LONDON BUS SERVICES LIMITED

Specification for New Buses: Attachments

Version 2.4

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1 Preface

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

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

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

2 Disclaimer & Copyright

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

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Attachment 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 reflect 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 service to issue LBC certification.

2 Normative References

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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.

- 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

For the purpose of this Protocol:

Kerb Weight:

- **ECU**: Electronic Control Unit
- **GVW:** Gross Vehicle Weight is the maximum weight of the vehicle permitted by law or defined by the vehicle OEM, whichever is the lower.
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **Passenger load**: The passenger load is a mass equal to the number of passengers multiplied by 68 kg plus 75kg to represent the driver.
- **Payload capacity:** is the GVW minus the ULW.

- **Test Bus:** is the vehicle being assessed for its emissions performance
- **Test Service:** The test service is an organisation designated by TfL to ensure comparative standards and quality of testing is achieved. Only an accredited testing authority service can be used, a list of approved authorities is available on request to TfL
- **Test weight:** Is the total mass of the vehicle at which testing shall be undertaken and is equal to the ULW plus the passenger load
- **ULW**: Unladen weight of the bus when all fluid levels are filled to recommended levels but no driver, passengers or luggage are on board.

4 Vehicle Preparation

The Test Bus shall be provided either by the OEM or by TfL. It shall be specified in accordance with the full applicable requirements of the London bus specification with respect to features required as part of this test.

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

OEMs 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 service and TfL. A software ID and serial number will be noted by the test service and recorded on the test certificate issued. Any adjustments will be noted by the testing service. 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.

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

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

a) 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.

b) 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).

Wheels and tyres shall meet the OEMs specifications. Tyre pressures shall be set to the OEM’s recommendation and shall be the same for both track coastdown and dyno tests.

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 OEM specification. Track coastdown and dyno tyre pressure must be the same.

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

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

Testing shall in principle follow UNECE Regulation 101, whole vehicle testing procedure for passenger cars, with regards to the capabilities of the test facility. 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.

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.

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

Drivers cab demisters shall be turned on to full.

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

Interior heating shall be set at 17°C ± 2°C (if not automatically controlled) 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 warmup phase of the test procedure. Doors shall remain closed throughout the warmup phase.

The Test service shall monitor the temperature in the centre aisle. 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:

a) Lower Saloon, 1m above the saloon floor
b) Centre front of bus (0.5m from windscreen)
c) Centre of middle aisle
d) Centre rear (0.5m from back of bus)
e) Next to front windscreen demister vent

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)

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

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

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

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

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.

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.

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

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.

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.

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.

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

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 NO_x, NO, NO_2, HC, CO, CO_2 at 1 Hz
b) Tailpipe NO_x, NO, NO_2, HC, CO, CO_2 at 1 Hz

c) FTIR at tailpipe (NO, NO_2, N_2O, methane (CH_4), NH_3)

d) Particle number to PMP method

e) Three dilute ‘bags’ collected and analysed for NO_x, CO, HC & CO_2

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

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 $CO_{2\text{-}e}$.

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

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.

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)			

Where:

- $CO_{2\text{-}e}$ is equivalent CO_2 due to non-CO_2 Greenhouse Gases at tailpipe
- $CO_{2\text{-}Tot}$ is Total CO_2, the combination of tailpipe CO_2 and $CO_{2\text{-}e}$

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

5.3 Battery Electric Buses

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.

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.

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).

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.

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 OEMs recommended equipment and process. OEMs must liaise with the test house to ensure the correct charging equipment is provided for vehicle charging.

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.

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

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.

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

The OEM 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.

The OEM shall declare the minimum SOC that the vehicle will operate normally at, as well as the maximum available on-board energy that can be used for vehicle operation in kWh.

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.

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.

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.

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.

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

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

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

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

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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 Services Limited New Bus Specification: Section 5.4
- 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 Calibrators
- 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 Speech Intelligibility Index”

3 Definitions

- **Articulation Index (AI)** - 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.
- **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.
- **Decibels (dB)** - 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.

- **L_{EQ} -** 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
- **Maximum SPL** - The peak value of SPL recorded during any given measurement period.
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **Sound Intensity** - 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).
- **Sound pressure level (SPL) -** 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.

4 Test Site

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

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

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

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

6 Instrumentation

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

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

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.

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

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

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

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

8 Dynamic tests

8.1 General

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

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

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

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

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

8.2 Exterior

8.2.1 Vehicles with Internal Combustion Engines

Tests shall be undertaken as defined in UNECE R51-03

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.

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.

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

The tests shall be completed with cooling fans disabled.

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

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.

It is expected that the OEM 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.

8.2.3 Stationary Vehicle Sound Emissions and Compressed Air Noise

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

8.2.4 ECE R51-03 Improved

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

8.3 Interior

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.

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.

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

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

All measurements shall be A-weighted, fast response.

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

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

Arithmetic average to be declared.

9.2 Exterior

9.2.1 Door Warning Device(s)

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.

Maximum SPL shall be declared.

Requirements are applicable to each door.

9.2.2 Ramp Warning Device(s)

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.

Maximum SPL shall be declared.

Applicable to each ramp fitted.

9.3 Interior

Interior measurements for 9.3.3 and 9.3.4 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.

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.

9.3.1 Door Warning Device(s)

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.

Maximum SPL shall be declared

Requirements are applicable to each door.

9.3.2 Ramp Warning Device(s)

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.

Maximum SPL shall be declared.

Applicable to each ramp fitted.

9.3.3 Engine Idle, HVAC system off

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

9.3.4 Engine Idle, HVAC system on

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

10 Articulation Index (AI)

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

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

Average of AI values to be declared.

11 Sound Pressure Level Limits

Table 2_1. Noise Limits for all powertrain types

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	8.2.3 ECE R51-03 “Compressed Air” , Exterior	72	N/A
Both	8.2.4 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	9.3.11 Door Warning Device, Interior	75	N/A
Both	9.3.22 Ramp Warning Device, Interior		N/A
Both	9.3.3 Powertrain Idle, HVAC off, Interior	50	
Both	9.3.4 Powertrain Idle, HVAC on, Interior	72	

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.

Attachment 3: Fleet Management Systems (FMS)

1 Introduction

This initial specification sets out as mandatory and desirable implementation of the Fleet Management System (FMS). At some point in the near future desirable requirements will be substantially enhanced and made mandatory. Bus-FMS CAN to IP Network Bridge will be provided by London Buses.

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Attachment 4: Installation Specification for Fleet Management Systems (FMS) and London Bus Services Limited New Bus Specification: Section 6.4.2

2 Mandatory

2.1 FMS v3

All buses will be supplied with FMS version 3 implemented.

The data required from the interface is shown in Table 3_1 below.

Parameters for Bus-FMS Version 3	Data required
1.1.1 Fuel Consumption: LFC 7	Yes
1.1.2 Dash Display: DD 8	Yes
1.1.3 Electronic Engine Controller #1: EEC1 9	Yes
1.1.5 Vehicle Identification: VI 11	No
1.1.6 FMS-standard Interface Identity / Capabilities: FMS 12	Yes
1.1.7 High Resolution Vehicle Distance: VDHR 14	Yes
1.1.10 Ambient Conditions: AMB 18	Yes
1.1.12 Fuel Economy: LFE 20	Yes
1.1.15 After treatment 1 Diesel Exhaust Fluid Tank 1 Information: AT1T1I 23	Yes
1.3 Parameters for Bus FMS-Standard	
1.3.1 Cruise Control/Vehicle Speed: CCVS 36	Yes
1.3.2 Electronic Engine Controller #2 : EEC2 38	Yes
1.3.3 Door Control 1: DC1 39	Yes
1.3.4 Door Control 2: DC2 40	Yes

Table 1_1 Parameters for Bus-FMS version 3

In the event that the data items detailed in Table 3_1 are not available a formal request to LBSL shall be made for a concession.

LBSL has a specific requirement for the use of the following data items listed in Table 3_2 below.

1.1.10 Ambient Conditions: AMB 18	This will be the temperature of the upper deck measured at an agreed location.
1.1.16 FMS Tell Tale Status: FMS1 24	No mandatory alarms are defined for buses. London buses will work with suppliers to agree the mandatory set.
1.3.3 Door Control 1: DC1 39	Monitor open/closed the status of the door. Monitoring the deployment of the wheelchair ramp.
1.3.4 Door Control 2: DC2 40	Status of each of the doors, Door 1 = front door Door 2 = middle door Door 3 = rear door on New Route Master only. Locked refers to Conductor mode. Note – driver only/crew mode is a separate input from Door Control.
1.3.5 Time / Date : TD 41	GMT

Table 3_2 LBSL Specific use data requirements

Where the data item is a measured value LBSL requires the accuracy of the data items reported along with documentary evidence. Should LBSL consider the accuracy of the data provided not fit for purpose LBSL will work with the supplier to improve the accuracy such that it is fit for purpose.

2.2 Details of the location and physical interface.

Specification of the capability of the Bus-FMS CAN Interface. This should include, as a minimum, configuration management and support for remote Operational Management.

3 Desirable

3.1 Capability

The data items listed in Table 3_3 are desirable and thus if available with the current implementation should be made available. If not available a plan should be put in place and agreed with LBSL to provide the data.

1.1.4 Engine Hours, Revolutions: HOURS 10
1.1.8 Tachograph : TCO1 15
1.1.9 Engine Temperature 1: ET1 17
1.1.14 High Resolution Fuel Consumption (Liquid): HRLFC 22
1.1.16 FMS Tell Tale Status: FMS1 24

Table 3_3 LBSL desirable data requirements

The following data element in Table 3_4 is under consideration and should be discussed with London Buses.

1.3.8 Air Suspension Control 4 : ASC4 44

Table 3_4 LBSL data under consideration

3.2 Operability

London Buses need to ensure that the implementation of FMS across the entire fleet is supported by the capabilities to operate FMS with minimal day to day involvement. The specification below will be required and will be finalised through discussions with suppliers.

3.2.1 Configuration Management

It shall be possible for the user to configure the interface to enable the data elements required and set the repetition interval as defined by the FMS specification.

It shall be possible to configure the FMS gateway remotely via either

- Bus-FMS CAN to IP Network Bridge using a standard protocol – TBD

OR

- A LAN port on the Bus-FMS CAN Interface using a standard protocol – TBD

3.2.2 Operational Management

The Bus-FMS CAN Interface will:-

- Initialise at ignition on.
- Maintain the configuration.
- Generate alarms when the device is faulty or the CAN input has failed.
- Provide monitoring & diagnostics capabilities to allow analysis of the data provided and interface.

3.3 FMS Energy Extensions

Following consultation LBSL require delivery of additional data from the CAN BUS which give a clear view on the energy consumption per bus for Hybrid, Electric and Fuel Cell buses. This data shall be provided through an FMS2IP bridge. This will require substantial development on behalf on the OEM's. This desirable requirement hereby gives notice that these development should be initiated. The data required is in table 3_5 below.

Parameter	Unit	Sample time (s)	Resolution	Range	Bits	Bytes	Data Source	PGN	SPN
Brake pedal position	%	0.1	1%	0-100%	7	1	Brake pedal		521
Operational mode	unit	1	Off/EV/Hybrid/En-route charge/Overnight charge		3	1	Powertrain control system		
Power Pack charge/discharge (battery)	kW	1	0.5kW	-3000 to 3000	16	2	BMS		
Power Pack Voltage	V	1	0.1V	0 to 3000	16	2	BMS		
Power Pack Current	I	1	0.1A	-3000 to 3000	16	2	BMS		
Power Pack charge/discharge (supercap)	kW	0.1	0.5kW	-3000 to 3000	16	2	BMS		
Power Pack Voltage (supercap)	V	0.1	0.1V	0 to 3000	16	2	BMS		
Power Pack Current (Supercap)	I	0.1	0.1A	-3000 to 3000	16	2	BMS		
Power Pack SoC (Supercap)	%	0.1	1	100%	8	1	BMS		
Power Pack SoC (Battery)	%	1	0.5	100%	8	1	BMS		
Diesel heater fuel tank level	%	10	0.01	100%	7	1	Vehicle CAN		
Ancillary power	kW	1	0.1kW	0-50	9	2	Ancillary sub-system output (e.g. HVAC)		

Traction power	kW	1	0.1kW	-3000 to 3000	16	2	Motor Input		
Phase shift									
Traction Voltage	V	1	0.1V	0 to 3000	16	2	Motor Input		
Traction Current	I	1	0.1A	0 to 3000	16	2	Motor Input		
Generator output	kW	1	0.1kW	0 to 3000	16	2	Generator output		
Phase shift									
Generator Voltage	V	1	0.1V	0 to 3000	16	2	Generator output		
Generator Current	I	1	0.1A	0 to 3000	16	2	Generator output		
En-route charger Power	kW	1	0.1kW	0 to 3000	16	2	Rectifier output at the Vehicle side		
En-route charger Voltage	V	1	0.1V	0 to 3000	16	2	Rectifier output at the Vehicle side		
En-route charger Current	I	1	0.1A	0 to 3000	16	2	Rectifier output at the Vehicle side		
Phase shift									
Overnight charger power	kW	1	0.1kW	0 to 3000	16	2	Rectifier output at the Vehicle side		
Overnight charger voltage	V	1	0.1V	0 to 3000	16	2	Rectifier output at the Vehicle side		
Overnight charger Current	I	1	0.1A	0 to 3000	16	2	Rectifier output at the Vehicle side		
Phase shift									
Ignition	1/0	1	binary	1/0	1	1	Ignition key activation		
Mean Power Pack1 temp limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Max cell temp in the Power Pack1 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Min cell temp in the Power Pack1 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Mean Power Pack2 temp limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Max cell temp in the Power Pack2 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Min cell temp in the Power Pack2 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Mean Power Pack3 temp limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Max cell temp in the Power Pack3 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Min cell temp in the Power Pack3 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	

Mean Power Pack4 temp limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Max cell temp in the Power Pack4 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Min cell temp in the Power Pack4 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Mean Power Pack5 temp limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Max cell temp in the Power Pack5 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	
Min cell temp in the Power Pack5 limits exceeded	On/off	1	Binary	1/0	1	1	BMS	Tell-tale	

Table 3_5 Vehicle CANBus data requirements and details

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

1 Introduction

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

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Attachment 3: Fleet Management Systems (FMS) and London Bus Services Limited New Bus Specification: Section 6.4.2

2 Definitions

- **Cable** - A generic term used for a wire or loom 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 -** 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

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.

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

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.

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

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.

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

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

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.

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.

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.

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.

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.

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.

All access panel fastenings shall be captive.

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.

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.

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

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.

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.

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

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

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

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.

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

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

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

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

Attachment 5: Driver-Passenger Two-Way Communication Protocol

1 Introduction

This attachment provides specifications, test methods and test values for Driver-Passenger two-way communication systems system as required by the main specification document.

The two-way communication system should allow adequate communication between driver and passenger, regardless of accessibility needs. This protocol sets out the design, feature and performance requirements in order to implement such a system for use on buses within the TfL fleet.

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.2.1.

2 Scope

These requirements apply 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.

3 Normative References

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

- London Bus Services Limited New Bus Specification: Section 4.2.1
- London Bus Services Limited New Bus Specification: Section 6.4.1

4 General Requirements

The driver/passenger 2-way intercom system shall provide an enhanced amplification for both driver and passenger to achieve clear speech at the front entrance platform, and driver cab area.

The system activation shall be fully automatic and require no operation by the passenger.

The system shall incorporate: -

- Driver - Press to Talk button (PTT) - cab microphone – cab speaker
- Passenger - one or more microphones – one or more speakers
- Override function - to allow for driver instructions when doors are closed

Microphones shall be of the close-proximity directional type to ensure only conversations in the immediate area around the cab can be heard. Further development work is being undertaken in this area to refine microphone directionality if necessary.

Speakers shall be a minimum of 5 watts and similar in size and design to the current iBus speaker.

The system performance shall be such that it allows for comfortable speech levels at the platform area of those expected within a busy bus environment.

5 Passenger Platform Area

The system shall be installed such that it does not require passengers to speak directly into a mounted microphone for clear communications to take place.

The microphone shall be mounted at a height of not less than 2m measured from the platform floor, and angled, directed at the front entrance door.

The platform microphone shall be mounted to one of the following areas:

- The panelling above the cab door
- The roof
- To the side of the cab door.

The microphone should not be mounted on the cab door, frame or panels exposed to high vibration or shock levels.

The microphone range performance must be capable of providing good coverage, such that the driver is able to clearly hear a passenger speak when either standing or sitting (e.g. a wheelchair user) on the pavement/ground at the entrance door.

The speaker performance shall reproduce comfortable volume levels, clear speech and be mounted such that it provides good coverage to someone at the platform and is audible to someone either standing or sitting (e.g. a wheelchair user) on the pavement/ground at the entrance door.

6 Driver Cab

The driver PTT button and microphone shall wherever possible be mounted in a position and close proximity to the partition screen to encourage the driver to face passengers when communicating. Care must be taken with the layout to ensure an ergonomically design in consideration of reducing the driver's overall movement.

7 System Activation/ Deactivation

The system activation shall be fully automatic and have a control logic capable of integration with CAN bus in order to receive the front door open signal for system activation/deactivation.

A separate override function to allow for speech while the doors are closed shall also be incorporated. The use of the override function shall only be possible with the park brake engaged. The override function must remain deactivated at all times while the park brake is disengaged.

