** means the nominal mass of a driver that shall be [68] kg.

3.14 **Ground reference plane -** means a horizontal plane, either real or imaginary, that passes through the lowest points of contact for all tyres of a vehicle. If the vehicle is resting on the ground, then the ground level and the ground reference plane are one and the same. If the vehicle is raised off the ground such as to allow extra clearance, then the ground reference plane is above ground level; and if the vehicle (perhaps a test sample) is lower than it would be in running order, then the ground reference plane is below the ground level.

3.15 **Head Injury Criterion (HIC_{15}) -** means the calculated result of accelerometer time histories over a maximum recording period of 15 milliseconds using the following formula:

3.16 $HIC_{15} = \left[\frac{1}{t_2-t_1}\int_{t_1}^{t_2} a\,dt\right]^{2.5}(t_2-t_1)$

3.17 Where:

(a) “a” is the resultant acceleration measured in units of gravity “g” (1 g = 9.81 m/s²);

(b) “t1” and “t2” are the two time instants (expressed in seconds) during the impact, defining an interval between the beginning and the end of the recording period for which the value of HIC is a maximum (t2 - t1 ≤ 15 ms).

3.18 **Mass in running order -** means the nominal mass of a vehicle as determined by the sum of the unladen vehicle mass and driver’s mass.

3.19 **Measuring point -** The measuring point may also be referred to as "test point" or "impact point".

3.19.1 In all cases, the result of the test shall be attributed to this point, independent of where first contact occurs.

3.19.2 "Measuring point" for the headform test means a point on the vehicle's outer surface selected for assessment. The measuring point is where the headform's profile contacts the vehicle’s outer surface cross section in a vertical longitudinal plane through the centre of gravity of the headform (see Figure 61). It will not be coincident with the centre of the headform for contacts with an inclined surface.

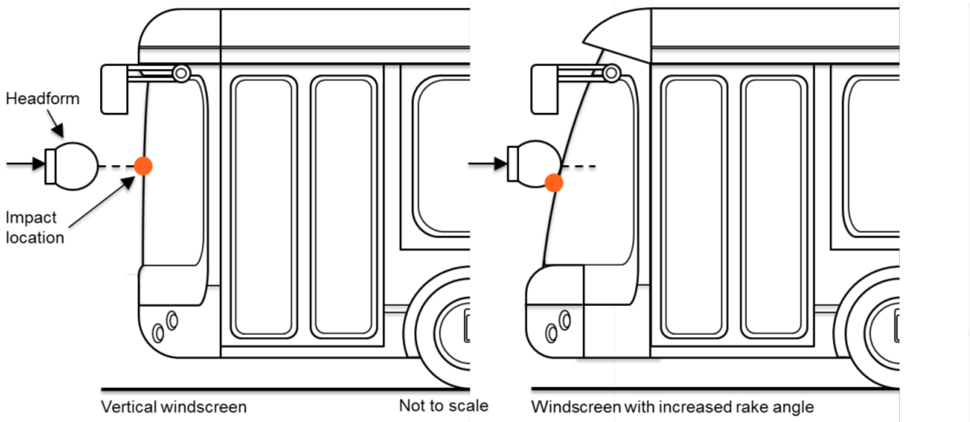

Figure 61: Measuring point in the vertical longitudinal plane through the centre of the headform impactor

3.20 **Maximum ride attitude -** means the vehicle positioned on a flat horizontal surface with its mass in running order, with the tyres inflated to manufacturer recommended pressures, the front wheels in the straight-ahead position. The suspension shall be set in normal running condition as specified by the manufacturer for a speed of 40 km/h.

3.21 **Minimum ride attitude -** means the vehicle positioned on a flat horizontal surface (as per the maximum ride attitude, but) with its mass increased to gross vehicle mass; the maximum mass of the fully laden vehicle based on its construction and design performances, as declared by the manufacturer. This shall be less than or equal to the sum of the maximum axles' (group of axles) capacity. The suspension shall be set in the running condition for this condition as specified by the manufacturer for a speed of 40 km/h.

3.22 **Nominal ride attitude -** means the vehicle positioned at the mid-point of the maximum and minimum ride attitudes.

3.23 **Primary reference marks -** means holes, surfaces, marks and identification signs on the vehicle body. The type of reference mark used and the vertical (Z) position of each mark relative to the ground shall be specified by the vehicle manufacturer according to the running conditions specified along with the Minimum, Maximum and Nominal ride attitudes. These marks shall be selected so as to be able to easily check the vehicle front and rear ride heights and vehicle attitude.

3.24 **Side reference line -** means the geometric trace of the highest points of contact between a straight edge 700mm long and the sides of the vehicle, when the straight edge, held parallel to the transverse horizontal plane of the vehicle and inclined rearwards by [60°], is traversed rearwards, and maintains contact with the sides of the bus front end (Figure 62).