The system once activated shall illuminate the PTT button to alert the driver that the system is live, and extinguished once doors are closed and system is deactivated. The passenger platform microphone or microphone housing must also incorporate a discrete LED to illuminate and function in the same way as the PTT.

8 Testing/Sound Level Settings

The volume control level for speakers and microphones shall be set during installation and commissioning. The volume control switch for adjustments shall be behind panelling requiring tools to remove. Volume adjustments shall be carried out by engineering staff only.

During testing and sign off special attention must be given to ensure there is no feedback or other interference present, both during system activation, and speech taking place. Further testing must also be carried out while other radio and driver announcement systems are being used to ensure no feedback or other interference is present.

Using a class 1 calibrated sound meter

Sound meter measurement position	Test heights (meters)	Speaker Volume	Driver microphone test message 70db
Driver Cab	1.0m from seat cushion (mid height adjustment)	70db	
Platform:- (i) centre (ii) step	1.2 1.45 } from floor 1.7	70-75db	70-75db
At entrance door	1.2 1.45 } * Note 1.7	70-75db	70-75db

*From pavement/ground bus at ride height

9 Compliance

The system control and management devices must be E marked for automotive use.

10 Development for New Buses

During the design and installation of the Driver-Passenger Two-Way Communication systems, TfL would like to introduce additional functionality and integration with other systems.

a) The CCTV system to record and retain audio files at the driver cab/platform during system activation. (Where operators choose to install the optional functionality for recording/retention of audio files. The General Data Protection Regulations (GDPR) must be fully complied with as defined in the Specification for new buses section 6.4.1)

b) The Induction Loop system at the driver cab/platform during system activation.

c) The driver PA system

These system integrations will deliver additional driver and passenger safety benefits and accessibility enhancements. Integration will also reduce hardware duplication such as microphones and speakers to decrease clutter and improve driver cab ergonomics.

This specification sets out the minimum performance requirements. However, TfL would welcome suggestions from operators and OEMs on higher specifications standards and/or innovative solutions.

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.

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 4.1

2 Scope

These requirements apply 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.

3 Normative References

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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 Services Limited New Bus Specification: Section 4.1
- UNECE Regulation 118-03 (Revision 02, Amendment 01) - Uniform Technical Prescriptions Concerning the Burning Behaviour of Materials Used in the Interior Construction of Certain Categories of Motor Vehicles.
- BS5852 – Methods of test for the assessment of the ignitibility of upholstered seating by smouldering and flaming ignition sources.
- ECE Regulation 100-R02 – Uniform Provisions Concerning the Approval of Vehicles with Regard to Specific Requirements for the Electric Power Train.

4 Requirements

4.1 Vehicle Body Components

Each OEM must verify that all components of their products meet the technical requirements of UNECE Regulation 118-03 (Revision 02, Amendment 01). This will apply to Category M3, Class I vehicles via any approval route. OEMs will be expected to demonstrate that adequate arrangements are in place to ensure that subsequent products continue to meet and conform to the approved type and to monitor these arrangements to be effective during the life of the approval.

For vehicles fitted with an electric powertrain, the UNECE Regulation 118-03 (Revision 02, Amendment 01) definition of “Engine compartment” (section 2.3) shall in addition include any compartment that contains one or more of the following electric drivetrain components.

- Rechargeable energy storage system used for traction energy
- DC-DC convertor
- Traction motor
- Power invertor
- Onboard charger
- Power electronics controller
- Air compressor

4.2 Seat Assemblies

In addition to the requirements set out in UNECE Regulation 118-03 (Revision 02, Amendment 01), seat assemblies shall pass the criteria when tested to BS5852, Crib ignition source 7 and smouldering cigarette test; ignition source 0.

4.3 Rechargeable Energy Storage Systems (RESS)

Where the vehicle incorporates a Rechargeable Energy Storage Systems (RESS) as defined in ECE 100-R02 – Uniform Provisions Concerning the Approval of Vehicles with Regard to Specific Requirements for the Electric Power Train, then the RESS should meet the requirements of this Regulation via any type approval route.

From **September 2024**, all vehicle Rechargeable Energy Storage Systems shall be meet and be certified to ECE 100-R03, via any type approval route.

4.4 Operational Requirements

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

4.5 Replacement Parts

Replacement parts supplied by the manufacturer must achieve, or exceed, the same fire-resistance ratings as that supplied originally.

4.6 Compliance

Vehicle manufacturers are required to provide an auditable self-certification evidence pack of compliance with requirements in sections 4.1 – 4.3, per each vehicle model. Evidence pack shall as a minimum include a bill of materials within scope of the requirements, and corresponding approval certification reference information. For model variants i.e. minor interior options or alternative vehicle lengths, an evidence pack only detailing changes from the full bill of materials evidence pack for that model is required.

Attachment 7: Wheelchair Floor Logo

1 Introduction

This document provides a description of the requirements for Floor Logo to be situated in the demarcated wheelchair area of a bus.

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 7.

2 Scope

These requirements apply 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.

3 Purpose

The purpose of this document is to define the requirements for the Wheelchair Floor Logo.

4 Normative References

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

- London Bus Services Limited New Bus Specification: Section 7
- London Bus Services Limited New Bus Specification: Attachment 33 Slip Prevention Assessment Protocol
- London Bus Services Limited New Bus Specification: Attachment 33 Slip Prevention Guidance Notes

5 Wheelchair area floor covering

The wheelchair logo shall be incorporated into the floor covering which identifies the designated wheelchair area.

6 Dimension requirements

The wheelchair floor logo shall be of identical style to that shown in Figure 7_1 and to the dimensions as shown ± 10% as shown in Figure 7_1.

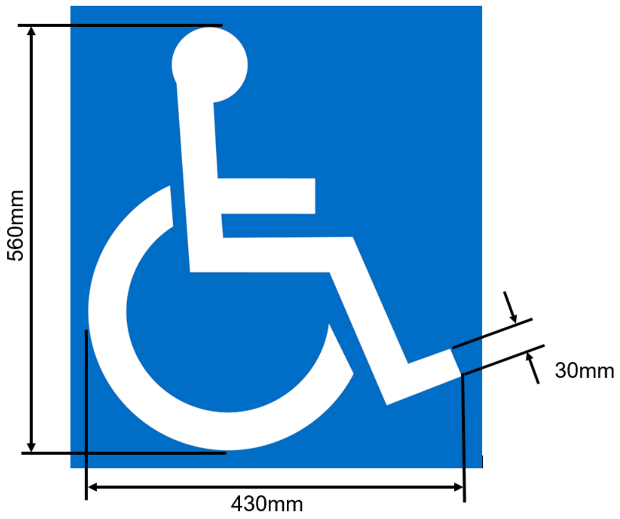


Figure 7_1 Wheelchair Logo

7 Colour requirements

The floor covering used across the whole Wheelchair bay, as shown by OEM's drawings, 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.

8 Slip prevention requirement

Material used for the floor logo must conform to the slip prevention assessment protocol and guidance notes found in Attachments 32 and 33 respectively.

9 Location and Orientation requirement

The logo in the wheelchair bay should always be positioned, readable by a person standing on the longitudinal centreline of the vehicle, in such a way to demonstrate the location and orientation which the wheelchair should be positioned. The logo must be located entirely within the bounds of the wheelchair bay, with positional requirements as detailed below:

- The longitudinal (vehicle X axis) centre line of the floor logo should be on the centre line of the vertical wheelchair back board ± 55mm.
- The lateral (vehicle Y axis) centre line of the floor logo should be no more than 550mm from the wheelchair back board ± 55mm.

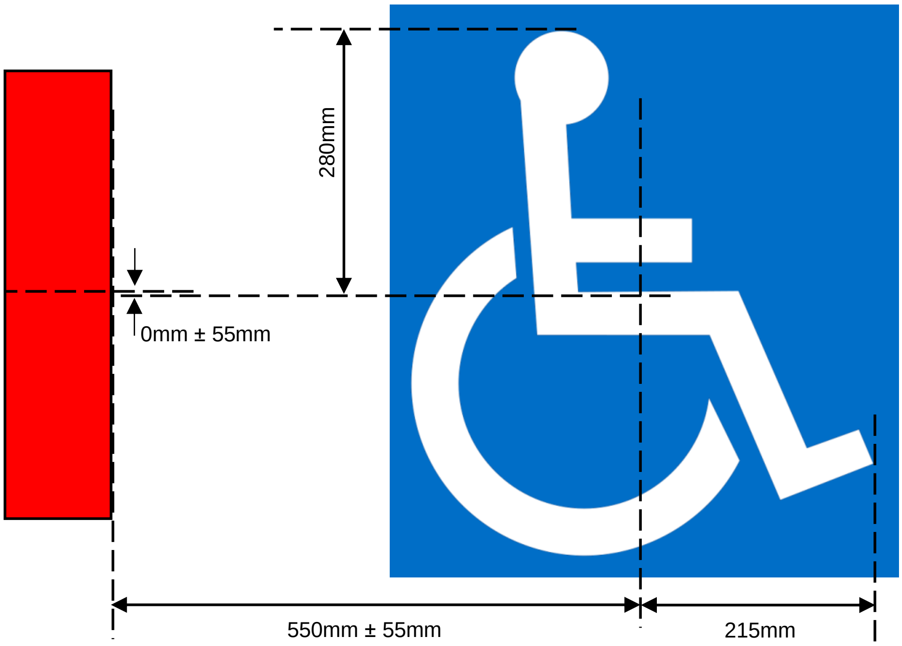


Figure 7_2 Wheelchair logo longitudinal and lateral location relative to back board

Attachment 8: Staircase Handrail Layout

1 Introduction

This document provides a description of the requirements for Handrail layout to be situated by the staircase of a double-deck bus.

2 Scope

These requirements apply to all new double-deck 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.

3 Purpose

The purpose of this document is to define the requirements for the Staircase Handrail Layout.

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 New Bus Specification: Section 4.5.1 – 4.5.3

5 Dimension requirements

The size and layout of the staircase and handrail shall be as shown below, Figure 8_1. All positional dimensions given shall be achieved within a tolerance of [± 10]mm. (Tolerance applies to position/placement of handrail as shown in Figure only. Any other dimensions, such as handrail diameter, should be separately assessed as appropriate).

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

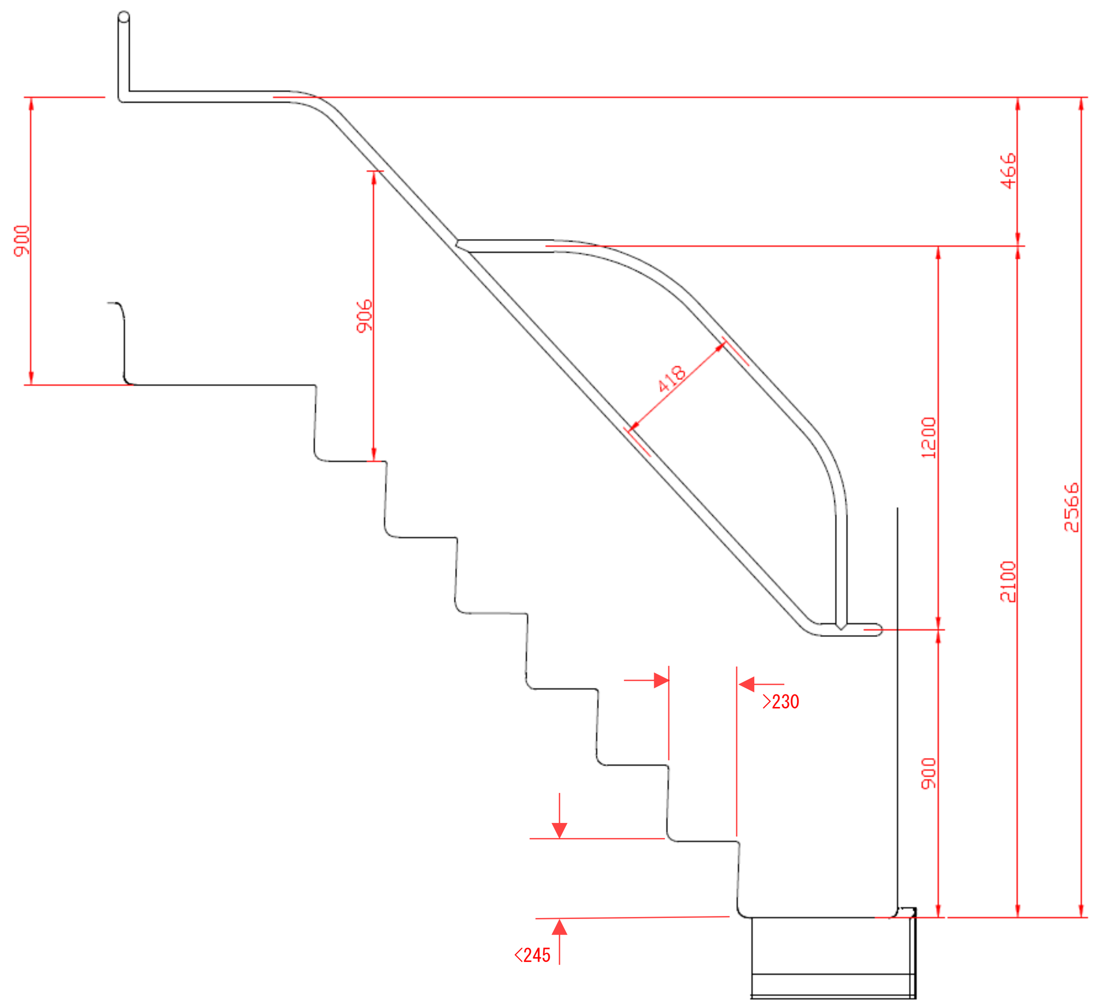


Figure 8_1 Staircase handrail dimensions given in mm

6 Handrail construction and arrangement

All handrails must be securely fixed to body structure.

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

No potential hand traps shall be permitted.

Continuous rails are the preferred arrangement.

Rails must be of a continuous profile throughout.

Attachment 9: Heating Ventilation and Air Conditioning (HVAC)

A Draft Version of this Attachment is available for review and consultation on the BVS Database

Attachment 10: Destination Display Output

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 10

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

1 Introduction

This attachment provides hardware, functionality and performance requirements for CCTV systems fitted to buses entering the LBSL fleet as laid out in the main specification.

For full understanding of this Attachment it should be read in conjunction with the New Bus Vehicle Specification, Sections 4.3.5.1 and 6.4.1.

2 Scope

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

3 Purpose

The objective of this Attachment is to detail the hardware and performance requirements for CCTV systems fitted to buses entering the LBSL fleet.

4 Normative references

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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 Service Limited New Bus Specification Section 4.3.5.1
- London Bus Service Limited New Bus Specification Section 6.4.1
- ONVIF™ Media Service Specification - Version 21.12
- ONVIF™ Media2 Service Specification - Version 21.12

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
- **CCTV:**– Closed Circuit Television
- **NMEA -** National Marine Electronics Association

- **NVR:-** Network Video Recorder
- **LAN:** – Local Area Network
- **ONVIF:-** Open Network Video Interface Forum

6 General Specification

6.1 Connectivity

The NVR shall have the following interfaces:-

- A Local Area Network (LAN) interface, presented as Ethernet through an RJ45 connection.
- An integrated 4G/5G modem.

For the integrated Mobile Network modem, there is a preference that this modem fits within the Network Video Recorder (NVR), thus minimising installation cost and footprint.

The LAN and modem interfaces shall be password protected and have multiple levels of access i.e. administration, user, read only.

The NVR's interface shall be ONVIF profile G compliant and accessible via the LAN or modem to allow full control of the NVR. The specification, protocols used and command strings will be provided to LBSL on request.

LBSL reserves the right to use these interfaces.

6.2 Function

a) The image resolution shall be 720p or better, 720p will be set as a default.

b) Each camera input shall be capable of recording at 25 frames per second at the maximum image size and highest image quality concurrently.

c) The CCTV system shall have the flexibility to select the frame rate for each individual camera up to the maximum rate.

d) The NVR shall support a minimum total global frame rate of 100 frames per second.

e) The NVR shall support 16 camera inputs as a minimum.

f) The NVR shall have an easily removable hard disc for external monitoring or ability to be downloaded via external connection.

g) Bus data to be recorded on the disc drive

h) Bus road speed taken from the GPS, foot brake application and traffic Indicator "left and right" recorded with date and time identification

i) Recording not to be displayed on driver's cab monitor or passenger monitor

j) All images shall be watermarked or equivalent.

k) The NVR shall have the capability to record an audio input from two or more microphones.

l) The NVR shall use a high compression video codec to encode and store the image data on the hard disk, this shall be the following:-

- ITU-T H.264 that meets the requirements of:
  - https://www.onvif.org/specs/srv/media/ONVIF-Media-Service-Spec.pdf
  - https://www.onvif.org/specs/srv/media/ONVIF-Media2-Service-Spec.pdf

Note: the use of any other codecs not referenced in ONVIF is prohibited

The NVR shall be able to dual stream i.e. code an image at different rates such that a low rate can be streamed for Live CCTV and a higher rate recorded to disk for collection later. This shall be possible with the codec listed in 6.2L above.

The NVR shall be Live Closed Circuit Television (CCTV) capable so that should LBSL decide to rollout Live CCTV in the future the NVR will support this, more specifically:-

- The NVR shall have the capability to stream video through either of the interfaces, LAN and modem, to a control and management system developed for the solution.
- Live streaming shall be ONVIF Profile S or Profile T compliant
- The system shall have a documented interface from the control and management system that is made available to TfL for use in a potential Central CCTV Control and Management system.