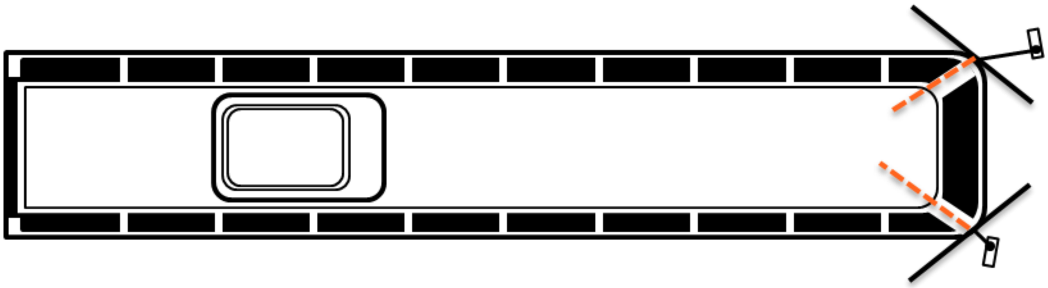

Figure 62a: Side reference line – plan view

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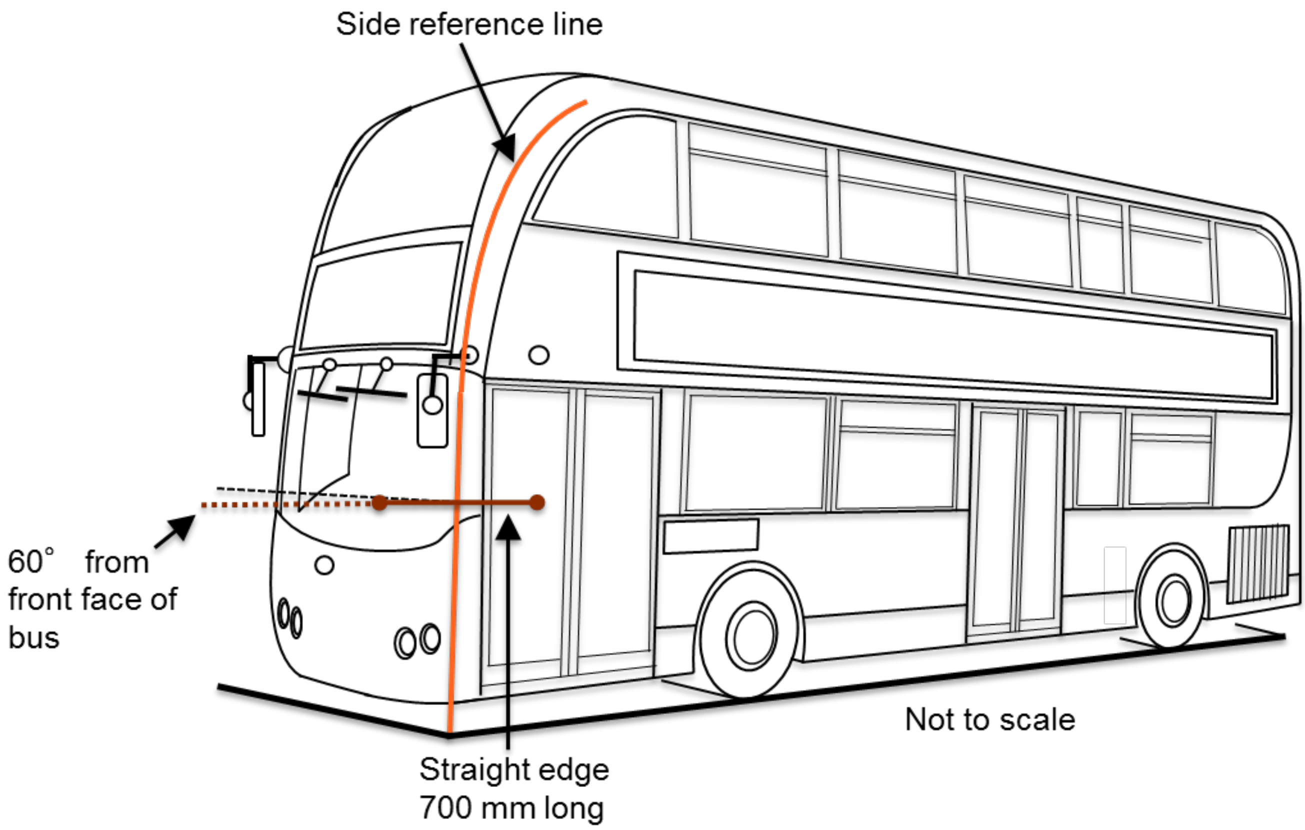

Figure 2b: Side reference line – front/side view

3.25 **Test zones -** Both the child and adult headform test areas shall be divided into six test zones labelled A1, A2, … C5, C6 with each of these test zones further sub-divided into four sub-sections labelled A-D (Figure 63).

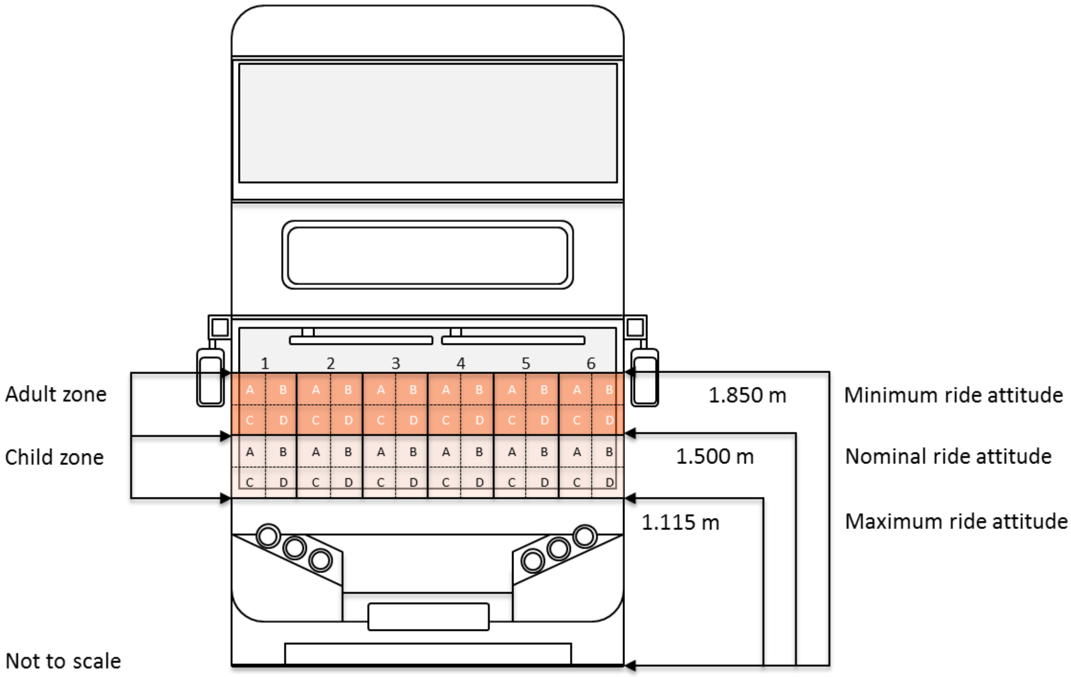

Figure 63: Labelling of test zones

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3.26 **Unladen vehicle mass -** means the nominal mass of a complete vehicle as determined by the following criteria:

3.26.1 Mass of the vehicle with bodywork and all factory fitted equipment, electrical and auxiliary equipment for normal operation of the vehicle, including liquids, tools, fire extinguisher, standard spare parts, chocks and spare wheel, if fitted.

3.26.2 The fuel tank shall be filled to at least 90 per cent of rated capacity and the other liquid containing systems (except those used for water) to 100 per cent of the capacity specified by the manufacturer.

3.27 **Vehicle type with regard to the pedestrian protection requirements -** means a category of vehicles with front end designs which, forward of the side reference lines, do not differ in such essential respects as:

a) The structure,

b) The main dimensions,

c) The materials of the outer surfaces of the vehicle,

d) The component arrangement (external or internal),

3.27.1 in so far as they may be considered to have a negative effect on the results of the impact tests prescribed in this Regulation.

3.28 **Windscreen -** means the frontal glazing of the vehicle.

3.29 **Wrap Around Distance (WAD) -** means the geometric trace described on the outer surface of the bus front end by one end of a flexible tape, when it is held in a vertical longitudinal plane of the vehicle and traversed across the bus front end. The tape is held taut throughout the operation with one end held at the same level as the ground reference plane, vertically below the front face of the bumper and the other end held in contact with the front structure (see Figure 64). The vehicle shall be either positioned in the maximum, minimum or nominal ride attitudes.

This procedure shall be followed, using alternative tapes of appropriate lengths, to describe wrap around distances of [1,115] mm (WAD1115), of [1,500] mm (WAD1500) and of [1,850] mm (WAD1850).

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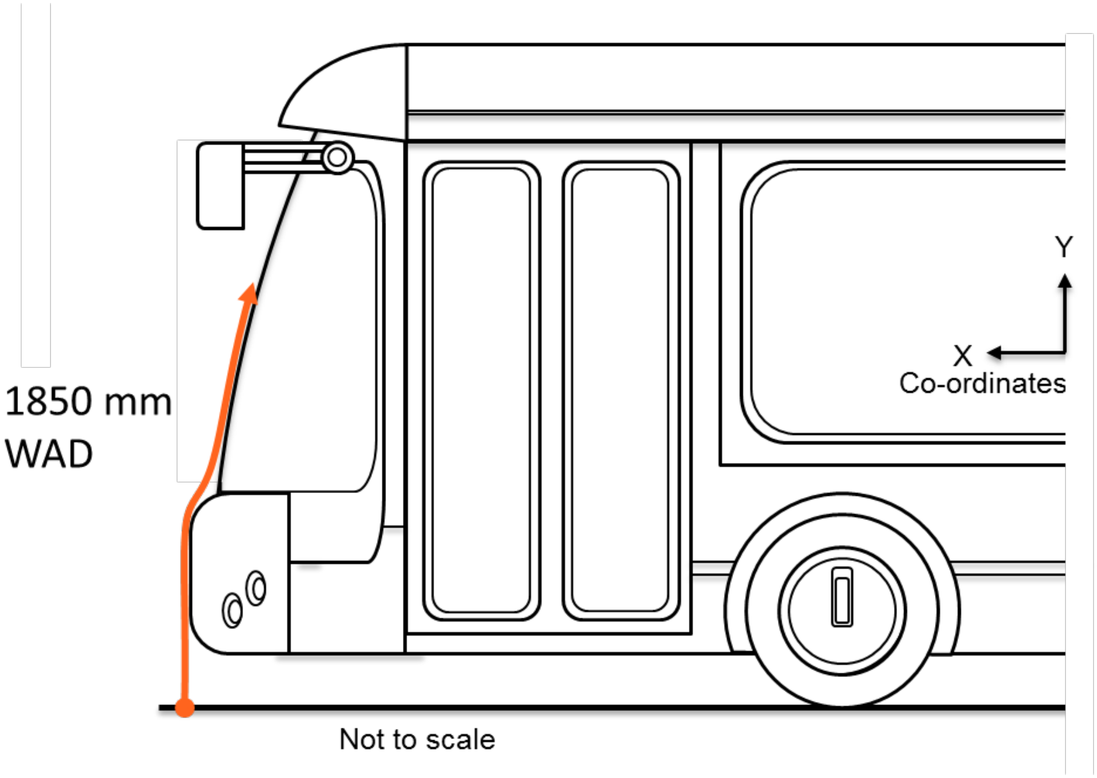

Figure 64: Wrap around distance measurement

4 Specifications

4.1 Minimum requirements

4.1.1 When tested in accordance with the test procedures in Section 5, all recorded HIC15 values shall not exceed [1,300].

4.1.2 In addition, the Bus VRU Impact Test Performance Score (BITS) (as defined in Section 4.3) must be, at least [25%].

4.2 Manufacturer selected points

4.2.1 The manufacturer may select up to three test points across both test areas to be retested. A supplementary test may then be performed to a different measuring point selected by the manufacturer within the same test zone (i.e. testing different sub-sections in the same test zone is permitted). The results from these supplementary tests will be averaged with the first result when used in the following rating system.

4.2.2 Example:

a) First test results in HIC = 1250

b) Manufacturer elected retest results in HIC = 700

c) Mean HIC = 975

4.3 Bus VRU impact test performance scores (BITS)

4.3.1 The bus VRU impact performance score (BITS) shall be calculated for the bus front end using the following approach:

4.3.2 HIC15 values shall be converted to points using the following scale:

a) HIC < 700 = 2 points

b) 700 ≤ HIC < 1000 = 1 point

c) HIC ≥ 1000 = 0 points

4.3.3 The total points score shall be divided by 24 to give a value between 0% and 100%.

5 Test procedure

5.1 When performing measurements:

5.1.1 If the vehicle is fitted with a badge, mascot or other structure, which would bend back or retract under an applied load of maximum 100N, then this load shall be applied before and/or while these measurements are taken.

5.1.2 Any vehicle component which could change shape or position, other than suspension components or active devices to protect pedestrians, shall be set to their stowed position.

5.2 Impact tests

5.2.1 For all impact tests, the headform impactors shall meet the specifications provided in Appendix A and be certified pursuant to Appendix B. General testing conditions shall be provided pursuant to Appendix C, whilst common testing procedures are provided in Appendix D.

5.2.2 Tests shall be made to the bus front end within the boundaries, as defined in Section 3 of this protocol.

5.2.3 A minimum of six tests shall be carried out with the child headform impactor, one test to each of the six child test zones within the child headform test area (as defined in Section 3 of this protocol), at positions judged to be the most likely to cause injury.

5.2.4 A minimum of six tests shall be carried out with the adult headform impactor, one test to each of the six adult test zones within the adult headform test area (as defined in Section 3 of this protocol), at positions judged to be the most likely to cause injury.

5.2.5 Tests shall be to different types of structure, where these vary throughout the area to be assessed.

5.2.6 Any parts damaged by an impact must be replaced before carrying out the next test.

5.2.7 The selected measuring points for the child and adult headform impactors shall be a minimum of 165mm apart.

5.2.8 These minimum distances are to be set with a flexible tape held tautly along the outer surface of the vehicle.

5.2.9 No measuring point shall be located so that the impactor will impact the test area with a glancing blow resulting in a more severe second impact outside the test area.

5.2.10 For all child and adult headform tests, a vertical and lateral impact location tolerance of ±10mm shall apply. This tolerance is measured along the surface of the vehicle front. The test laboratory may verify, at a sufficient number of measuring points, that this condition can be met and the tests are thus being conducted with the necessary accuracy.

5.2.11 The headform velocity at the time of impact shall be either [6.94] ±0.2m/s or [11.11] ±0.2m/s. The speed shall be selected at random, with the constraint that at least half of the tests must be conducted at the 11.11

±0.2m/s velocity. Supplementary tests shall always be performed at the same headform velocity as the first test.

5.2.12 The direction of impact shall be perpendicular to the lateral vertical plane of the vehicle to be tested.

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6 Test Report

6.1 The Test Service shall provide a comprehensive Test Report that will be made available to TfL. The test report shall consist of three distinct sections:

a) Reference information

b) Confirmation of protocol compliance

c) Performance data

6.2 Reference information

6.2.1 As a minimum, the Test Service shall provide reference information including:

d) Make (trade name of manufacturer);

e) Model/Type;

f) Commercial name(s) (if available);

g) Means of identification of type, if marked on the vehicle;

h) Location of that marking;

i) Variant (if applicable);

j) Category of vehicle;

k) Name and address of manufacturer;

l) Name(s) and address(es) of assembly plant(s);

m) Name and address of the manufacturer's representative (if any);

n) General construction characteristics of the vehicle;

o) Photographs and/or drawings of a representative vehicle;

p) Bodywork;

q) Type of bodywork;

r) Materials used and methods of construction;

s) Running order information;

t) Pedestrian protection;

u) A detailed description, including photographs and/or drawings, of the vehicle with respect to the structure, the dimensions, the relevant reference lines and the constituent materials of the frontal part of the vehicle (interior and exterior) shall be provided.

6.3 Confirmation of protocol compliance

6.3.1 Predominantly this item will relate to providing a description of testing completed.

6.3.2 The positions tested by the laboratories shall be indicated in the test report. The quadrant of each zone shall be noted as well as specific descriptions of the structures contacted.

6.3.3 Photographs should identify the test site before and after each test.

6.3.4 Records should be kept of the components changed between tests due to damage.

6.4 Performance data

6.4.1 Every test shall be reported along with the corresponding HIC15 value.

6.4.2 Furthermore, the BITS score associated with each result shall be recorded as well as the overall BITS score for the bus (Table 43 provides a blank example of a results table).

6.4.3 The BITS scores should also be presented visually. Such images shall be colour coded to distinguish between the tests receiving 0, 1 or 2 points. A legend to the colour coding shall be provided within the Test Report. A hypothetical example is shown in Figure 65.