The system's control and management system shall be able to:-

- Manage the video stream i.e. start/stop, pause, Fast Forward, Rewind during the event etc.
- Select the camera required.
- Select multiple cameras in thumb nail form.
- Manage the parameters that control the quality of the video stream.
- Perform System Administration and Operations and Maintenance functions.

The unit shall have an NMEA compatible Global Positioning System (GPS) interface.

The system clock shall have a resolution of 1 second and the time will be maintained to an accurate to +/- 10 seconds

6.3 Diagnostic Interface

The unit shall have the TfL diagnostic interface implemented and approved for use with iBus.

The LAN interface of the NVR will be made available to LBSL for diagnostics and other uses agreed at a later date.

6.4 Cameras

- All cameras shall be digital, ONVIF Profile S or Profile T compliant, and antiglare
- The cameras used shall be high quality colour 720p or better with day/night or low light capability
- The camera shall have an SNR of equal or greater that 50 dB in colour
- The camera shall support a mini ambient light level in colour of 0.5 lux
- All cameras must be housed in a Vandal Resistant Dome or Concealed
- Wide angle lenses utilised where necessary to improve vision coverage as identified on Bus type layout drawings submitted for TfL review and upload to the TfL BVS Database

6.5 Displays

The displays shall be LCD colour monitors.

All the displays shall show the time which is derived from the system radio adjusted clock.

The display shall be available in the following sizes:-

- 5” or equivalent suitable for locating in the drivers cab
- 15” or equivalent suitable for placing in the passenger area

6.6 Type Approval

The CCTV systems shall be designed to operate in a public transport environment. The operator will be required to supply type approval for:-

- E Mark
- Electromagnetic Compatibility
- Shock and Vibration
- Temperature
- Water ingress

Note: the CCTV system comprises the NVR, Cameras, intermediate cables, screens, connectors and any ancillary equipment.

The integrity of the type approval shall be maintained throughout the life of the contract.

The cameras should be rated as IP65 as a minimum.

7 Implementation

7.1 Installation

The CCTV systems shall be built in accordance with the TfL CCTV System Installation Guidelines. The key aspects of this are:-

- LBSL approval of the installation, the operator will present the installation instructions for approval prior to build.

- Documentation, the operator shall maintain the documentation for each build type and make them available for LBSL inspection.
- Co-existence with iBus, where possible the NVR shall be placed in the same location as the iBus unit.
- The NVRs shall be designed to work with the bus native power supply; any additional equipment necessary for this shall be considered part of the CCTV system.
- The NVRs shall remain on for 20 minutes once the ignition has been turned off.
- Installers of the CCTV system should be accredited to FCS 1362 (formally MPT 1362) or equivalent.

LBSL reserve the right to inspect the installation at source to ensure the standards are being applied appropriately.

7.2 Configuration

The image quality configuration parameters will be set to a TfL default as a minimum.

Each camera will be set to a frame rate as defined by TfL as shown in Table 11_1 below.

Location	Reference	Frame rate
Entrance/Exit Platform, wheelchair space and Passenger / Driver Interface	A1, A2	4
Rear of interior seated area	A3, C1	4
General passenger space	A4, B1, C2, C4	4
Forward facing to road	A5	4
Driver's Cab	A6	4
Stair Well	C3	4

Table 11_1 Camera frame rate parameter requirements

Note: The reference refers to the camera locations specified in section 7.3.

The operator will ensure that the parameters in Table 11_1 are maintained throughout the life of the contract.

TfL may choose to change this throughout the lifetime of the contract.

Note: The parameters will only be changed in exceptional circumstances.

The NVR will provide a minimum of 240 hours of storage space for each bus at the quality and frame rates defined above. The dimensioning of this should account for operating environment i.e. level of movement and lighting conditions.

If the operator uses the CCTV system beyond the minimum requirement set out here any additional CCTV resources that are required shall be supplied by the operator such that minimum requirements set out in this specification are met.

7.3 Camera Locations

The cameras shall be identified on the NVR system by the camera alpha numeric code as shown below (When two are cameras used to cover one location /1 or /2 should be added). Cameras must be located in accordance with the following guidelines for monitored areas with the area identified on channels as shown and as on Bus type layout drawings submitted for TfL review and upload to the TfL BVS Database.

All operator required additional cameras identified on subsequent channels as O13, O14 and above as necessary.

7.3.1 Mandatory All Buses (SD, DD)

- Entrance Platform and Passenger / Driver Interface (Channel 1)
- Exit Platform, Wheelchair Space and Deployed Ramp Area -Viewing Wheelchair Space only on Single Door Buses under 9m (Channel 2)
- Two cameras at rear of interior seated area looking forwards covering minimum rear five-way and last four rows of seats. Alternatively use of single camera with a wide-angle lens. (Channel 3 and 4 if two utilised)
- Between the centre door and the front of the bus which may be mounted either at the front looking rearwards or at the centre door looking forwards. (Channel 5)
- Forward facing to road ahead of bus (Channel 6)
- Interior Drivers Cab looking towards Drivers Signalling Window (Channel 7)
- Footwell camera as specified in Section 4.3.5.1 of the LBSL Bus Vehicle Specification (Channel 14)

7.3.2 Additional Mandatory All Single Deck Buses Over 10.4m length

- Centre door and the rear of the bus, looking rearwards (Channel 8)

7.3.3 Additional Mandatory All Double Deck Buses

- Two cameras at rear of upper saloon interior seated area looking forwards covering minimum rear five-way and last four rows of seats. Alternatively use of a single camera with a wide-angle lens. (Channel 9 and 10 if two utilised)
- Lower saloon between the centre door and the rear of the bus which may be mounted either at the rear looking forwards or at the centre door looking rearwards. (Channel 11)
- Top of stairwell looking downwards (Channel 12)

- Front of upper saloon interior seated area looking rearwards (Channel 13)

Note: Prior to building of the bus the operator shall confirm that the camera layout drawing has an approval reference (as submitted for TfL review and upload to the TfL BVS Database) given by LBSL. In the case where the layout does not meet the LBSL approved reference / guidelines the operator will be required to revise appropriately.

7.4 Displays

There shall be a display in the drivers cab, the display:-

- Shall be a 5" or equivalent LCD colour monitor.
- Suitably mounted in drivers cab area.
- Monitor to display the system time clock.

Shall, as default, display the exit platform and ramp deployment area when the centre exit door opens.

There shall be a display in the passenger area, the display:-

- Shall be a 15" or equivalent LCD colour monitor positioned in the lower saloon.
- Shall be suitably and securely mounted behind a vandal resistant protective screen.
- Monitor to display the system time clock

Shall be generally positioned so that the maximum number of passengers entering the bus will have the opportunity to view the screen when in one of the following positions:-

- Rearward exit door partition facing forwards
- Staircase to aisle fascia lower saloon facing inwards to centre of bus
- Staircase rearward partition facing up the staircase and viewable from lower saloon aisle at staircase entrance.
- Monitor will continuously cycle around all the cameras remaining on each camera for 5 seconds and end with an all camera view.
- Shall be installed in a manner consistent with the current iBus policy.

Use of displays on the upper deck is prohibited.

7.5 Security

The NVR and any additional equipment necessary for Live CCTV shall be enclosed in a secure, lockable and vandal proof enclosure that is located in accordance with the TfL design guides.

8 Operation

8.1 Performance

TfL will be providing a diagnostic and reporting capability utilising the current iBus system and will work with the NVR suppliers to ensure the NVR interface (Section 1.3) is developed and approved for use by TfL. The following is based on the use of this capability.

The performance of the CCTV system shall be 98% availability. For a system to be available the following is required:-

1. The NVR and ancillaries are fully operational
2. The NVR configuration is correct
3. The system time is correct to +/- 10 seconds
4. All but one of the cameras is working i.e. 1 camera failure is allowed without reducing the availability in the first week. For week 2 and onward the system is considered unavailable.

Availability is defined as:-

<u>Total Time period – Total Hours unavailable during time period</u>

Total Time Period

Time Period is the sum of all the operational hours of buses operating on contracts compliant with this specification during a period.

<u>Total Hours unavailable during time period</u>

Total Hours unavailable during a time period is the sum of all the unavailable hours of buses operating on contracts compliant with this specification during a period

Unavailable Hours are calculated from the time the fault status is made available to the operator to the time the system is fixed.

For a system to be considered as unavailable one or more of the criteria detailed in 1 - 4 above is not met.

The period is 28 days.

8.2 Maintenance

In the event of any errors or interruption of CCTV service the fault diagnosing procedure stipulated in the TfL-supplied CCTV User Guide shall be used. The operators maintain ownership and responsibility for repairing all CCTV equipment from Port 4 of the IBIS onwards.

8.3 Audit

The operator will be audited to ensure compliance against the required performance. The operator will be expected to maintain records of:-

- CCTV system inspections.
- Faults identified and date/time fixed.

The operator will provide Availability reports on request.

LBSL shall have the right to audit against the requirements in this specification to ensure traceability and accuracy of the data recorded.

8.4 Enforcement

Should the operator breech the availability targets then the operator shall put in place a recovery plan.

8.5 Provision of Data

The operator framework agreement contains all information related to the provision of data and should be reviewed as an overview of this Attachment.

Attachment 12: Exterior and Interior Notices

1 Introduction

This attachment provides hardware, functionality and performance requirements for Exterior and Interior Notices on buses entering the LBSL fleet as laid out in the main specification.

For full understanding of this Attachment it should be read in conjunction with the New Bus Vehicle Specification, Section 10, Specifically Section 10.3.

2 Scope

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

3 Purpose

The objective of this Attachment is to detail the hardware and performance requirements for Exterior and Interior Notices on buses entering the LBSL fleet.

4 Normative references

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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 Service Limited New Bus Specification Section 10.3

5 Requirements

Exterior and interior notices are provided by LBSL as listed in the London Buses – Bus Graphics Standard (http://content.tfl.gov.uk/london-buses-graphics-standard.pdf), and must be fitted in the appropriate positions.

Please refer to the relevant section of the New Bus Vehicle Specification listed above for full details.

Attachment 13: Operator Codes and Fleet Number Identification

1 Operator Code Requirements

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 10.3

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

Figure 13_1 Rear of Vehicle

a) All Characters shall be in New Johnston Bold font
b) Characters shall be in Matt Black cut out vinyl
c) Characters shall be 350mm in height

Attachment 14: Free Issued Equipment

1 Introduction

This attachment provides hardware, functionality and performance requirements for Free Issued Equipment fitted to buses entering the LBSL fleet as laid out in the main specification

For full understanding of this Attachment it should be read in conjunction with the New Bus Vehicle Specification, Sections 6.4.3 and 6.4.4 respectively.

2 Scope

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

3 Purpose

The objective of this Attachment is to detail the installation and hardware requirements for free issued equipment systems fitted to buses entering the LBSL fleet.

4 Normative references

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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 Service Limited New Bus Specification Section 6.4.3
- London Bus Service Limited New Bus Specification Section 6.4.4

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
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator

6 Free Issued Equipment

Provision must be made for the following free issue equipment to be installed in an approved package of arrangement and quality, as agreed between LBSL and each OEM.

6.1 iBus Equipment

The approved package of installation must consider the free issue iBus equipment as an integral part of the vehicles design. Particular consideration must be given to the practical requirements of maintaining the free issue equipment during the lifetime of the vehicle whilst in service on London Buses contracted routes.

For full details of the installation principles recommended please refer to the generic 'iBus Installation Manual' (**Document Ref: LBSL Equipment for new buses Installation manual BHN01 170970V18**) which has been issued to all OEMs. A copy of the 'iBus Installation Manual' is available on the Hyperion server to all bus operators.

The method of connecting iBus to the required inputs from the vehicle including power, door signal and odometer will be via automotive connectors at three converged points within the main iBus equipment compartment.

The connectors for iBus inputs at the converged points are as follows:

- 15 Way Connector
- 9 Way Connector
- 9 Way Connector

Part List – iBus Free Issue Equipment

PART NO.	DESCRIPTION	QTY/COMMENTS
UK-WRIGHT-VOL-CH	**CONTI CABLE KITT**	**1 per vehicle - see breakdown below**
TTS-0820-1009	**EME CABLE KITT 6M**	**1 per vehicle - see breakdown below**
TTS-0820-2157-XXX	MDT CABLE	1
TTS-0820-2191-B010	TRS CABLE	1
TTS-0820-2218-XXX	OBNSS CABLE - POWER	1 for Single Deck / 2 for Double Deck
TTS-0820-2219-XXX	OBNSS CABLE - DATA	1 for Single Deck / 2 for Double Deck
TTS-0967-0180	DC/DC MPT CABLE	1
TTS-0807-0003-D	TRS	1
TTS-0807-0004	IBIS UNIT	1
TTS-0919-0404	MPT RADIO	1
TTS-0919-0586	DC /DC CONVERTER	1
TTS-0945-0090	LOUDSPEAKER GRILL	6 per deck
TTS-0945-0094	PASSENGER LOUDSPEAKER	6 per deck
TTS-0945-0096	DRIVER SPEAKER	1
TTS-0945-0102	MICROPHONE	1
TTS-0709-0001-A	OBNSS DISPLAY SHORT - ADDRESS 1	Only one used per vehicle deck
TTS-0709-0002-A	OBNSS DISPLAY SHORT - ADDRESS 2	
TTS-0709-0003-A	OBNSS DISPLAY LONG - ADDRESS 1	
TTS-0709-0004-A	OBNSS DISPLAY LONG - ADDRESS 2	
TTS-0961-0475	FOOTSWITCH	1
TTS-0964-0476	FOOTSWITCH HOUSING	1
TTS-0945-0113	2 STUD ANTENNA	1
TTS-0945-0111	1 STUD ANTENNA WITH CLIP	1
TTS-0919-0418	TLP RADIO	1
TTS-0803-0012-A	MDT DISPLAY	1
TTS-0803-1516	MDT BRACKET - 90 DEGREE ANGLE	Only one used per bus/bus type
TTS-0803-1519	MDT BRACKET - 60 DEGREE ANGLE	
TTS-0803-1506	MDT FLUSH BRACKET	
TTS-0807-0002	DONGLE	1
TTS-0807-1016	DONGLE COVER WITH DAMPER	1
TTS-0807-1021	TRS MOUNTING BRACKET	1
TTS-0945-0103	MICROPHONE BRACKET	1
UK-WRIGHT-VOL-CH	**CONTI CABLE KITT**	**INCLUDES**
UK-TTS-0027	VEHICLE TERMINAL BLOCK & CABLES (2MT, 1MT or 0.5MT)	1
TTS-0820-2152-XX	Cable 2 - TLP radio to IBIS	1 - Flexible lengths
TTS-0820-2153-XX	Cable 3 - MPT Radio to IBIS	1 - Flexible lengths
TTS-0820-2154-XX	Cable 4 - Driver Mic to IBIS	1 - Flexible lengths

TTS-0820-2155-XX	Cable 5 - Ticket Machine to IBIS	1 - Flexible lengths
TTS-0967-0457-XX	CABLE 30 PERMANENT POWER CABLE	1 - Flexible lengths
TTS-0967-0438-XX	CABLE 32 IGNITION CABLE - NOT REQURED	1 - Flexible lengths
TTS-0967-0457-XX	CABLE 35- DRIVER SPEAKER CABLE	1 - Flexible lengths
TTS-0967-0457-XX	CABLE 36-PASS SPEAKER CABLE	1 - Flexible lengths
TTS-0967-0438-XX	CABLE 37 - DOOR 1 CABLE	1 - Flexible lengths
TTS-0967-0438-XX	CABLE 38 - DOOR 2 CABLE	1 - Flexible lengths
TTS-0967-0438-XX	CABLE 40 - FOOTSWITCH	1 - Flexible lengths
TTS-0967-0438-XX	CABLE 41- VEHICLE STOPPING	1 - Flexible lengths
TTS-0967-0449-XX	CABLE 42 - ODO CABLE	1 - Flexible lengths
TTS-0967-0457-XX	CABLE 43 DC/DC CONVERTER CABLE (POWER)	1 - Flexible lengths
TTS-0967-0438-XX	CABLE 45 DC/DC CONVERTER CABLE (SWITCH)	1 - Flexible lengths
TTS-0820-1009	**EME CABLE KITT (Flexible Lengths)**	**INCLUDES**
TTS-0820-2192-XXX	CABLE ANTENNA UMTS SYSTEMKABEL 20	1 - Flexible lengths
TTS-0820-2193-XXX	CABLE GHP-WLAN SYSTEMKABEL 21	1 - Flexible lengths
TTS-0820-2194-XXX	CABLE GHP-GSM/GPRS SYSTEMKABEL 22	1 - Flexible lengths
TTS-0820-2195-XXX	CABLE GHP-GPS SYSTEMKABEL 23	1 - Flexible lengths
TTS-0820-2196-XXX	CABLE ANTENNA MPT RADIO SYSTEMKABEL 24	1 - Flexible lengths

The schedule of parts for installation components shown in this document and Volume 2 Annex C, of the framework agreement will be provided to the OEM and must be included by the operator in the bus manufacturing specification.

6.1.1 Electrical and Signal Interface for iBus

In addition to the Installation manual previously stated. The electrical and signal interface between the bus and iBus terminal block is to be via a 15-way connector, and interface between the iBus terminal block and OBNSS, DC converter and MPT radio is to be via 9-way connectors as shown in Figure 14_1 below. The remaining iBus peripherals connect directly to the IBIS unit via D-connectors.