Table 43: Example table for reporting of results

Test site	**Quadrant tested**	**HIC_{15}**	**BITS score (%)**
A1	A, B, C or D	XXX	YY
A2			
A3			
A3 (manufacturer elected retest)			
A4			
A5			
A6			
C1			
C2			
C3			
C4			
C5			
C6			
Total			

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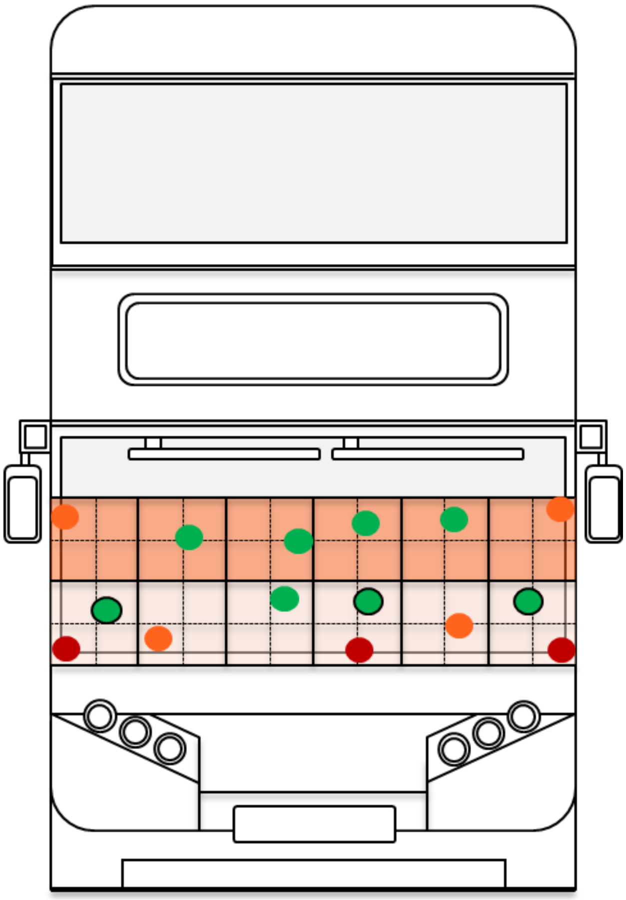

Not to scale

Figure 65: Example image showing test results from Bus VRU Impact Test Standard (BITS)

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Annex 1 Test impactor specifications

The specifications for the test impactors are taken from the international pedestrian safety regulations for passenger cars and car-derived vans which also use these impactors. In particular, these specifications feature within UN Regulation No. 127.

1 Child and adult headform impactors

The child headform impactor (Figure 66) shall be made of aluminium, be of homogenous construction and be of spherical shape. The overall diameter shall be 165mm ±1mm. The mass shall be 3.5kg ±0.07kg. The moment of inertia about an axis through the centre of gravity and perpendicular to the direction of impact shall be within the range of 0.008 to 0.012kgm^2. The centre of gravity of the headform impactor including instrumentation shall be located in the geometric centre of the sphere with a tolerance of ±2mm.

- The sphere shall be covered with a 14mm ±0.5mm thick synthetic skin, which shall cover at least half of the sphere.
- The first natural frequency of the child headform impactor shall be over 5,000Hz.

2 Child headform instrumentation

A recess in the sphere shall allow for mounting one triaxial or three uniaxial accelerometers within ±10mm seismic mass location tolerance from the centre of the sphere for the measurement axis, and ±1mm seismic mass location tolerance from the centre of the sphere for the perpendicular direction to the measurement axis.

If three uniaxial accelerometers are used, one of the accelerometers shall have its sensitive axis perpendicular to the mounting face A (Figure 66) and its seismic mass shall be positioned within a cylindrical tolerance field of 1mm radius and 20mm length. The centre line of the tolerance field shall run perpendicular to the mounting face and its mid-point shall coincide with the centre of the sphere of the headform impactor.

The remaining accelerometers shall have their sensitive axes perpendicular to each other and parallel to the mounting face A and their seismic mass shall be positioned within a spherical tolerance field of 10mm radius. The centre of the tolerance field shall coincide with the centre of the sphere of the headform impactor.

The instrumentation response value CFC, as defined in ISO 6487:2002, shall be 1,000. The CAC response value, as defined in ISO 6487:2002, shall be 500g for the acceleration.

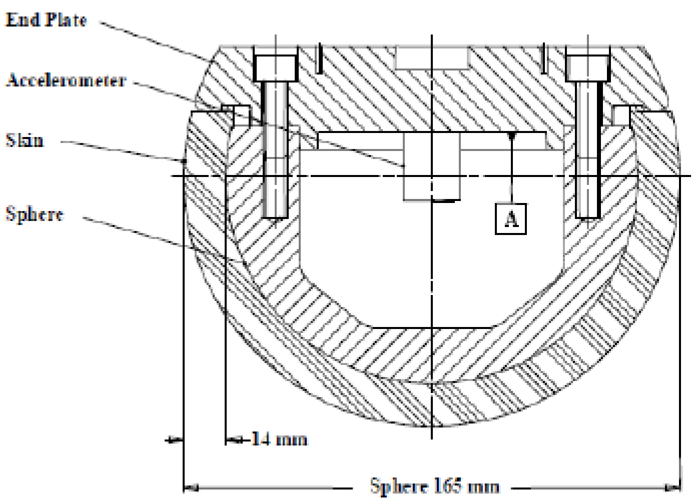

Figure 66: Child headform impactor

3 Adult headform impactor

The adult headform impactor (Figure 67) shall be made of aluminium, be of homogenous construction and be of spherical shape. The overall diameter is 165mm ±1 mm as shown in Figure 67. The mass shall be 4.5kg ±0.1kg. The moment of inertia about an axis through the centre of gravity and perpendicular to the direction of impact shall be within the range of 0.010 to 0.013kgm^2. The centre of gravity of the headform impactor including instrumentation shall be located in the geometric centre of the sphere with a tolerance of ±5mm.

- The sphere shall be covered with a 14mm ±0.5mm thick synthetic skin, which shall cover at least half of the sphere.
- The first natural frequency of the headform impactor shall be over 5,000Hz.

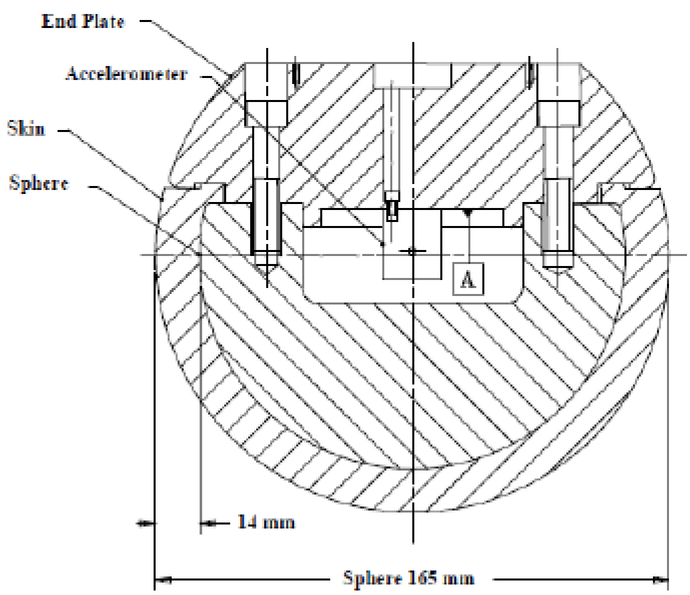

Figure 67: Adult headform impactor

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4 Adult headform instrumentation

A recess in the sphere shall allow for mounting one triaxial or three uniaxial accelerometers within ±10mm seismic mass location tolerance from the centre of the sphere for the measurement axis, and ±1mm seismic mass location tolerance from the centre of the sphere for the perpendicular direction to the measurement axis.

If three uniaxial accelerometers are used, one of the accelerometers shall have its sensitive axis perpendicular to the mounting face A (see Figure 67) and its seismic mass shall be positioned within a cylindrical tolerance field of 1mm radius and 20mm length. The centre line of the tolerance field shall run perpendicular to the mounting face and its mid-point shall coincide with the centre of the sphere of the headform impactor.