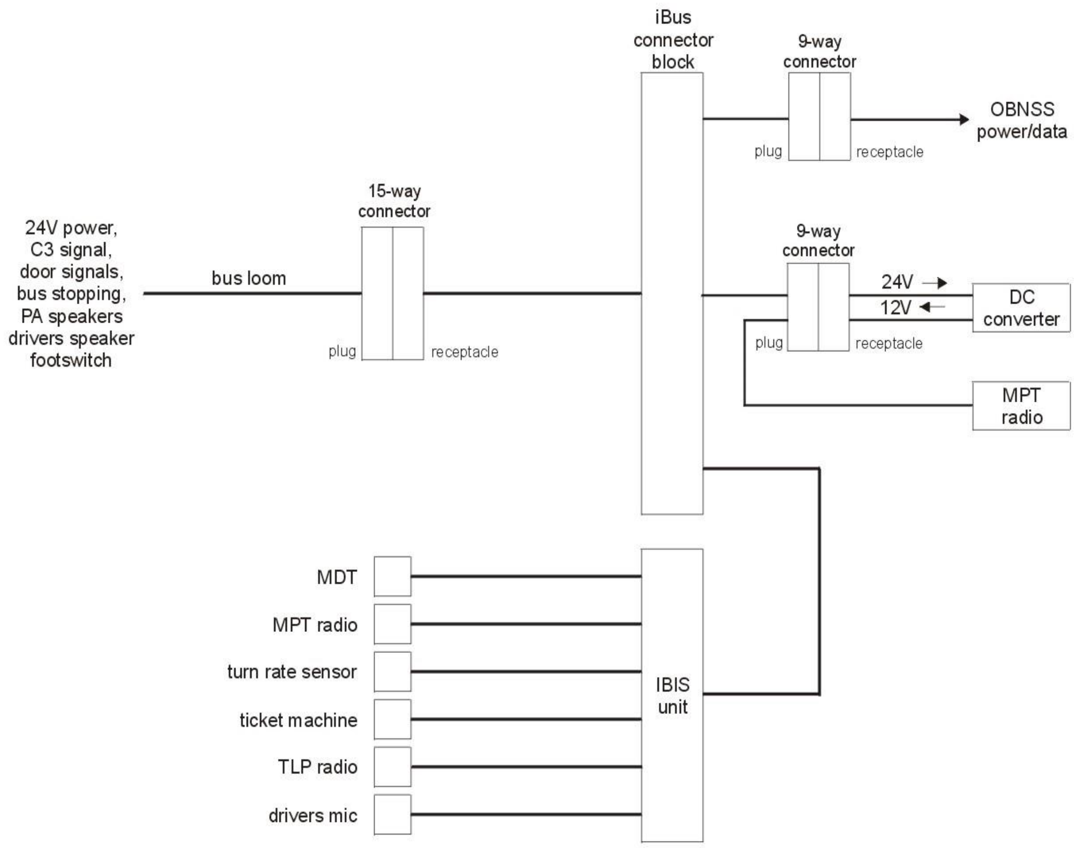


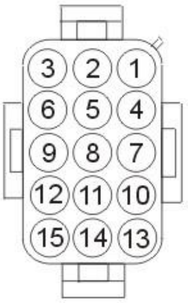
Figure 14_1 iBus Connection Schematic

The 15-way and 9-way connectors are manufactured by Tyco Electronics, details are as follows:

• 15-way plug	AMP 1-480710-0	pin	AMP 1-350536-1
• 15-way receptacle	AMP 1-480711-0	pin	AMP 1-350218-1
• 9-way plug	AMP 1-480672-0	pin	AMP 1-350388-1
• 9-way receptacle	AMP 1-480673-0	pin	AMP 1-350389-1

Pin-outs of the connectors are shown in Figures 14_2-14_4 below.

15-WAY
CONNECTOR

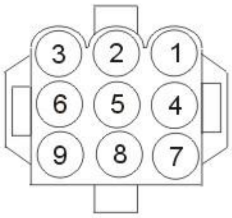


plug
(towards bus loom)
view from wire side

PIN	FUNCTION	PIN	FUNCTION
1	+24V perm	9	PA speakers
2		10	footswitch
3	+24V ignition	11	footswitch
4	bus stopping	12	driver speaker
5	door 1	13	driver speaker
6	door 2	14	0V
7	C3 signal	15	0V
8	PA speakers		

Figure 14_2 15-way connector pin-outs

OBNSS
9-way
connector

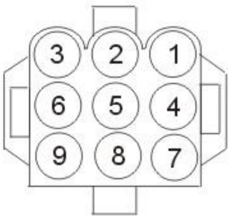


plug
(towards connector block)
view from wire side

PIN	FUNCTION	PIN	FUNCTION
1	+24V	6	data (YEL)
2	0V	7	screen
3	data (WH)	8	
4	data (BRN)	9	
5	data (GRN)		

Figure 14_3 OBNSS 9-way connector pin-outs

MPT
9-way
connector



plug
(towards connector block)
view from wire side

PIN	FUNCTION	PIN	FUNCTION
1	+24V	6	
2	0V	7	
3	ignition feed	8	
4	12V positive	9	
5	12V negative		

Figure 14_4 MPT 9-way connector pin-outs

External connections to the iBus connection block are shown in Figure 14_5 below.

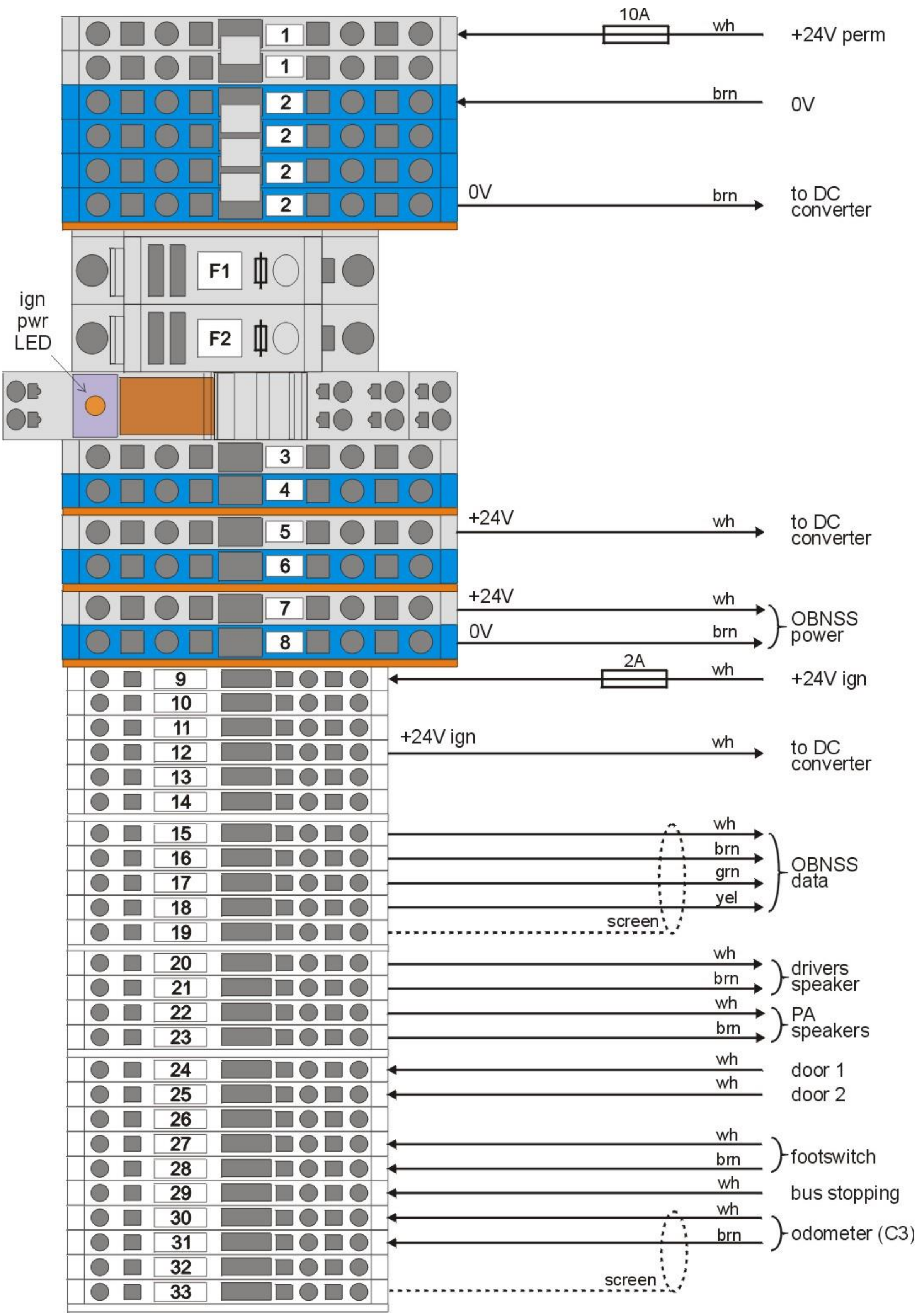


Figure 14_5 iBus connection block external connection pin-outs

6.2 Ticketing Equipment

Ticket Machine and base plate with smartcard readers will be installed after bus arrives in London

6.3 Bus Lane Enforcement Cameras

These are no longer required in a new bus installation.

Attachment 15: Advanced Emergency Braking (AEB) Assessment Protocol

1 Introduction

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

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

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

2 Scope

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

3 Purpose

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

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

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

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

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

4 Normative references

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

- For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 4.3.2
- For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Attachment 16 AEB Test Guidance Notes
- Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- Regulation (EU) 2018/858 of the European Parliament and of the Council of 30th May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC
- UNECE Regulation 107 Uniform provisions concerning the approval of category M_2 or M_3 vehicles with regard to their general construction
- Euro NCAP Test Protocol AEB VRU Systems Version 2.0.1 August 2017
- Euro NCAP Test Protocol AEB Systems Version 1.1 June 2015
- Euro NCAP Test Protocol AEB Systems Version 2.0.1 November 2017
- ISO 19206-2:2018 Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 1: Requirements for passenger vehicle rear end targets.
- ISO 19206-2:2018 Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 2: Requirements for pedestrian targets.
- ISO 19206-2:2018 Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 3: Requirements for passenger vehicle 3-D targets.

- ISO 19206-4:2020 Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 4: Requirements for bicyclist targets.
- ISO 15037-2 Road vehicles – Vehicle Dynamics Test Methods – Part 2: General conditions for heavy vehicles and buses

5 Definitions

For the purpose of this Protocol:

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

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

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

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

- **Approval Authority:** The Approval Authority is the body within TfL that certifies that a bus is approved for use in the TfL fleet and assigns its score under the bus safety standard for use in procurement processes.
- **FCW: Forward Collision Warning** – An audiovisual warning that is provided automatically by the vehicle in response to the detection of a likely collision to alert the driver.
- **OEM: Original Equipment Manufacturer** - The business responsible for the manufacture of the bus being assessed.
- **PBC: Peak Braking Coefficient** – The measure of tyre to road surface friction based on the maximum deceleration of a rolling tyre, measured using the American Society for Testing and Materials (ASTM) E1136-10 (2010) standard reference test tyre, in accordance with ASTM Method E 1337-90 (reapproved 1996), at a speed of 64.4km/h, without water delivery.
- **Test Path:** For the bus stop test, the test path is defined by the co-ordinates specified in Appendix A. For all other tests, the test path is a virtual straight-line path equivalent to the centreline of the lane in which the collision occurs.
- **Test Scenario:** An arrangement and movement of vehicles and test equipment that is intended to represent a particular collision type. A range of different test scenarios are referred to in this protocol:

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

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

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

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

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

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

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

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

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

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

EBT: Euro NCAP Bicyclist and Bike Target – Means the bicyclist and bike target as specified in ISO 19206: Part 4.

EPTa: Euro NCAP Pedestrian Target – Means the adult pedestrian target with articulating legs as specified in ISO 19206: Part 2.

EPTc: Euro NCAP Child Target – Means the child pedestrian target as specified in ISO 19206: Part 2.

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

EVT: Euro NCAP Vehicle Target – Means the rear end car target defined in ISO 19206: Part 1

GVT: Global Vehicle Target – Means the 3-Dcar target defined in ISO 19206: Part 3.

- **Vehicle width:** The widest point of the vehicle ignoring the rear-view mirrors, side marker lamps, tyre pressure indicators, direction indicator lamps, position lamps, flexible mud-guards and the deflected part of the tyre side-walls immediately above the point of contact with the ground.
- **Vehicle Under Test (VUT)**: Means the vehicle assessed according to this protocol.

6 Reference system

6.1 Local co-ordinates

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

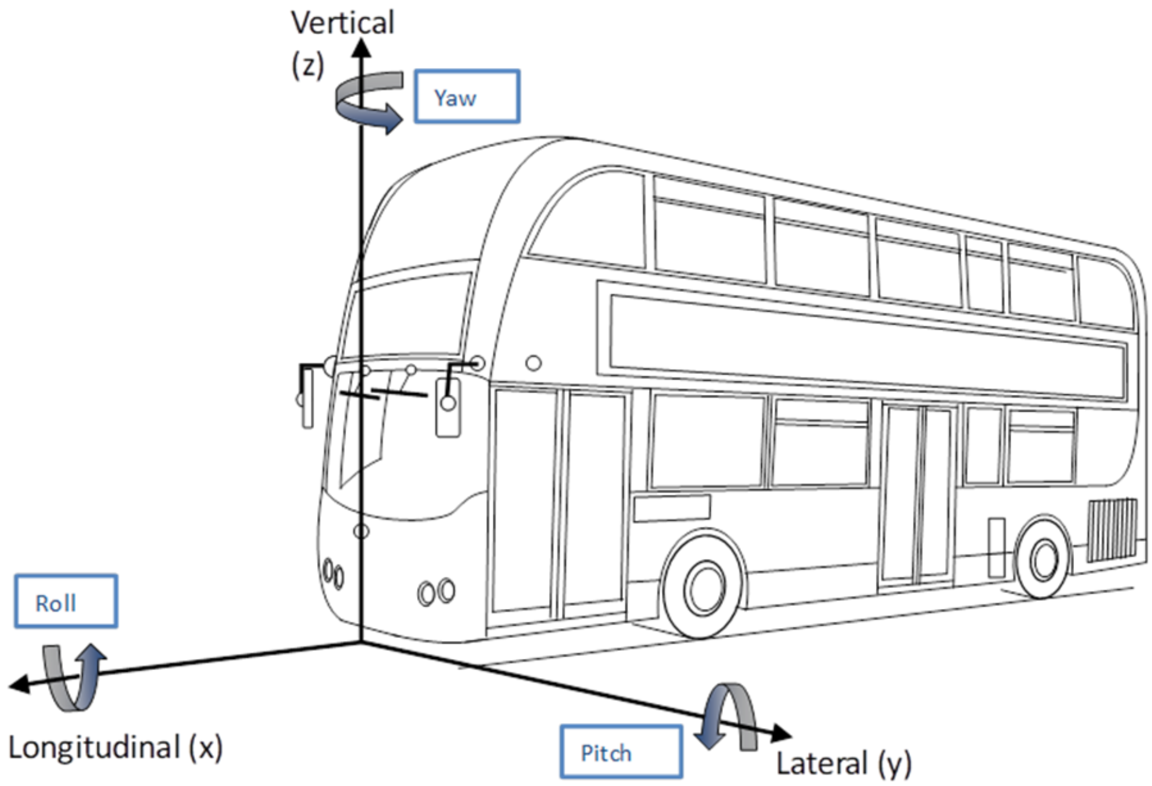


Figure 15_1: Local co-ordinate system and notation

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

6.2 Global co-ordinates

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

7 Measurements and variables

7.1 Variables to be measured

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

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

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

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

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

7.2 Measuring equipment

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

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

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

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

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

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

7.3 Variables to be derived from the measurements

7.3.1 General

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

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

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

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

7.3.2 Determination of impact

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

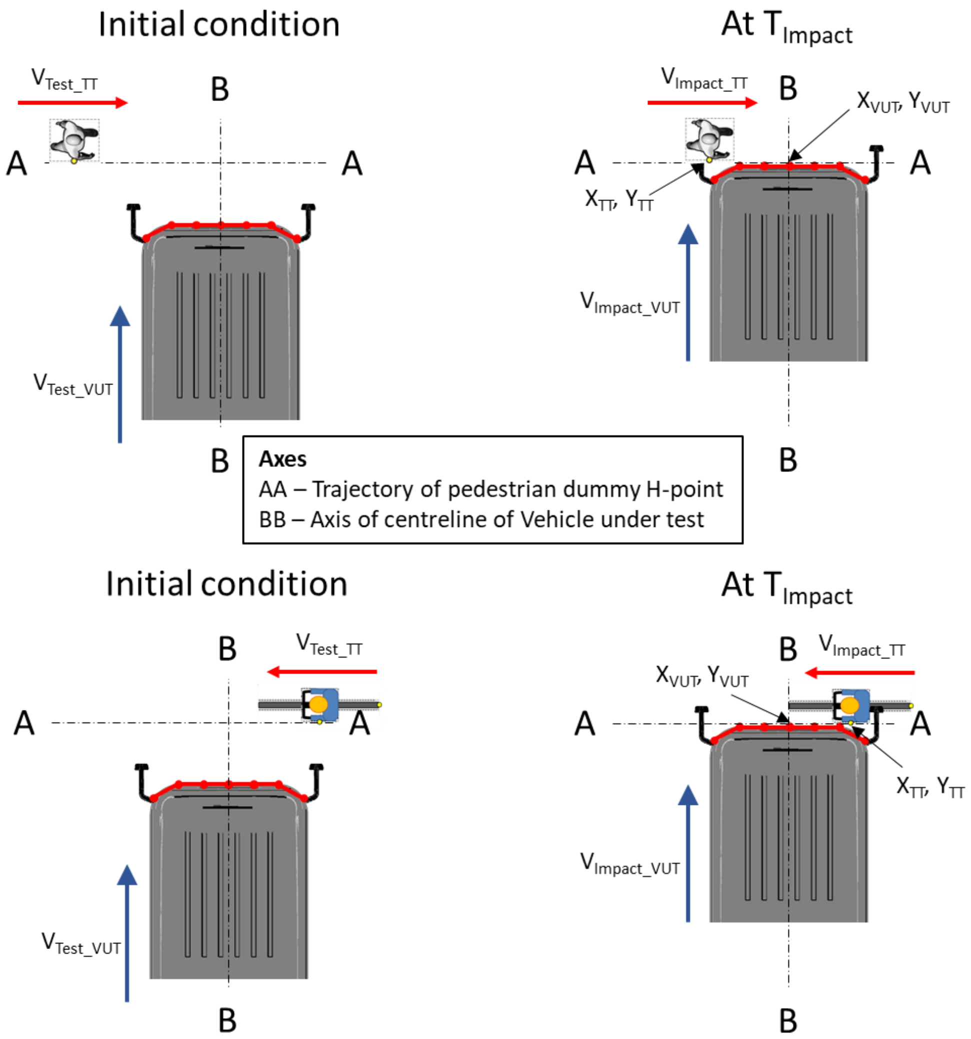


Figure 15_2: Illustration of the definition of the moment of impact (Pedestrian (top), Cyclist (bottom))

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

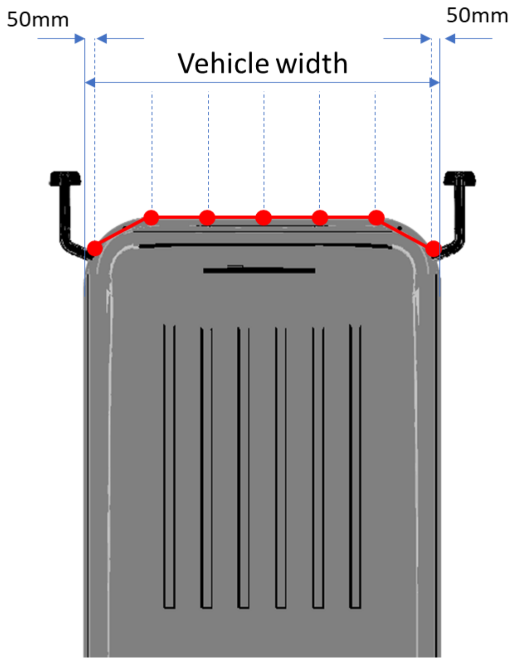


Figure 15_3: Virtual profile for determining impact for VUT

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

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

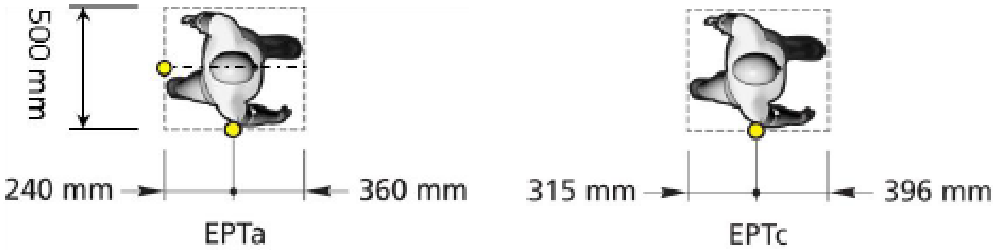


Figure 15_4: Virtual box around EPT

For the cyclist targets (EBT), the dimensions of the virtual box are shown in Figure 25_5. For crossing scenarios, the reference point of the EBT is the centre of the bottom bracket (crank shaft, indicated by a dashed line in Figure 25_5) and for the longitudinal scenario the most rearward point on the rear wheel is used.

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

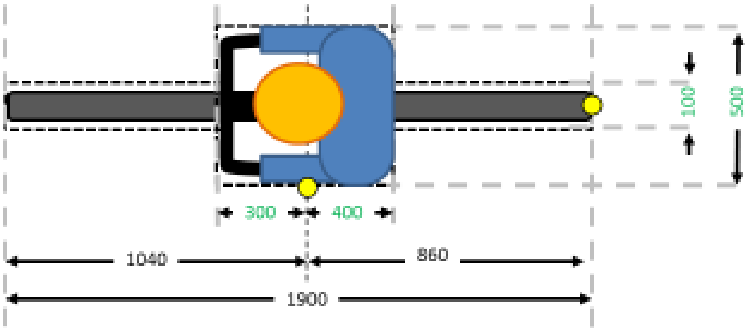


Figure 25_5: Virtual box around EBT

8 Test conditions

8.1 Test track

Tests shall be conducted on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%.

The test surface shall have a minimal peak braking coefficient (PBC) of 0.9 in the region where data is recorded.

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

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

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

8.2 Weather and lighting conditions

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

No precipitation shall be falling and horizontal visibility at ground level shall be greater than 1km.

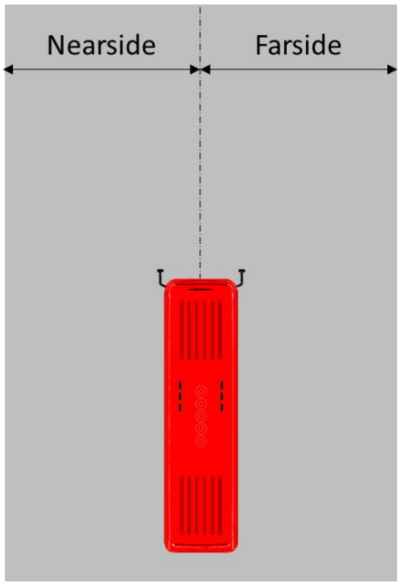
Wind speeds shall be below 10m/s to minimise EPT, EBT and VUT disturbance. The Test Service may, at their discretion repeat tests if unexpected results are observed at a time when wind speed exceeds 5 m/s.

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

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

8.2.1 Surroundings

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



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

Figure 15_6: Free surroundings

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

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

9 Vehicle preparation

9.1 Deployable protection systems

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

9.2 Tyres

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

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

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

9.3 Wheel alignment measurement

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

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

9.4 Vehicle mass

The AEB shall be operative at all states of load.

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

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

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

9.5 AEB/FCW system check

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

9.6 Measuring front end geometry

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

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

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

10 Test procedure

10.1 VUT pre-test conditioning

10.1.1 Sensor calibration

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

10.1.2 Brake conditioning

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

10.1.3 Tyre conditioning

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

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

10.1.4 Alignment checks

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

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

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

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

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

10.2 Protection of Equipment

The near vertical front of buses can make it more likely that test targets, particularly pedestrians, may be damaged during test runs where the AEB does not fully avoid impact. The test service may take all reasonable steps to protect the dummy from excessive damage in tests where impact cannot be avoided, provided that it does not influence the test result. This includes but is not necessarily limited to:

- Not testing at higher speeds when no speed reduction has been achieved at a lower speed, provided there is confidence that the absence of performance was not due to limited horizontal field of view angle of the sensing system.
- Where manufacturers provide expected test results that anticipate dummy impacts at high speeds and the test house verify the accuracy of manufacturers results at the highest speeds, lower speed tests where impacts are still expected can be omitted.
- [The test service may choose to test all configurations where avoidance is expected first and to cease testing once the minimum pass mark has been achieved]
- Braking may automatically be applied via the service brake pedal by the automated test device at the moment of impact. Where a lag exists between pedal application and deceleration, the pedal may be applied in advance of the impact point such that deceleration commences at the impact point.
- Devices that attempt to rapidly physically move the dummy out of the path of the vehicle are only permitted after the point of impact and not before.

10.3 Car tests

10.3.1 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.

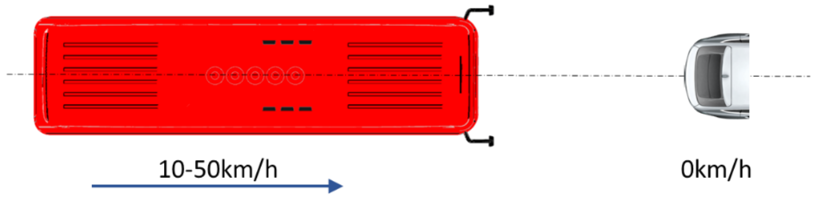


Figure 15_7: BCRs Scenario

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

10.3.2 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, 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 OEM states that they expect no performance at the next speed, then testing shall cease.

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

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

10.3.3 Test execution

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

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

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

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

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

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

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

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

i. $V_{VUT} = 0$ km/h

ii. VUT has made contact with the TT.

10.3.4 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 V_{VUT} ≤ Test Speed + 1 km/h

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

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

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

e) Centreline of the Test Target is within ± 0.05 m 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.

10.4 VRU crossing tests

10.4.1 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 15_8 to Figure 15_10 . FCW is not assessed.

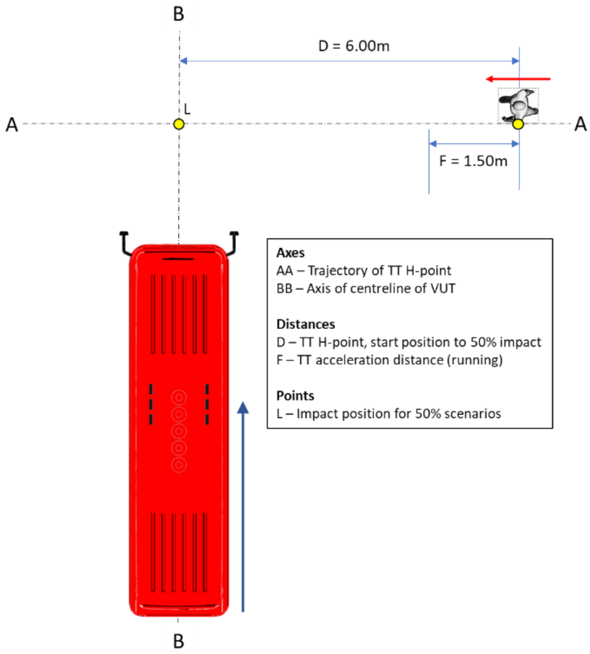


Figure 15_8: BPFA-50 scenario, adult running from the farside of the road

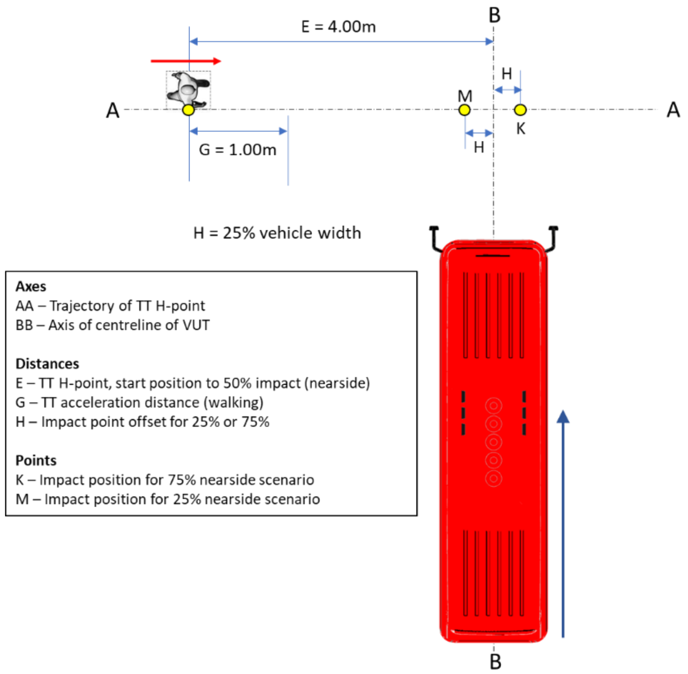


Figure 15_9: BPNA-25 & BPNA-75 scenario, adult walking from the nearside of the road

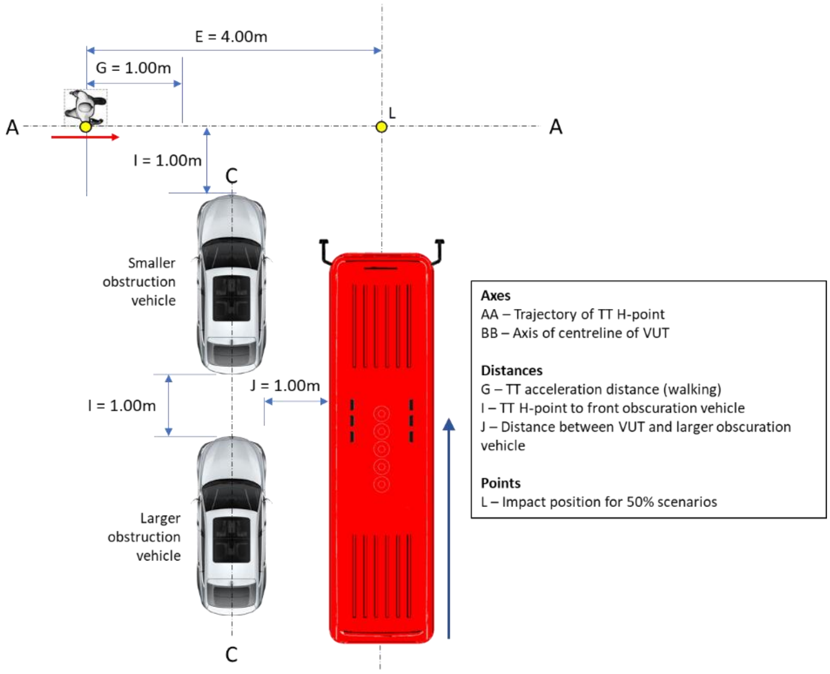


Figure 15_10: BPNC-50 scenario, child running from the nearside from behind obstructing vehicles

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

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

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

Table 15_4: Test variables for the VRU crossing tests

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

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

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

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

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

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

The number of test runs to be completed in each test condition and the process of determining the result to be recorded for that condition are the same as those defined in section 10.3.2.

10.4.3 Test execution

The process for executing each test shall be as defined in section 10.3.3. 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

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

10.4.4 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 $V_{VUT} \leq$ Test Speed + 0.5 km/h

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

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

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

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

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

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

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

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

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

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

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

10.5 VRU longitudinal tests

Test scenarios

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

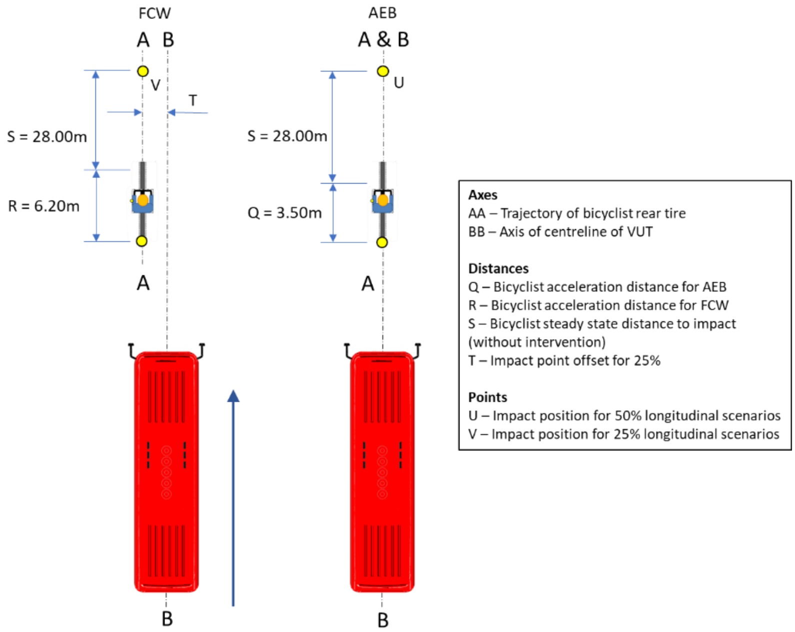


Figure 15_11: Longitudinal bicyclist scenarios; BBLA-25 (left) & BBLA-50 (right)

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

Table 15_5: Test Variables: Longitudinal scenarios

	Test Scenario	
	BBLA-25	**BBLA-50**
Type of Test	FCW	AEB
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	

10.5.1 Sequence and number of test runs

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

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

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

b) $V_{TEST\_VUT} - V_{IMPACT\_VUT} \geq 5$ 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 10.3.2.

10.5.2 Test execution

The test execution shall be as specified in section 10.3.3, 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.