The remaining accelerometers shall have their sensitive axes perpendicular to each other and parallel to the mounting face A and their seismic mass shall be positioned within a spherical tolerance field of 10mm radius. The centre of the tolerance field shall coincide with the centre of the sphere of the headform impactor.

The instrumentation response value CFC, as defined in ISO 6487:2002, shall be 1,000. The CAC response value, as defined in ISO 6487:2002, shall be 500g for the acceleration.

5 Rear face of the child and adult headform impactors

A rear flat face shall be provided on the outer surface of the headform impactors which is perpendicular to the direction of travel, and typically perpendicular to the axis of one of the accelerometers as well as being a flat plate capable of providing for access to the accelerometers and an attachment point for the propulsion system.

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Annex 2 Certification of the impactor

The specifications for the certification of the test impactors are taken from the international pedestrian safety regulations for passenger cars and car-derived vans which also use these impactors. In particular, these specifications feature within UN Regulation No. 127.

1 Child and adult headform

The certified impactors may be used for a maximum of 20 impacts before re-certification. The impactors shall be re-certified if more than one year has elapsed since the previous certification or if the transducer output, in any impact, has exceeded the specified CAC.

When the headform impactors are dropped from a height of 376mm ±1mm in accordance with the conditions described below, the peak resultant acceleration measured by one triaxial (or three uniaxial) accelerometer (accelerometers) in the headform impactor shall be:

a) For the child headform impactor not less than 245*g* and not more than 300*g*;

b) For the adult headform impactor not less than 225*g* and not more than 275*g*.

The acceleration time curve shall be uni-modal.

The instrumentation response values CFC and CAC for each accelerometer shall be 1,000Hz and 500g respectively as defined in ISO 6487:2002.

The headform impactors shall have a temperature of 20 ±2°C at the time of impact. The temperature tolerances shall apply at a relative humidity of 40 ±30 per cent after a soak period of at least four hours prior to their application in a test.

2 Test procedure

The headform impactor shall be suspended from a drop rig as shown in Figure 68.

The headform impactor shall be dropped from the specified height by means that ensure instant release onto a rigidly supported flat horizontal steel plate, over 50mm thick and over 300mm x 300mm square which has a clean dry surface and a surface finish of between 0.2 and 2.0 micrometer.

The headform impactor shall be dropped with the rear face of the impactor horizontal and parallel with the impact surface. The suspension of the headform impactor shall be such that it does not rotate during the fall.

The drop test shall be performed three times.

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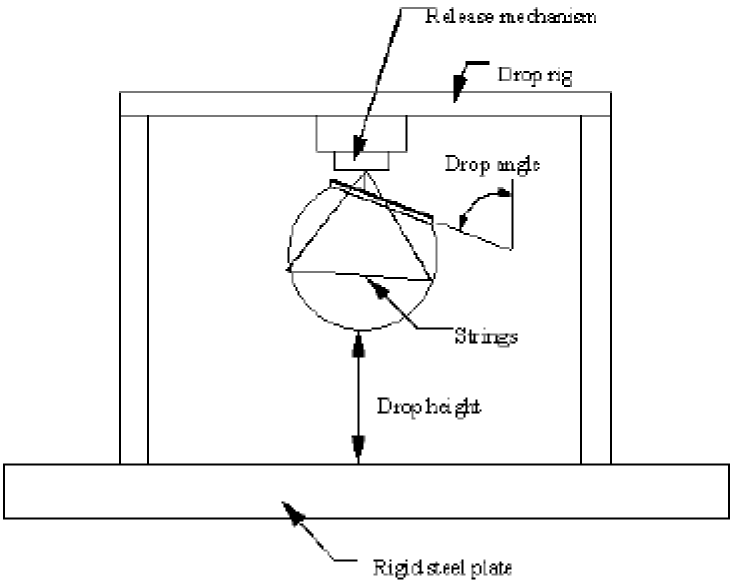

Figure 68: Test set-up for dynamic headform impactor certification test

Annex 3 General test conditions

1 Temperature and humidity

At the time of testing, the test facility and the vehicle or sub-system shall have a relative humidity of 40 per cent ±30 per cent and stabilized temperature of 20ºC ±4ºC.

2 Impact test site

The test site shall consist of a flat, smooth and hard surface with a slope not exceeding 1 per cent.

3 Preparation of the vehicle

Either a complete vehicle, or a cut-body, adjusted to the following conditions shall be used for the test.

- The vehicle shall be in either its maximum, minimum or nominal ride attitude, and shall be either securely mounted on raised supports or at rest on a flat horizontal surface with the parking brake applied.
- The cut-body shall include, in the test, all parts of the bus front end, all under-bonnet components and all components behind the windscreen that may be involved in a frontal impact with a vulnerable road user, to demonstrate the performance and interactions of all the contributory vehicle components. The cut-body shall be securely mounted in the maximum, minimum or nominal vehicle ride attitude.

All devices designed to protect vulnerable road users when impacted by the vehicle shall be correctly activated before and/or be active during the relevant test. It shall be the responsibility of the manufacturer to show that any devices will act as intended in a pedestrian impact.

For vehicle components which could change shape or position, other than active devices to protect pedestrians, and which have more than one fixed shape or position shall require the vehicle to comply with the components in each fixed shape or position.

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Annex 4 Common test specifications

1 Propulsion of the headform impactors

The headform impactors shall be in “free flight” at the moment of impact, at the required impact velocity and the required direction of impact.

The impactors shall be released to “free flight” at such a distance from the vehicle that the test results are not influenced by contact of the impactor with the propulsion system during rebound of the impactor.

2 Measurement of impact velocity

The velocity of the headform impactor shall be measured at some point during the free flight before impact, in accordance with the method specified in ISO 3784:1976. The measured velocity shall be adjusted considering all factors which may affect the impactor between the point of measurement and the point of impact, in order to determine the velocity of the impactor at the time of impact. The angle of the velocity vector at the time of impact shall be calculated or measured.

3 Recording

The acceleration time histories shall be recorded, and HIC shall be calculated. The measuring point on the bus front end shall be recorded. Recording of test results shall be in accordance with ISO 6487:2002.

Attachment 37: Bus Impact Test Standard Guidance Notes

1 Introduction

Bus fronts have been identified as one of the key contact causing parts of the vehicle in collisions with Vulnerable Road Users (VRU). Therefore, all bus front ends, in the region of potential head contacts, are required to have a construction that absorbs energy and protects VRUs in the event of a contact at that location on the vehicle.

As such, all buses shall have their VRU impact testing performance assessed against the associated VRU impact testing protocol. All buses shall have front ends which are energy absorbing or sufficiently compliant or frangible to meet the performance requirements.

This document sets out the guidance notes related to the assessment of VRU impact performance. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Procedure background

Test procedures for the assessment of the structural interaction between passenger cars and pedestrians exist, both for type approval purposes (UN Regulation No. 127 and UN GTR No. 9) and for use in consumer assessment ratings of vehicles (e.g. Euro NCAP). These existing protocols have been used as a basis for the development of a test procedure for the assessment of the protection for Vulnerable Road Users (VRU) in impacts with buses. This procedure extends that already developed within the Aprosys Project for Heavy Goods Vehicles.

2.1 Vehicle preparation and marking

The protocol specifies the marking out of the front of the vehicle into two zones, one an adult zone, and the other a child zone. The adult zone is the area where the head of an adult pedestrian is likely to hit and the child zone is the equivalent area for a child pedestrian. The marking procedure includes allowances for changes in ride height of the vehicle and defines the “corners” of the vehicle at either side. The lower boundary of the test zone is defined with the vehicle at its normal ride height, and the upper boundary with the vehicle at its minimum ride height. The heights of the boundaries are defined based on anthropometric data, with the maximum boundary height of 1850 mm relating to the height of a 95th percentile adult male and the

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minimum boundary height of 1115 mm relating to the height of a 5th percentile 6 year old. Figure 69 shows the marking of the two test zones.