10.5.3 Validity of tests

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

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

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

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

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

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

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

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

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

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

10.6 Aborted crossing test

10.6.1 Test scenario

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

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

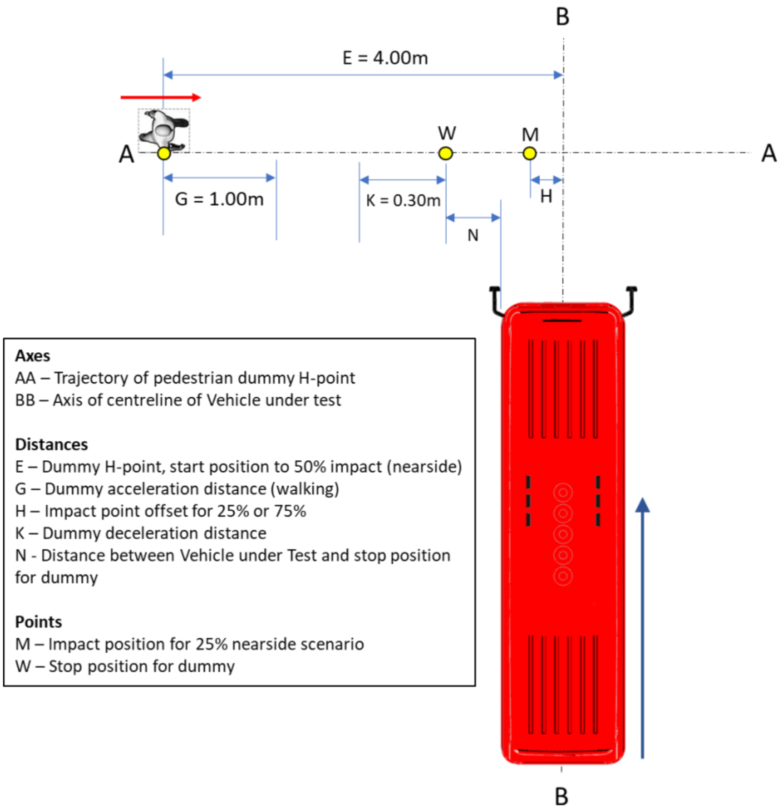


Figure 15_12: TT start and stop positions in aborted crossing test

Tests shall be undertaken at V_{TEST_VUT} = 30 km/h for:

- N_1; where N = 0.6 m
- N_2; where N = 0.75 m
- N_3; where N = 0.9 m

10.6.2 Sequence and number of test runs

The first test N_1 shall be undertaken at N = 0.6 m 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.

10.6.3 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).

10.6.4 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 times between T_0 and activation of AEB or the end of test, whichever comes first:

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

b) Lateral deviation from VUT Test Path = 0 ± 0.0 5m

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

d) Actual measured distance N for tests N_1, N_2, and N_3 = N ± 0.07 m

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

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

g) 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.

10.7 Bus stop test

10.7.1 VUT path geometry

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

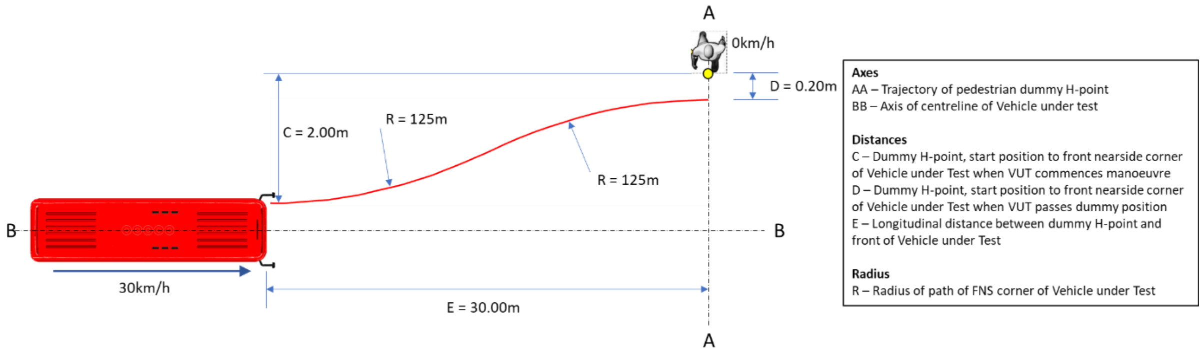


Figure 15_13: VUT Path and pedestrian position in false positive bus stop test

10.7.2 False positive test – TT Stationary

The geometry remains as shown in Figure 15_13. The TT shall always remain stationary 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 2 m (Point C).

This distance shall reduce as the VUT approaches the TT until a distance of 0.2 m (Point D) at the moment the front nearside corner of the VUT is at the same position as the TT on the Global X-axis.

V_{VUT} shall be 30 km/h at a distance in the X-axis of 30 m from the line AA. The bus shall be decelerated at a nominally constant rate such that its speed when it reaches line AA is between 0 and 10 km/h, unless AEB is activated.

10.7.3 True positive test – TT non-stationary

As described in Figure 15_14. 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 4.55 m (Point C).The TT shall be accelerated to a speed of V_{TEST_TT} = 5 km/h at a time such that it is on a collision course with the front of the VUT where the nominal impact point (Point L) is 50% ± 3% of bus width. V_{TEST_VUT} shall be 30 km/h and shall remain constant throughout the test.

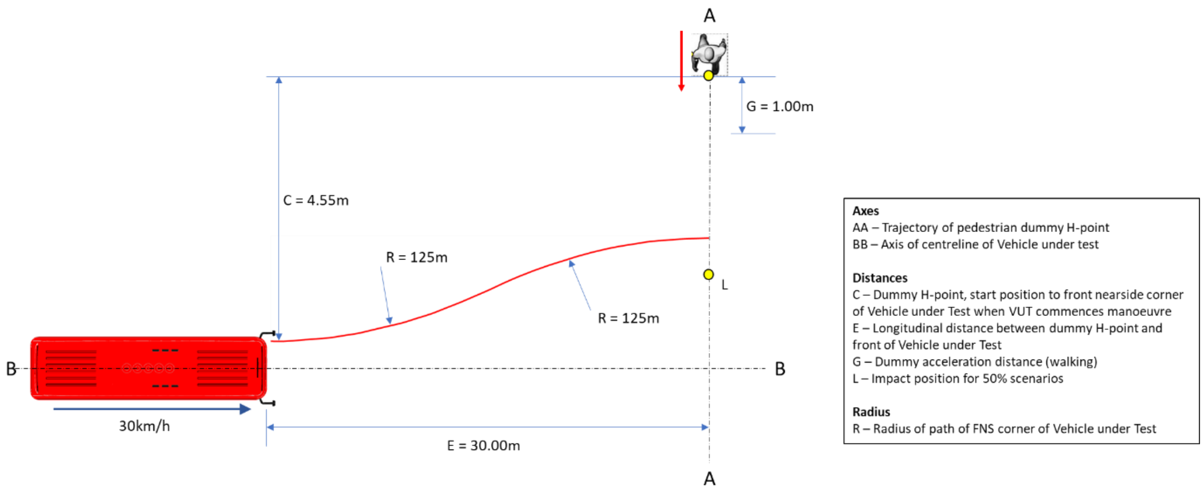


Figure 15_14: VUT path and TT position in true positive bus stop test

10.7.4 Sequence and number of test runs

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

10.7.5 Test execution

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

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

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

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

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

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

10.7.6 Validity of tests

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

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

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

b) Front nearside corner remains in defined corridor

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

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

10.8 Validation of OEM supplied test data

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

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

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

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

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

11 Assessment of results

11.1 Assessment criteria

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

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

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

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

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

11.2 Pre-conditions

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

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

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

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

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

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

11.3 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.

11.3.1 Car tests

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

Table 15_7: Scoring and weighting applicable to scenario BCRS

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

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

11.3.2 VRU crossing tests

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

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

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

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

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

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

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

11.3.3 VRU longitudinal tests

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

Table 15_10: Scoring and weighting for VRU longitudinal tests

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

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

11.3.4 False positive aborted crossing scenario

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

a) For Test N_1

i. $A_{PEAK\_VUT\_Long} \leq -5$ m/s^2: 0%

ii. $A_{PEAK_VUT_Long} > -5$m/s^2 AND ≤ 0m/s^2: 100%

b) For tests N_2 and N_3

i. $A_{PEAK_VUT_Long} \leq -5$m/s^2: 0%

ii. $A_{PEAK_VUT_Long} > -5$m/s^2 AND ≤ -1.5 m/s^2: 50%

iii. $A_{PEAK\_VUT\_Long} = -1.5$ m/s^2 AND ≤ 0 m/s^2: 100%

The Scenario Score is the mean of each of the 9 test results, as per the example given in Table 15_11.

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

TT distance to VUT	Test 1	Test 2	Test 3	Total
N_1	0%	0%	100%	33.3%
N_2	50%	100%	50%	66.7%
N_3	100%	100%	100%	100%
			Scenario Score	**66.7%**

11.4 Overall score

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

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

Crash Type	A Crash type score	B Crash type weighting	C= A*B Weighted score	D Performance type weighting	E = (∑C)*D Weighted performance score
True Positive: Car	87.0%	10.0%	8.7%	90%	67.1%
True Positive: VRU crossing	73.2%	85.0%	62.2%		
True Positive: VRU longitudinal	71.5%	5.0%	3.6%		
False positive: aborted crossing	66.7%	100.0%	66.7%	10%	6.7%
				Total (Overall AEB Score)	**73.8%**

12 Test report

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

a) Performance data

b) Confirmation of protocol compliance

c) Reference information

The minimum performance data required is:

a) The value V_{Impact} and $A_{PEAK\_VUT\_Long}$ for each and every individual test run, with the number of tests reported based on the rules in, for example, section 10.3.2

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

To confirm protocol compliance, the Test Service shall:

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

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

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

The reference information required includes as a minimum:

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

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

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

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

Attachment 16: Advanced Emergency Braking (AEB) Guidance Notes

1 Introduction

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

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

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

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 4.3.2,Attachment 15: AEB Assessment Protocol and Attachment 42: Complex Electronic Control Systems

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

AEB shall be provided on all new build buses and its performance shall be closely monitored in order to check that it is having the expected effects in terms of both true and false positive situations.

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, Attachment 15. The protocol has been designed to appropriately balance true and false positive performance and, therefore, a higher score should always produce a better net number of casualties.

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

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

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 OEM shall target zero false positive activations and will need to demonstrate evidence to TfL that the vehicle is capable of driving for at least 300,000 km in mixed city traffic without any false positives.

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

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 OEMs may produce systems that apply only partial braking in an emergency or differ in terms of the vehicle speed that the system will be active at. Operators should aim to consult different OEMs to identify any such differences, explain the rationale and then decide which best suits their corporate aims, balancing any incentives with the effect on any internal objectives.

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 advanced braking system did not exist. TfL has, therefore, mandated that if an AEB system is fitted, it must make data available for recording via the CCTV system or some other suitable method. A minimum set of data to be reported to TfL on a monthly basis has also been included in the specification.

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.

Where operators fit and use a standard telematics device for fleet management, it may be much more effective to ask the telematics supplier to integrate the provided AEB signal and record it as an ‘event’ in routine reporting such that rates per km as defined in the specification for new buses can be derived automatically and used to trigger downloading of CCTV with minimum effort.

3 Training

3.1 For test services

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

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 OEM advises differently, they should understand this as an 'amber' warning where the loss of capability is explained to the driver and the vehicle is taken out of service for repair as soon as possible. The system should fail safe in that it will simply stop providing the benefit rather than cause any new problems. As such it is not necessary to stop immediately (e.g. at the roadside) in the case of a warning light illuminating in the cab.

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 OEMs' guidance. However, this is likely to include understanding the importance of ensuring the sensors are correctly aligned, undamaged and unobstructed since the performance of the AEB system is completely contingent on the sensors the system is connected to.

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

4 Maintenance

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

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

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

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 OEM advises to the contrary, the system should fail safe such that it is not necessary to stop the vehicle immediately, for example, at the side of the road. OEM guidelines in relation to the repair of the vehicle body and/or windscreen in the vicinity of sensors. For example, some may prohibit the use of body fillers or aftermarket components in front of a sensor.

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 only act to limit the vehicle response to the accelerator pedal input whilst the bus is travelling within a speed limit zone and do not actively control the vehicle speed.

For full understanding of this Attachment it should be read in conjunction with the Attachment 18: Intelligent Speed Assistance (ISA) Guidance Notes and New Bus Specification, Section 4.3.3.

2 Scope

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

3 Purpose

The purpose of 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 OEMs, test services, assessors) with instructions regarding the test and assessment of ISA systems.

4 Normative references

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct 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 Service Limited New Bus Specification Section 4.3.3
- London Bus Service Limited New Bus Specification – Attachment:18 Intelligent Speed Assistance (ISA) Guidance Notes

- UN ECE Regulation 39 Uniform Provision concerning the approval of vehicles with regard to the speedometer and odometer equipment including its installation

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
- **Vehicle Speed** – Measurement of the vehicle speed shall be taken by the Test Service using the vehicle CAN. This measurement shall be used for all assessments and comparison to Target Speed and Speed limits. The CAN speed shall comply with the accuracy requirements of UN ECE Regulation 39 and shall be reflected on the Speedometer..
- **Target Speed** – The vehicle speed which must be achieved as defined in each Test procedure of this protocol. The vehicle speed must be maintained within ±2mph of any target speed defined during each test procedure.
- **Speed Limit** – The maximum acceptable vehicle speed within any specific zone of the Digital Speed Map. Should the VUT vehicle speed be 2mph greater than the Speed limit, the speed limit shall be said to have been exceeded.
- **Test Track** – Any sealed area of carriageway without general access to the public
- **Digital Speed Map** – An electronic map which indicates the speed limit of roads. This may be for On-Road use, provided by TfL, or Test Track, provided by ISA system supplier, OEM or TS.
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **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.
- **Zone –** An area of the Digital Speed Map with a specified speed limit

6 Test Conditions

6.1 Test environment

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

A test track area shall be used by the TS which permits the various tests required (10mph, 20mph, 30mph, unrestricted). The coordinates and speed limits shall be provided to TfL which will incorporate the details into 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%

b) Be paved and shall not contain any irregularities (e.g. large dips or cracks, manhole covers) which might excessively slow the VUT.

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., At one point within the TfL Digital Speed Map zone, the bus will be stopped and the system powered down, restarted and the journey continued. The route shall incorporate 20mph, 30mph, and 40mph sections with transitions between each.

6.2 Weather and lighting

Tests shall be conducted in conditions representative of year-round London weather. Permissible weather conditions for testing are decided at the discretion of the TS.

Wind speeds should be below 22mph (approx. 10m/s) to minimise the effect of wind on bus speed. In case of wind speeds above 11mph (approx. 5m/s) during test, the validity of the test is decided at the discretion of the TS using the OEM predicted performance.

7 Pre-test submissions

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 OEM 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 (ROM)

c) Evidence from an appropriately certified body that the system has been tested and approved as per the requirements for Speedometer equipment within UN ECE Regulation 39

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 as to whether speed restriction is assisted by any system, and a description of the operation of this system

l) A statement as to whether a function that provides an over-speed notification to the bus driver is fitted, and provide details of the form of this notification

m) A statement that the vehicle performance characteristics are unaffected when the vehicle is not in Restricted Operating Mode

n) Instructions regarding how the ISA system is enabled and disabled

o) It is the responsibility of the test requester to ensure any vehicle tested for ISA provides a method to allow for the GPS, FMS and CAN signals received by the ISA system to be independently isolated. Modification of the relevant vehicle systems and/or cables may be allowed to provide this function during testing.

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

q) 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.

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

s) 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. It is the OEM’s responsibility to ensure the correct digital map is uploaded prior to test. Two maps shall be provided, with different zones and speed limits as agreed with the test service. These may include one map for the off-road test track and another map for the on-road tests. This shall also include the description of how the map update is protected from unauthorised access.

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

u) 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.

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

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

x) A record shall be made of the method provided to inform the drive of ISA fitment. This may be by a photograph for visual methods such as a sticker or light, or by video recording for audio method such as a voice recording.

8 System checks

A number of checks should be made by the Test Service whilst the vehicle is static. Support to achieve the following checks may be provided by the OEM or ISA system supplier where appropriate:

a) 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.

b) Any speed retardation system declared by the OEM shall be investigated and observed by the TS.

c) The TS shall enable and disable the system using the instructions provided by the OEM.

d) 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.

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

   i. Green – The system is functioning correctly within the Digital Speed Map area

   ii. White – The vehicle is not within the Digital Speed Map area and/or there is loss of GPS signal

   iii. Amber – The ISA system has a fault with its communication (CAN or FMS) signal

The system shall be deemed to have failed unless all the dash lamps are fitted. Each lamp may be in the same position and simply change colour as relevant, with the fault warning taking precedence.

f) 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 lamp is not illuminated when a system fault is caused.

g) 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. The OEM is responsible for providing a CANbus database file for the ISA system that details system states and faults.

h) The ISA system supplier or OEM shall provide the TS with method to clear the fault from the system. Fault shall be cleared and the illumination status of the amber light observed. The system shall be deemed to have failed if the system cannot be cleared and if the amber light does not extinguish.

i) The TS shall review all mapping formats successfully load and correctly function by driving the vehicle on the off-road test track and testing for the correct application of 20mph and 30mph 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.

j) 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.

k) The TS shall assess 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.

l) Addition of a specific antenna for updating the Digital Speed Map is prohibited. The presence of such an antenna shall result in test failure.

9 Test procedure

The vehicle speed for each test shall be measured and recorded from the vehicle CAN. This measurement shall be used for all assessments and comparison to Target Speed and Speed limits. The CAN speed shall comply with the accuracy requirements of UN ECE Regulation 39 and shall be reflected on the Speedometer.

Note: A check should be performed before starting each defined test to ensure the ISA is in the correct enabled/disabled condition applicable for the relevant test.

9.1 Track Testing

The following tests shall be undertaken at a suitable test track (see Section 6.1).

Where reasonable and appropriate the test service may assess multiple functions at the same time whilst still conforming to the procedures defined in this document. This may be conducted at the discretion of the test service, with prior agreement from the Approval Authority.