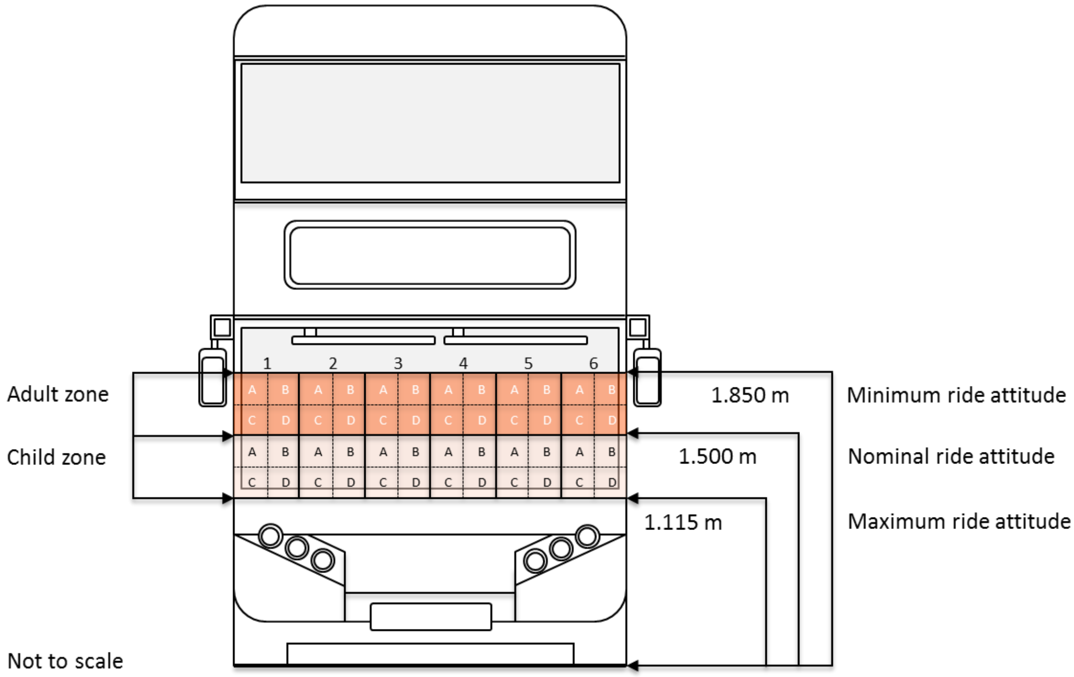

Figure 69: Marking out of test zones

Both the child and adult test zones are divided horizontally into six areas and labelled A1,

A2……C5, C6 as shown in Figure 63. Each area is then sub-divided into quarters.

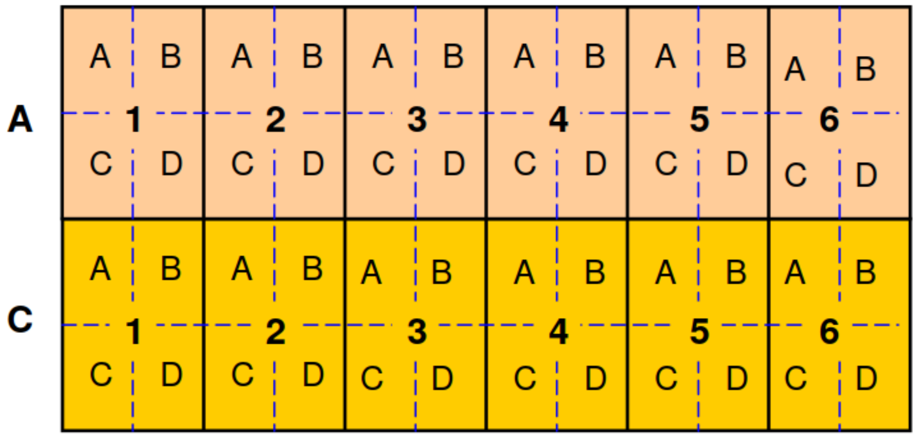

Figure 70: Labelling of test zones

2.1.1 Impact points

The test points are selected by the test engineer from the testing organisation (as is the case in EuroNCAP pedestrian testing of passenger cars and regulatory testing). One point must be selected from each test zone (A1, A2…..C5, C6). The test point selected should be expected to be the most injurious within that zone. In some cases, multiple test zones can cover the same structure, which is expected to have equivalent performance (e.g. the windscreen).

The vehicle manufacturer may specify up to three additional tests (one per test zone), allowing for a total maximum of 15 tests.

2.1.2 Testing

The testing is carried out with air, spring or hydraulically propelled headforms. The protocol provides details of how to position the headform. The headform is propelled at the vehicle in the x-direction parallel to the longitudinal axis of the vehicle (nominally this is normal to the surface).

The testing is carried out using an adult headform and a child headform for the respective test areas. The prime test speed used is 11.1 ± 0.2m/s. A second speed of [8.3 ± 0.2m/s] will be used in addition for at least one of the test points in each zone. These lower speed tests will be selected at random from the proposed matrix of tests.

To avoid repeated testing of the same parts, no two tests may be carried out in the same quarter of each zone. Furthermore, no two tests are allowed within 165 mm (an adult head/headform diameter).

2.2 Assessment criteria

The 15ms Head Injury Criteria (HIC_{15}) is used for the assessment of the structural aggressivity. For each test location, up to two points can be awarded, based on the performance criteria shown below (and in the protocol). The scores for each test zone are combined to give a total out of 24. This is then scaled to a maximum score of 100% (divided by 24, multiplied by 100%).

Performance criteria.

- [HIC < 700 = 2 points (Green)
- 700 ≤ HIC < 1,000 = 1 point (Yellow)
- 1000 < HIC = 0 points (Red)]

A test failure would occur with a HIC value greater than 1300.

Also, all [new] buses shall meet the minimum bus VRU impact test performance score (BITS) requirement of [25%].

3 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The VRU Impact Protection requirements may be assessed against a new build bus.

3.1 Compliance and warranty

A bus operator should ask to see a VRU Impact Performance test report from the bus manufacturer including the performance rating (a value between 0 and 1).

3.2 Interpreting the requirements and selecting the most effective way to fulfil them

The requirements relate to the energy-absorbing compliance or frangibility of the bus front end. In order to minimise the acceleration transmitted to the head of a vulnerable road user in the event of a collision, then the following elements should be avoided or minimised:

- **Sharp:** In accordance with the requirements of exterior projections, then sharp edges and features must be avoided on the outer surface of a vehicle (in locations where they may contact a vulnerable road user). Furthermore, tight radii tend to concentrate stiffness and hence should be avoided from the point of minimising the acceleration of a contacting head or headform.
- **Hard:** Wherever possible yielding structures should be provided to avoid hard transfers of momentum to the head
- **Heavily featured:** As mentioned under sharpness, transitions of features on a bus front end that involve changes in angle are likely to provide natural stiffness to the structure. Therefore, ideally any changes in profile throughout the head impact areas should be progressive, offering a relatively flat bending surface.
- **Robust:** One of the most important features for components such as windscreens is their ability to fracture during an impact. The onset of fracturing should be as early in the impact event as possible to gain full advantage of that energy-absorbing failure. For glazing this could be tuned through careful selection of thickness, composition of layers and potentially the manufacturing process, etc. Advice from windscreen manufacturers may need to be sought on compliance with regulated behaviour of screens and tuning impact performance.