The VUT shall be driven on a test track whereby separate areas of the track are entered into the VUT's Digital Speed Map with speed limits of; 20mph, 30mph, 40mph and unrestricted.

Tests shall be conducted in an unladen condition with a driver (and observer if required).

9.1.1 Test Procedure

9.1.1.1 Check ISA will impose a speed restriction as soon as all conditions of ROM are met.

The VUT shall be driven at a speed of 30mph whilst with in a 30mph zone.

It shall enter into a 20mph zone with the accelerator pedal fully depressed and continue travelling with pedal fully depressed.

After entering the 20mph zone the ISA shall actively reduce the speed of the VUT in the manner describe by the vehicle OEM.

9.1.1.2 Check of ISA that vehicle speed reduction has been achieved without intervention of braking.

Note: Deceleration produced by energy recovery and/or engine retardation up to the level of $0.15m/s^2$.

The VUT shall be driven at a speed of 30mph whilst within a 30mph zone.

It shall enter into a 20mph zone with the accelerator pedal fully depressed and continue travelling with pedal fully depressed.

After entering the 20mph zone the ISA shall actively reduce the speed of the VUT in the manner described by the vehicle OEM.

The VUT shall continue travelling with accelerator pedal fully depressed until vehicle speed remains stable at 20mph [+0 -2mph] for the duration of at least 15 seconds.

9.1.1.3 Check of driver notification should ISA enforce any retardation of vehicle speed.

The VUT shall be driven at a speed of 30mph whilst within a 30mph zone.

It shall enter into a 20mph zone with the accelerator pedal fully depressed and continue travelling with pedal fully depressed for at least 15 seconds.

After entering the 20mph zone the ISA shall actively reduce the speed of the VUT in the manner describe by the vehicle OEM.

Whilst the VUT is travelling in excess of zone speed limit and the ISA system is actively retarding the vehicle speed, the driver shall be notified. This may be via a flashing speed limit symbol and by a reduction in the indicated speed.

The flashing frequency of the speed limit symbol shall be between 1Hz and 5Hz

9.1.2 Other tests

The VUT shall be tested to the following procedures.

9.1.2.1 Check that the ISA system does not affect the operation of the VUT below the speed limit.

a) The VUT shall be accelerated at full rate from 0mph within a 20mph zone.

   The time taken to reach a vehicle speed of 16mph (equivalent to 80% of the zone's speed limit), shall be measured and recorded.

   The ISA system shall then be disabled and the time taken to accelerate to the same speed shall be measured and recorded for the same section of track. (ISA system should be enabled after completing this measurement).

   The system shall be deemed to have failed if the difference in times to accelerate to same vehicle speed (80% of the zone's speed limit) with and without the ISA activated is more than 10%.

   This shall then be repeated within a 30mph zone measuring the time taken to achieve a vehicle speed of 24mph (80% of the zone's speed limit).

b) The VUT shall be driven within a 20mph zone with the accelerator pedal fully depressed. The VUT shall be travelling at a constant 20mph limit.

It shall enter into a 30mph zone with the accelerator pedal fully depressed and continue travelling with pedal fully depressed, for at least 15 seconds.

The system shall be deemed to have failed if the measured VUT acceleration is greater than $1.2 m/s^2$.

This shall then be repeated starting within a 30mph zone and entering into an unrestricted zone.

9.1.2.2 Check that the system is secure from tampering.

a) It shall be possible for only qualified personnel to disable the speed limiting system and only when the ignition is on and the vehicle is stationary.

b) The disabling of the system must be via an electronic device (e.g laptop, tablet or similar) connected to the vehicle or over-the-air (if this feature is available). 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.

c) 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.

9.1.2.3 Check that in the event of loss of GPS signal the system will fail safe whereby no speed limits are implemented by the ISA system.

a) The VUT shall be driven at a speed of 20mph whilst within a 20mph zone, with the accelerator pedal fully depressed for the duration of the test.

The GPS shall be isolated, see Section 7 q) to replicate a signal loss and the vehicle speed shall be observed for 15 seconds and recorded.

- The system shall be deemed to have failed if the ISA icon on the dash does not turn white as soon as the GPS is isolated
- The system shall be deemed to have failed if the VUT is recorded as reaching speeds above 20mph.

b) The VUT shall be driven at a speed of 20mph whilst within a 20mph zone, with the accelerator pedal fully depressed, for at least 15 seconds, at the Test Service’s discretion.

The driver shall apply the brakes to reach a vehicle speed of 14mph or less, before accelerating to a speed above 20mph.

The system shall be deemed to fail if:

The VUT accelerates before a braking input is applied.

OR

The VUT fails to reach speeds above 20mph after reaching a vehicle speed of 14mph or less.

c) Tests shall be repeated with the FMS isolated.

- The system shall be deemed to have failed if the ISA icon on the dash does not turn amber as soon as the GPS is isolated

d) Tests shall be repeated with the CAN isolated.

- The system shall be deemed to have failed if the ISA icon on the dash does not turn amber as soon as the GPS is isolated

9.1.2.4 Check of the travelled distance before a change of the speed limit indicator when entering a speed limit zone. (Guard against spurious GPS inaccuracy)

a) The VUT shall be driven at a speed of between 5mph and 12mph whilst within a 20mph zone.

It shall enter into a 30mph zone whilst retaining the same vehicle speed.

Using the front of the bus as the reference point, the distance travelled within the 30mph zone before the indicator system displays the new speed limit shall be recorded in metres.

The system shall be deemed to have failed if the distance recorded less than 30.0m

b) This test shall be repeated with the VUT travelling at a speed of between 5mph and 12mph whilst within a 30mph zone and entering into a 20mph zone.

9.1.2.5 Check of the time to indicate VUT having entered a ROM zone (Guard against spurious GPS inaccuracy)

a) The VUT shall be driven at a speed of 20mph whilst within a 20mph zone for a time of at least 15seconds.

It shall enter into a 30mph zone whilst retaining the same vehicle speed.

The time taken once within the 30mph zone before the indicator system displays the new speed limit shall be recorded.

The system shall be deemed to have failed if the time recorded is less than 5.0seconds and greater than 8.0second.

b) This test shall be repeated with the VUT travelling at 30mph whilst within a 30mph zone and entering into a 20mph zone.

9.1.2.6 Check the indication that the VUT has entered or exited the digital map area

a) The VUT shall be driven at a speed of 20mph from outside of the Digital Map Area for a time of at least 15 seconds

It shall enter into the Digital Map Area.

The time and the distance travelled before the dash lamp displays that the VUT has entered the Digital Map Area shall be recorded.

The system shall be deemed to have failed if the time recorded is less than 5.0seconds and greater than 8.0seconds (5 < t < 8) OR the distance travelled was less than 30.0m.

b) This test shall be repeated with the VUT travelling from inside the Digital Map Area and exiting it. The time and distance constraints defined in section 9.1.3.6a do not apply to this test.

9.1.2.7 Check of the continuous illumination of the green dash lamp

a) The VUT shall be driven at a speed of 20mph whilst within a 20mph zone with the accelerator pedal fully depressed, for a time of at least 15 seconds.

   It shall enter into a 30mph zone continue to travel with the accelerator pedal fully depressed for a distance of at least 100m.

   The illumination status of the green dash lamp shall be recorded.

   The system shall be deemed to have failed if the continuous green lamp extinguishes during the test.

b) This test shall be repeated with the VUT travelling from a 30mph zone into a 20mph zone.

9.1.2.8 Check for failure indication of GPS, FMS and CAN

- The VUT shall be driven at a speed of 20mph whilst within a 20mph zone for a time of at least 15 seconds

  The GPS isolator switch shall be operated to replicate signal loss.

  The time and distance taken before the green ISA lamp is extinguished and the white dash lamp illuminate shall be recorded.

  The system shall be deemed to have failed if the time recorded is less than 5.0seconds and greater than 8.0seconds (5 < t < 8) OR the distance travelled was less than 30.0m.

- Test shall be repeated using the FMS isolator switch.
  - The system shall be deemed to have failed if the ISA icon on the dash does not turn amber as soon as the GPS is isolated
- Test shall be repeated using the CAN isolator switch.
  - The system shall be deemed to have failed if the ISA icon on the dash does not turn amber as soon as the GPS is isolated

9.1.2.9 Check for indication of VUT being outside of the Digital Map Area

Whilst outside of the Digital Map Area by a distance of greater than 100m the vehicle shall be started and driven. The VUT shall remain outside of the Digital Map area and complete at least 100m travel.

The status of the dash lamps indicating ISA status shall be recorded.

The ISA system shall be deemed to have failed if the green lamp is not extinguished AND the white lamp is not illuminated at all times.

9.1.2.10 Check for dash indication with ISA system disabled

Whilst outside of the Digital Map Area the ISA system shall be disabled.

The VUT shall then be driven into the Digital Map Area by for a distance of at least 100m and then driven at least 100m out of the Digital Map Area.

The status of the green and white dash lamps shall be recorded.

The ISA system shall be deemed to have failed if at any time the green lamp is illuminated OR the white lamp is extinguished.

9.1.2.11 Check "No Digital Speed Map" condition

The TS shall ensure that when there is no Digital Speed Map loaded on to the VUT there is no system activation and no speed restriction exists.

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.

9.1.2.12 Check VUT restricted speeds against Digital Speed Map speed limits

a) The TS shall ensure the maximum vehicle speeds achievable whilst within each zone are the same as the speeds limits defined in the Digital Speed Map

   The VUT shall be deemed to have failed if the maximum vehicle speed achievable for any zone is found to be different to those expected from the loaded map.

b) Test to be repeated using an alternative Digital Speed Map which consists of different zones and limits to ensure the speed restrictions have subsequently changed

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

9.2 On road testing

On road testing shall only be commenced upon successfully achieving all requirements defined for track testing.

The VUT shall be driven on the on road testing infrastructure as defined in Section 6.1

Tests shall be conducted in an unladen condition with a driver (and observer if required).

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 using a separate GPS system 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. Video is to be time aligned during test to speed and position data within the TS data acquisition software.

9.2.1 Check VUT restricted speeds against Digital Speed Map speed limits

The TS shall ensure the maximum vehicle speed achievable whilst within each zone are the same as the speed limit defined in the Digital Speed Map

The VUT shall be deemed to have failed if the maximum vehicle speed achievable for any zone is found to be different to those expected from the loaded map.

Note: Speed limit shall only be achieved when and where safe to do so.

9.2.2 Check of the travelled distance and time before a change of the speed limit indicator when entering a speed limit zone

A visual comparison of the digital speed limit map and the speed limit indicator shall be made as the VUT enters each speed limit zone.

The system shall be deemed to have failed if the time recorded is less than 5.0 seconds and greater than 8.0seconds ($5 < t < 8$) OR the distance travelled was less than 30.0m.

9.2.3 Check ISA will impose a speed restriction as soon as all conditions of ROM are met

Whilst the VUT is within a zone and has at any point travelled at a speed less than the speed limit, the ISA system will be expected to prevent the vehicle from exceeding the speed limit.

The system shall be deemed to have failed if the VUT exceeds the zone speed limit by greater than 2mph. Note: This shall not apply where the VUT is travelling downhill.

10 Assessment of results

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

10.1 Pre-test submissions

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

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

10.2 System checks

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

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

10.3 Track tests

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

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

10.4 On-road tests

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

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

10.5 Overall Assessment

In order to receive an overall “Pass” certification the ISA system must receive a “Pass” grade for each of the above sections on the checklists

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.

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

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) Reference information

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) Applicable mapping types

h) Details of the TS

i) Test date(s)

Appendix A - Pre-test submissions checklist

Details found in Section 7.

	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.	
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: No intervention by the 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 over-speed 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.	
15	Instructions are provided by the bus OEM regarding how the ISA system is enabled and disabled.	

	Pre-test submissions	Pass/Fail
16	The bus OEM has provided a test vehicle where the GPS, FMS and CAN speed signals in to the ISA system can be independently isolated. Included must be clarification of how this has been achieve and how to isolate each signal.	
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: [ ]

Appendix B - System checks.

Details found in Section 8.

	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 service.	
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 due to CAN or FMS isolation caused the green lamp to extinguish and the amber lamp was illuminated. Check there was no Audio alert	
7	Interrogation of the ISA system for the fault found a match to the caused fault.	
8	The fault can be cleared from the system.	
	The amber light was extinguished when the fault was cleared.	
9	The mapping format loaded and applied properly.	
	The correct application of 20mph and 30mph speed limits with applicable mapping formats was observed. Check there were no Audio alerts	
10	The outdated Digital Speed Map can be completely removed from the ISA system.	
	A new map can be uploaded properly.	
11	An ad-hoc change to the Digital Speed Map can be properly uploaded.	
12	No additional antenna for updating the Digital Speed Map is found.	

Result:

Appendix C - Track testing checklist

Details found in Section 9.

		Track testing	Pass/Fail
Tests	1	Check ISA will impose a speed restriction as soon as all conditions of ROM are met Check there were no Audio alerts	
	2	Check of ISA that vehicle speed reduction has been achieved without intervention of braking.	
	3	Check of driver notification should ISA enforce any retardation of vehicle speed. Check there were no Audio alerts	
Other tests	1	Check that the ISA system does not affect the operation of the VUT below the speed limit.	
	2	Check that the system is secure from tampering	
	3	Check that in the event of loss of GPS signal the system will fail safe whereby no speed limits are implemented by the ISA system Check there were no Audio alerts	
	4	Check of the travelled distance before a change of the speed limit indicator when entering a speed limit zone. (Guard against spurious GPS inaccuracy)	
	5	Check of the time to indicate VUT having entered a ROM zone (Guard against spurious GPS inaccuracy)	
	6	Check the indication that the VUT has entered or exited the digital map area Check there were no Audio alerts	
	7	Check of the continuous illumination of the green dash lamp	
	8	Check for failure indication of GPS, FMS and CAN Check there were no Audio alerts	
	9	Check for indication of VUT being outside of the Digital Map Area Check there were no Audio alerts	
	10	Check for dash indication with ISA system disabled Check there were no Audio alerts	
	11	Check “No Digital Speed Map” condition	
	12	Check VUT restricted speeds against Digital Speed Map speed limits	

Result:

Appendix D - On-road testing checklist

	On road testing	Pass/Fail
1	Check VUT restricted speeds against Digital Speed Map speed limits	
2	Check of the travelled distance and time before a change of the speed limit indicator when entering a speed limit zone	
3	Check ISA will impose a speed restriction as soon as all conditions of ROM are met	

Result:

Attachment 18: Intelligent Speed Assistance (ISA) Guidance Notes

1 Introduction

This document sets out the guidance notes related to Intelligent Speed Assistance. This system provides an aid to the driver, limiting the vehicle speed whilst travelling in designated speed limit zones.

These guidance notes are aimed at bus operators and OEMs as a practical guide for implementation of the Bus Safety Standard.

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

For full understanding of this Attachment it should be read in conjunction with London Bus Services Limited New Bus Specification: Section 4.3.3 and Attachment 17 – ISA Assessment Protocol.

1.1 ISA Description

Intelligent Speed Assistance (ISA) is a system fitted to buses which links an understanding of location (from GPS[1]) to an on-board map of speed limits (known as the TfL Digital Speed Map), and a reading of the bus speed. It uses this information to limit the speed of the bus without intervention by the foundation brakes to enforce a speed restriction, however energy recovery and engine retardation is permitted.

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 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.

[1] 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.

Driving at the speed limit is not always appropriate for the road curvature, surface, traffic, environmental conditions etc. 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.

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 system will not brake, or use the vehicle's foundation brakes.

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.

2 Selection of buses/systems

ISA can be fitted on new-build buses, conforming with either Attachment 17.

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. Only with express written approval from the Approval Authority within TfL, in the instance where an OEM has confirmed they have no intent to fit or support retrofit, will the use of aftermarket equipment be allowed.

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

3 Training

3.1 Driver training

Training of drivers should entail at least the following elements:

- 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
- Clear emphasis that the driver remains responsible for speed limit compliance at all times.

The ISA supplier should provide specific material or advice which is appropriate to the system.

3.2 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, and enabling and disabling the system. Additionally and depending upon any warranty and maintenance agreement, training may extend to fault finding/repair.

4 Maintenance

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

The bus operators and the ISA supplier/Bus supplier will reach an 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).

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).

For full understanding of this Attachment it should be read in conjunction with the Attachment 20: Bus Vision Standard Guidance Notes and New Bus Specification, Section 4.3.4.3.

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.

3 Purpose

The aim of the Bus Vision Standard (BVS) assessment protocol 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.

Over many years blind spots in a driver’s vision have been identified as a contributory factor in collisions between vehicles and pedestrians and cyclists which resulted in death or seriously injury. The BVS has been defined to reduce likelihood of these type of collisions.

Typically, direct vision blind spots in buses are 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. Indirect vision areas rear of the driver seat position and for wider fields of view may also be subject to blind spots

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 OEM 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 correct 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 New Bus Specification: Section 4.3.4.3
- London Bus Services Limited New Bus Specification: Attachment 20 Bus Vision Standard Guidance Notes
- Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- 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. At the point where a sightline intersects a surface (Obstruction point), the angle between the sightline and a plane 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 0.1m, 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 at right angles 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.

- **ETRTO -** European Tyre and Rim Technical Organisation.
- **Eye points (E_L, E_R) -** Two points representing the driver’s left and right eyes. These are the points from which sightlines originate.
- **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.
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **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 Coordinate System

A global coordinate system (X, Y, Z) for the VUT shall be defined such that the X axis is positive toward the front of the vehicle, the Y axis towards the left (nearside) and the Z axis upwards, as shown in Figure 19_1.