In the first instance, the Bus Vehicle Specification (BVS) and associated impact test and assessment procedure recognises that current buses already have large flat glazed areas on the front of the vehicle which have useful frangible properties for head protection. It is expected that the minimum standard can be met with conventional design techniques. However, through the performance rating, it will recognise improvements over and above this minimum standard if further improvements and tuning of the front end structures can be provided.

3.3 Susceptibility to damage

Increasing the tendency for glazing to fracture will have an adverse consequence on the ability of a windscreen to be durable and resistant to damage. For this reason, the current levels of performance required to achieve a high impact performance rating score are conservative. The precise definitions have been set around evidence of existing performance for bus fronts. However, if a technical solution can be provided that allows lower HIC test values without deteriorating maintenance costs and concerns and screen strength, then more stringent levels of performance could be encouraged.

3.4 Features sharing other functional requirements

To ensure that the front end of a bus performs well in other crash and failure modes, then certain requirements are placed for there to be strong structural members within the broad VRU contact area. To demonstrate crash protection for bus drivers, UN Regulation 29 (with regard to the protection of the occupants of the cab of a commercial vehicle) has been used by some manufacturers. The need to meet these structural requirements must coexist with new requirements for VRU impact protection. Experience within the passenger car industry says that the two design goals are not mutually exclusive. Effective VRU protection is at such a different level of stiffness to other crashworthiness protection that both sets of parts must be designed to act in series (with the VRU protection being placed in front of harder components). The consequence of this is that sufficient clearance must be designed between the exterior surface and underlying hard parts to allow deformation and cushioning during a VRU collision. The conflicts over packaging are recognised in this regard, but based on the experience with existing design of bus front ends are not considered to be prohibitive. Careful tuning of stiffness within deformable elements (as with car bumpers and bonnets) will minimise the clearance necessary to meet the VRU impact performance requirements.

4 Training

4.1 For test houses

Test houses accredited to undertake approval tests to UN Regulation No. 127 or UN Regulation GTR No. 9 will be considered suitable to undertake performance tests. Test houses without such accreditation will be required to demonstrate to TfL at their expense that they can achieve the same standard of testing as an accredited organisation.

Attachment 38: Bus Front End Design – Minimum Geometric Requirements Guidance Notes

(Vulnerable Road User (VRU) Frontal Crashworthiness)

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1 Introduction

Bus fronts have been identified as one of the key injury-causing contact areas of the vehicle in collisions with Vulnerable Road Users (VRU). Therefore, all bus front ends are required to have a geometric design that both improves protection for VRUs during the primary impact within a collision and reduces the risks of VRUs being run over subsequently.

As such, all buses new buses shall have a front end design that complies with the minimum bus front end geometry requirements for both vertical rake and horizontal curvature.

This document sets out the guidance notes related to the assessment of front end geometry and specifically, with respect to the minimum requirements. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

All [new] buses shall have a front end geometry that complies with the minimum bus front end geometry requirements for both vertical rake angle and horizontal curvature. Therefore, selection can be any bus that meets the TfL Bus Vehicle Specification.

The minimum geometry requirements may be assessed against a new build bus. It is expected that compliant vehicles can already be selected from the models available currently.

2.1 Compliance and warranty

A bus operator should ask to see documentary evidence of compliance with the requirements. Compliance may be established through either a CAD-based approach or physical testing. Whichever approach is adopted, a dossier of inspection points and measurements should be provided to assure compliance.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

The minimum requirements are intended to dictate a progressive surface geometry for the bus front end, as necessary to bring about improvements in vulnerable road user protection. It is expected that the surface is broadly continuous in this regard. However, it is also recognised that necessarily features are incorporated in the bus front end for functional reasons and styling. Experience from the car industry suggests that small projections and protuberances can be used to provide localised areas of angled surfaces. The most effective vulnerable road user protection will be realised if the geometry requirements are adopted generally, the greater the angles and the size of the areas presenting that angle then the more effective the measure will be.

3 Training

3.1 For test houses

The nature of verifying compliance with the requirements will depend on whether it is demonstrated through CAD or physically.

For CAD assessments, appropriate sections should be cut to demonstrate bus front end geometry in a way that can be visualised against the requirements. Any inspection should be facilitated by applying tangents to the surface where the appropriate angles of rake or horizontal curvature can be viewed. It should be possible for the inspection to identify the worst angle throughout the section.

For physical inspections, vertical rake can be measured with an inclinometer. Here it should be noted that the footprint for the measurements should be 236 mm x 236 mm. Smaller features are exempt from the requirements.

Compliance with the horizontal angle requirements may be determined by application of a geometric gauge. This would be a device that pushes forward either,

- a 236 mm x 236 mm probe, with a horizontal angle of [15]° ±0.5° along the longitudinal axis of the vehicle and at a known offset from the most lateral aspect of the vehicle, or
- a rounded panel with horizontal curvature of >0.3 m, again with a nominal face size of 236 mm x 236 mm.

Test houses undertaking approval tests to UN Regulation No. 127 or UN Regulation GTR No. 9 will already possess the capability to apply a 236 mm x 236 mm probe to the front of a car in order to determine the bumper corners. The difference with this application is that the horizontal angle is 15° instead of 30°.

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4 Ongoing observations

4.1 Glare and visual artefacts

In discussions around these geometric requirements, two issues have been raised as potential disbenefits associated with the improvements for vulnerable road user protection. These are:

1. That the vertical rake of the windscreen may refract light from overhead sources (such as street lights and the sun) creating glare for the driver.
2. That the horizontal curvature of the windscreen may create apparitions or visual artefacts that distort direct vision for the driver, particularly towards the corners of the screen.

These minimum requirements do not take design envelopes for bus front end geometry beyond that of existing designs, therefore these potential issues are not perceived to be critical factors (otherwise we would already be aware of the problem). However, operators should be mindful of the potential and will be expected to log and feedback any potential issues, if substantiated reports become available.

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Attachment 39: Bus Front End Design – Enhanced Geometric Requirements Guidance Notes

(Vulnerable Road User (VRU) Frontal Crashworthiness)

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1 Introduction

Bus fronts have been identified as one of the key injury-causing contact areas of the vehicle in collisions with Vulnerable Road Users (VRU). Therefore, all bus front ends are required to have a geometric design that both improves protection for VRUs during the primary impact within a collision and reduces the risks of VRUs being run over subsequently.

As such, all buses new buses shall have a front end design that complies with the minimum bus front end geometry requirements for both vertical rake and horizontal curvature.

This document sets out the guidance notes related to the assessment of front end geometry and specifically, with respect to the enhanced requirements. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

When implemented, all new buses shall have a front end geometry that complies with the enhanced bus front end geometry requirements for both vertical rake angle and horizontal curvature. Therefore, selection will be any bus that meets the TfL Bus Vehicle Specification.

The enhanced geometry requirements may be assessed against a new build bus. It is expected that existing designs will not be fully compliant. Therefore new build buses will be required before full compliance with these requirements can be demonstrated.

2.1 Compliance and warranty

A bus operator should ask to see documentary evidence of compliance with the requirements. Compliance may be established through either a CAD-based approach or physical testing. Whichever approach is adopted, a dossier of inspection points and measurements should be provided to assure compliance.

2.2 Interpreting the requirements and selecting the most effective way to fulfil them

At the enhanced level of geometry requirements, it may be possible that longer bus front ends are used to meet the design goals. This approach is not necessarily the only option, as an alternative (though an option with operational limitations) approach would be to reduce capacity instead.

Even with the enhanced requirements, the minimum scale of length difference necessitated to add curvature to the front end will be:

- Approximately 170 mm difference (versus a flat front end) in the longitudinal axis across whole front end due to vertical raking
- Approximately 294 mm difference (versus a flat front end) in the longitudinal axis at the centreline of the vehicle due to horizontal curvature.

The enhanced requirements are intended to dictate a progressive surface geometry for the bus front end, as necessary to bring about improvements in vulnerable road user protection. It is expected that the surface is broadly continuous in this regard. However, it is also recognised that necessary features are incorporated in the bus front end for functional reasons and styling. Experience from the car industry suggests that small projections and protuberances can be used to provide localised areas of angled surfaces. The most effective vulnerable road user protection will be realised if the geometry requirements are adopted generally, the greater the angles and the size of the areas presenting that angle then the more effective the measure will be.

Beyond this, it should be recognised that better VRU protection performance has been demonstrated in the modelling study parameter sweeps to be associated with greater curvature and raking. Therefore, maximising the rake and curvature would be preferential for VRU protection. Radical redesigns to bus front ends would be encouraged if VRU protection is considered in isolation. However, it should be kept in mind that extra rake or curvature has the likely effect of increasing further the vehicle length or reducing capacity.

If buses with enhanced geometry do indeed have an increased overall length (or perhaps a differing front overhang, then consideration will need to be given to:

- Door positions relative to the overall length of the vehicle

  Note that the required distance between doors (as specified in UN Regulation No. 107) is defined as a percentage of the overall length of the passenger compartment.

- The turning circle of the vehicle

  Again regulatory requirements will have to be maintained (as per Regulation (EU) No. 1230/2012 – Masses & Dimensions)

- Potential stabling of vehicles in capacity constrained depots

3 Training

3.1 For test houses

The nature of verifying compliance with the requirements will depend on whether it is demonstrated through CAD or physically.

For CAD assessments, appropriate sections should be cut to demonstrate bus front end geometry in a way that can be visualised against the requirements. Any inspection should be facilitated by applying tangents to the surface where the appropriate angles of rake or horizontal curvature can be viewed. It should be possible for the inspection to identify the worst angle throughout the section.

For physical inspections, vertical rake can be measured with an inclinometer. Here it should be noted that the footprint for the measurements should be 236 mm x 236 mm. Smaller features are exempt from the requirements.

Compliance with the horizontal angle requirements may be determined by application of a geometric gauge. This would be a device that pushes forward either,

- a 236 mm x 236 mm probe, with a horizontal angle of [15]° ±0.5°, along the longitudinal axis of the vehicle and at a known offset from the vehicle centreline, or

- a 236 mm x 236 mm probe, with a horizontal angle of [30]° ±0.5°, along the longitudinal axis of the vehicle and at a known offset from the most lateral aspect of the vehicle.

Test houses undertaking approval tests to UN Regulation No. 127 or UN Regulation GTR No. 9 will already possess the capability to apply a 236 mm x 236 mm probe to the front of a car in order to determine the bumper corners. The difference with this application is that the horizontal angle includes 15° as well as 30°.

3.2 Features sharing other functional requirements

It is important to ensure that the front end of a bus performs well in other crash and failure modes, such as with other buses, HGVs and cars. This would require certain strong structural members within the broad VRU contact area. It is advised that protection in these other modes is considered at the same time as making the design

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changes aimed at protecting the VRUs. This is needed to deliver protection to both the bus drivers and the VRUs.

One option is to use UN Regulation 29 (with regard to the protection of the occupants of the cab of a commercial vehicle), and this has already been used by some manufacturers. The geometry of category M3 buses is quite different to other vehicles, so the geometric and structural interactions with other vehicles must be carefully considered, and other tests may also be relevant. TfL is not yet making any requirements on this topic, but is recommending any new bus designs consider the interactions with a wide range of collision partners. For iterative, evolving designs this is unlikely to present a problem, but for those bus fronts designed with a substantially different front end geometry, then additional care should be taken over preserving safety for the driver and for ensuring crash compatibility for collisions with other road users.

4 Ongoing observations

4.1 Glare and visual artefacts

In discussions around these geometric requirements, two issues have been raised as potential disbenefits associated with the improvements for vulnerable road user protection. These are:

- That the vertical rake of the windscreen may refract light from overhead sources (such as street lights and the sun) creating glare for the driver.
- That the horizontal curvature of the windscreen may create apparitions or visual artefacts that distort direct vision for the driver, particularly towards the corners of the screen.

These enhanced requirements will take design envelopes for bus front end geometry beyond that of existing designs. Though unlikely, it is possible that the new designs are susceptible to these issues. Therefore, operators should be mindful of the potential and will be expected to log and feedback any potential issues, if substantiated reports become available.

Attachment 40: Bus Front End Design – Wiper Protection Guidance Notes

(Vulnerable Road User (VRU) Frontal Crashworthiness)

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1 Introduction

Bus fronts have been identified as one of the key contact causing parts of the vehicle in collisions with Vulnerable Road Users (VRU). Therefore, all bus front ends, in the region of potential head contacts, are required to have a construction that absorbs energy and protects VRUs in the event of a contact at that location on the vehicle.

As such, all buses shall have their VRU impact testing performance assessed against the associated VRU impact testing protocol. All buses shall have front ends which are energy absorbing or sufficiently compliant or frangible to meet the performance requirements.

This document sets out the guidance notes related to the assessment of VRU Impact Performance in the specific aspect of windscreen wipers. These guidance notes are aimed at bus operators and manufacturers 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 a manufacturer of the bus or system 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 manufacturers/suppliers.

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

The windscreen wiper requirements may be assessed against a new build bus.

2.1 Compliance and warranty

A bus operator should ask to see one of two things from the bus manufacturer.

a) A statement confirming that the windscreen wipers are mounted at a height greater than 2.0 m from the ground plane – making them exempt from impact testing

b) If mounted at or below 2.0 m, a VRU Impact Performance test report confirming that when impacted at the worst case location, the head injury criterion (HIC_{15}) value did not exceed [1,300].

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2.2 Interpreting the requirements and selecting the most effective way to fulfil them

The most effective way of controlling head injury risk through potential contacts with the windscreen wipers is to move the mounting points out of the likely regions of the bus front end that may be contacted in a collision. Citing them above 2.0 m fulfils this requirement for most of the vulnerable road user population.

Another method of mitigating injury risk is to make the structures compliant, frangible or shielded by a protective element. The extent to which this has been achieved can be assessed practically through the impact test protocol. Assuming that the windscreen wiper is no more injurious than the surrounding region of the bus front end, then this secondary approach may be considered as an appropriate alternative to repositioning the wiper mounting points.

2.3 Direct vision

If the windscreen wiper mounting points have been altered between bus design iterations, then care must be taken to ensure that the swept area of the windscreen is at least maintained. This must still be compliant with direct vision requirements.

2.4 Indirect vision

The nearside mirror of a bus may be visible to the driver though the swept area of the windscreen. If this is the design philosophy adopted by a manufacturer, then this requirement should be preserved.

3 Training

3.1 For test houses

Test houses accredited to undertake approval tests to UN Regulation No. 127 or UN Regulation GTR No. 9 will be considered suitable to undertake performance tests. Test houses without such accreditation will be required to demonstrate to TfL at their expense that they can achieve the same standard of testing as an accredited organisation.

3.2 Bus maintenance engineers

The engineers carrying out general bus maintenance should be aware that access to the windscreen wipers may be more difficult with them mounted at more than 2.0 m from the ground. This is considered to be a minor effect.