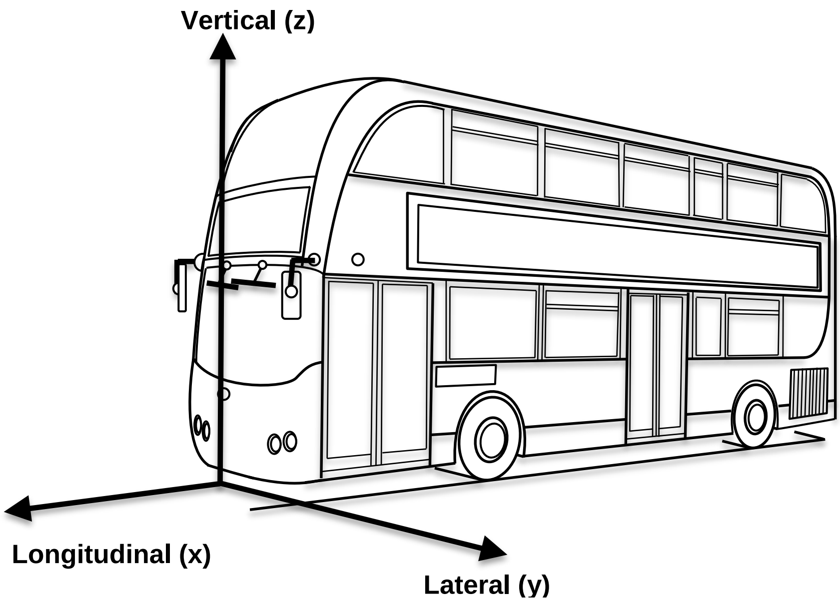


Figure 19_1: Global coordinate system and notation

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

6.2 Eye Points

The field of view of the driver shall be defined by a cyclopeanmonocular vision point (E_C) taken as the mid-point between two eye points (E_L and E_R). Rotation shall be possible about a neck pivot point (P). E_L, E_R and P locations are defined in relation to the E_{ref} position, which in turn is defined in relation to the AHP.

6.3 Reference Eye Point Location (E_{ref})

The reference eye point (E_{ref}) is defined as an offset from the AHP of 0.678 m in the X axis and 1.16325 m in the Z axis, as shown by Figure 19_2. 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:

$E_{ref\_x} = AHP_x + 0.678$ m

$E_{ref\_z} = AHP_z + 1.16325$ m

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.

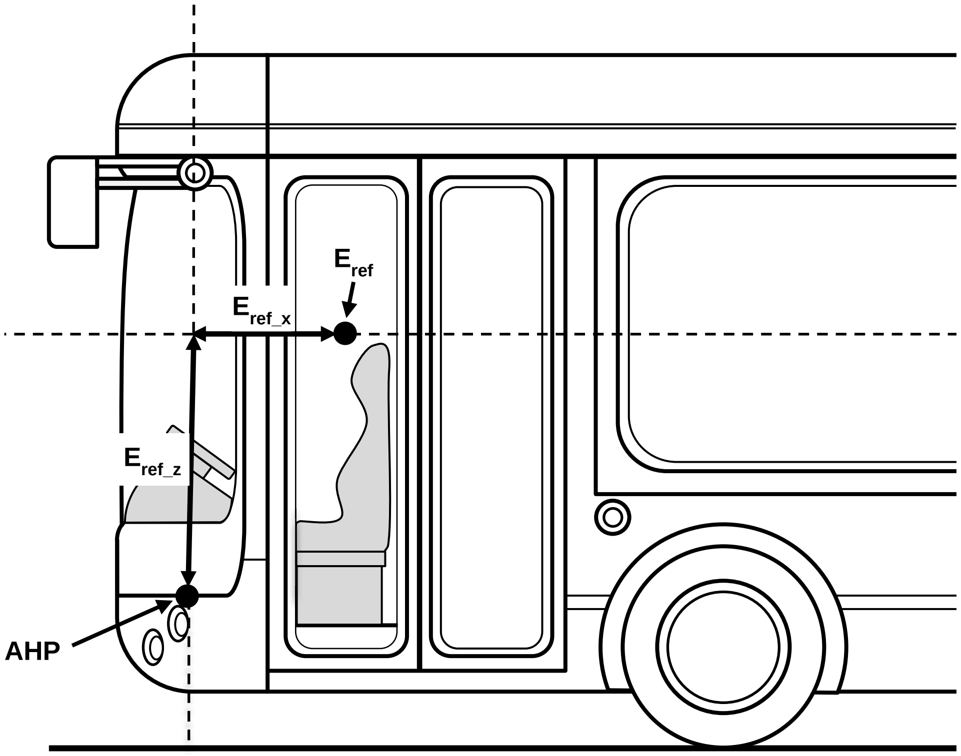


Figure 19_2: Definition of vertical (E_{ref_z}) and rearward (E_{ref_x}) offset of the reference eye point (E_{ref}) from the accelerator heel point (AHP)

6.4 Neck Pivot Point Location (P)

The neck pivot point (P) is defined as an offset of 0.098 m behind the E_{ref} point in the X axis, as shown in Figure 19_3.

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

The left and right eye points (E_L and E_R) are defined as an offset of ± 0.0325 m from the E_{ref} point in the Y axis, as shown in Figure 19_3.

E_L and E_R are not required to defined the sightlines or vision volumes using the method defined in this document but are included for completeness.

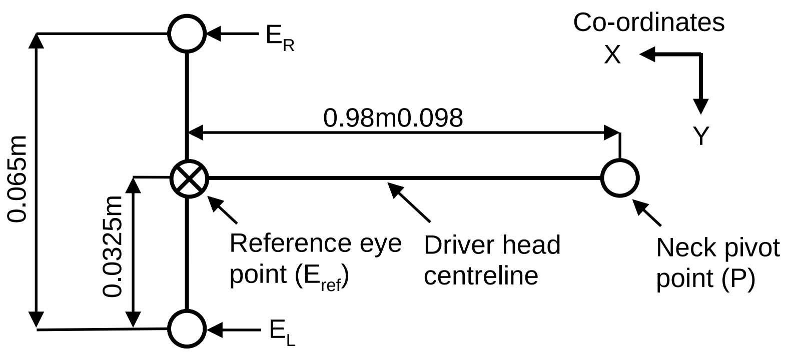


Figure 19_3: Definition of left and right eye point (E_L and E_R) positions relative to the neck pivot point (P) and reference eye point (E_{ref})

6.6 Neck Pivot Point Range of Motion (β)

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 19_3.

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

6.7 Eye Point Range of Motion (θ)

The horizontal rotation (θ_L, θ_R) for the Eye point E_C is defined by a maximum range of motion of ± 30°, as shown in Figure 19_4.

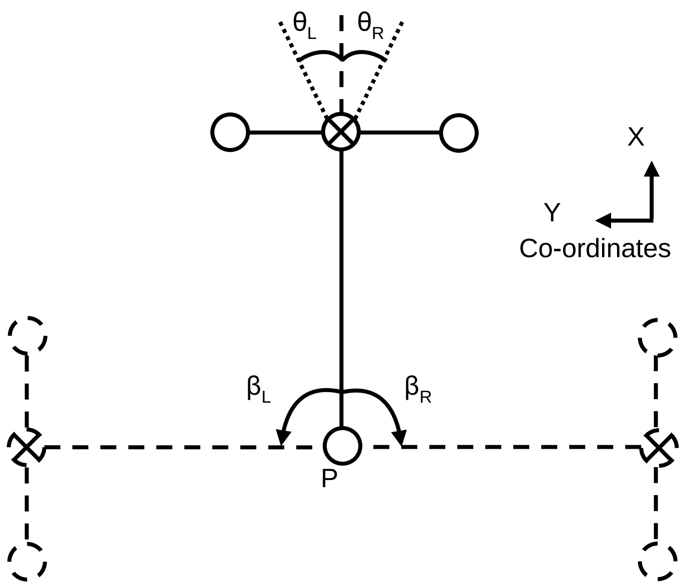


Figure 19_4: Plan view of horizontal neck point and eye point rotations

The vertical rotation (θ_U, θ_D) for the eye point is defined by a maximum range of motion of 45° upwards and 60° downwards as shown in Figure 19_5.

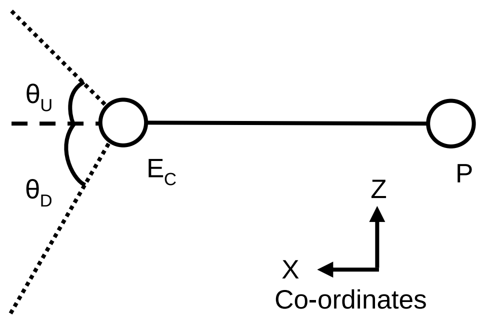


Figure 19_5: Side view of vertical eye point rotations

6.8 Camera Points

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.

6.9 Camera Point Locations (C)

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

6.10 Camera Point Fields of View (α, λ)

The angle of the centre of the field of view shall be provided for each camera point (C_n) by the OEM, as shown in Figure 19_66 and Figure .

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 XZ plane.

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 OEM, as shown in Figure 19_6.

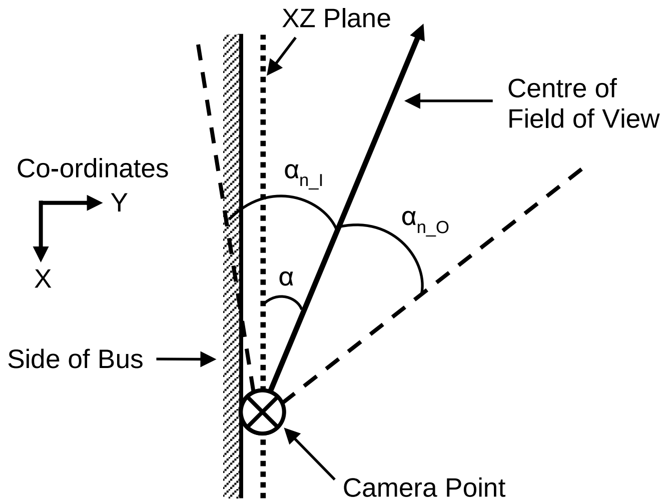


Figure 19_6: Plan view of horizontal field of view range for camera point

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.

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 OEM, as shown in Figure 19_7.

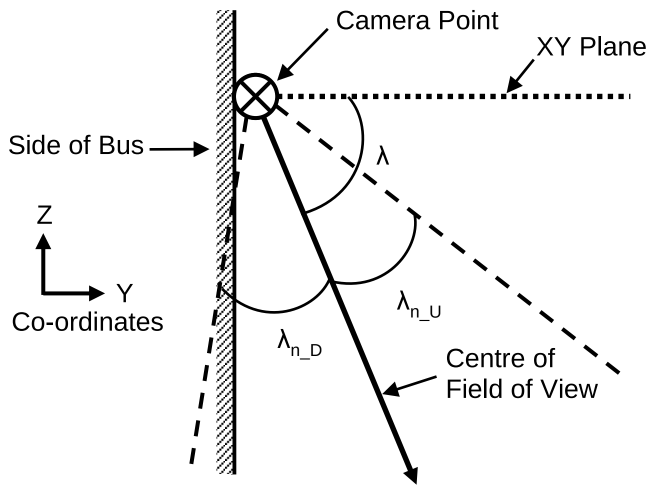


Figure 19_7: Frontal view of vertical field of view range for camera point

6.11 Assessment Zones

The following three assessment zones shall be defined:

- Forward Close Proximity Zone
- Rearward Close Proximity Zone
- Wide-Angle Zone

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.

6.12 Assessment Zone Height

Each assessment zone shall be formed by a volume, including the following defined areas, at heights from Z = 1.177 m through to Z = 1.602 m from the ground plane.

6.13 Forward Close Proximity Zone

The dimensions of the forward close proximity assessment zone are shown in Figure 19_8 to 19_10 and described below:

a) The fore outer boundary of the assessment zone is defined by a YZ plane 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 XZ plane 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 XZ plane located 2 m outboard (-Y axis) from the most lateral aspect of the offside of the vehicle structure.

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

e) The inner boundary is located 0.3m from the outermost aspect of the vehicle structure, when measured normal to the relevant vehicle structure (Figure . This may include curves, dependant on the geometry of the outmost vehicle structure.

f) Assessment Zone height as per Section 4.12, shown in Figure 19_10

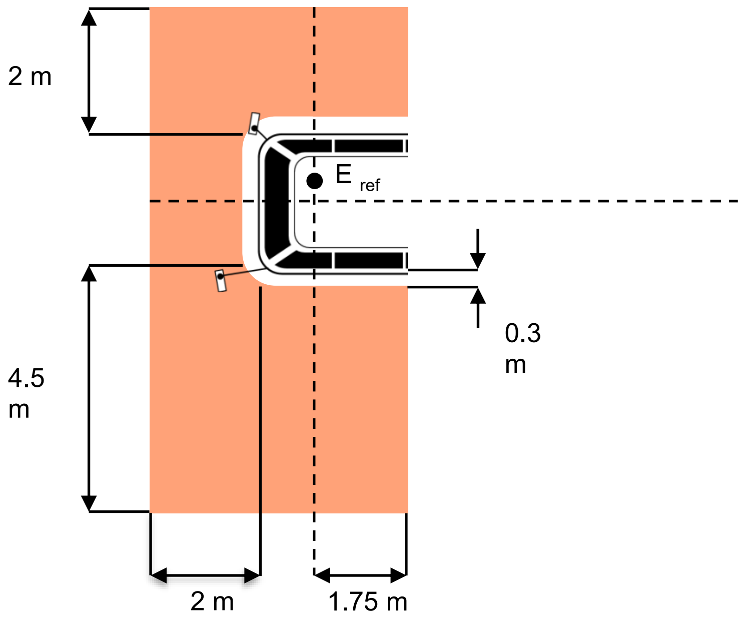


Figure 19_8: Plan view of forward close proximity assessment zone

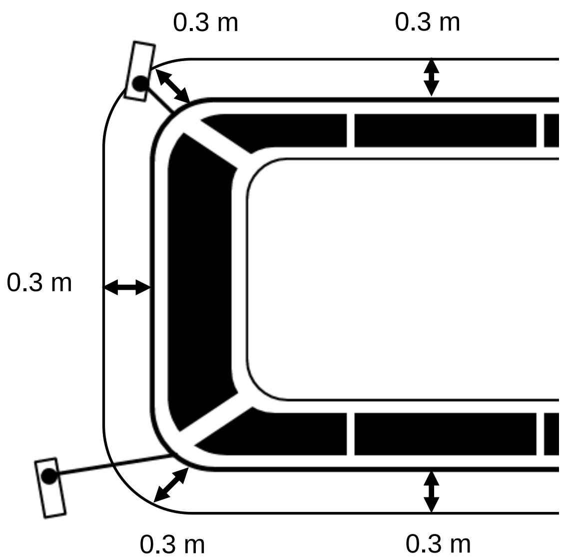


Figure 19_9: Illustration of profile for defining inner boundary of assessment zones

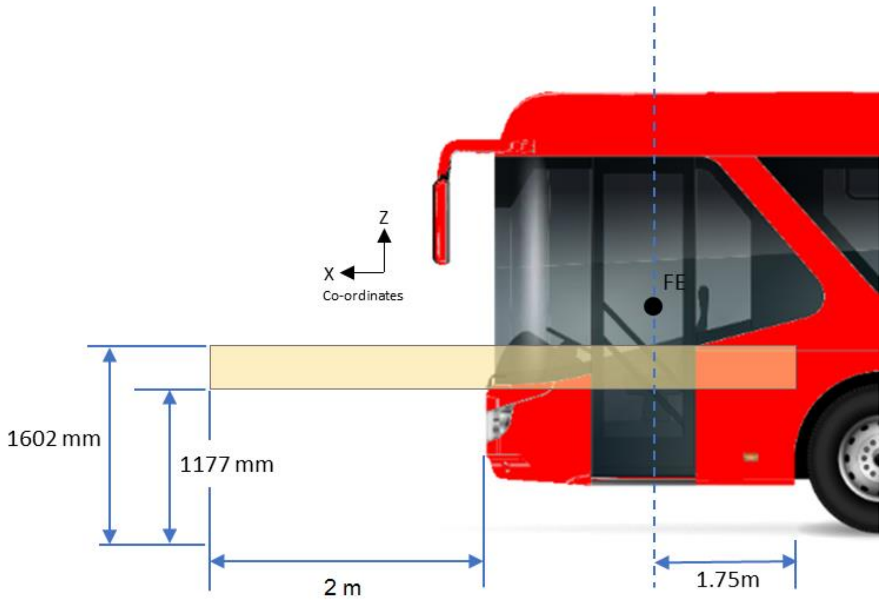


Figure 19_10: Side view of forward close proximity assessment zone

6.14 Rearward Close Proximity Zone

The dimensions of the rearward close proximity assessment zone are shown in Figure 19_11 and 19_12 and described below:

a) The fore outer boundary of the assessment zone is defined by a 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 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 XZ plane and located 2 m outboard (-Y axis) from the most lateral aspect of the offside of the vehicle structure.

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

e) The inner boundary is located 0.3 m from the outermost aspect of the vehicle structure, when measured normal to the relevant vehicle structure (Figure 19_11). This may include curves, dependant on the geometry of the outmost vehicle structure.

f) Assessment Zone height as per Section 4.12, shown in Figure 19_12

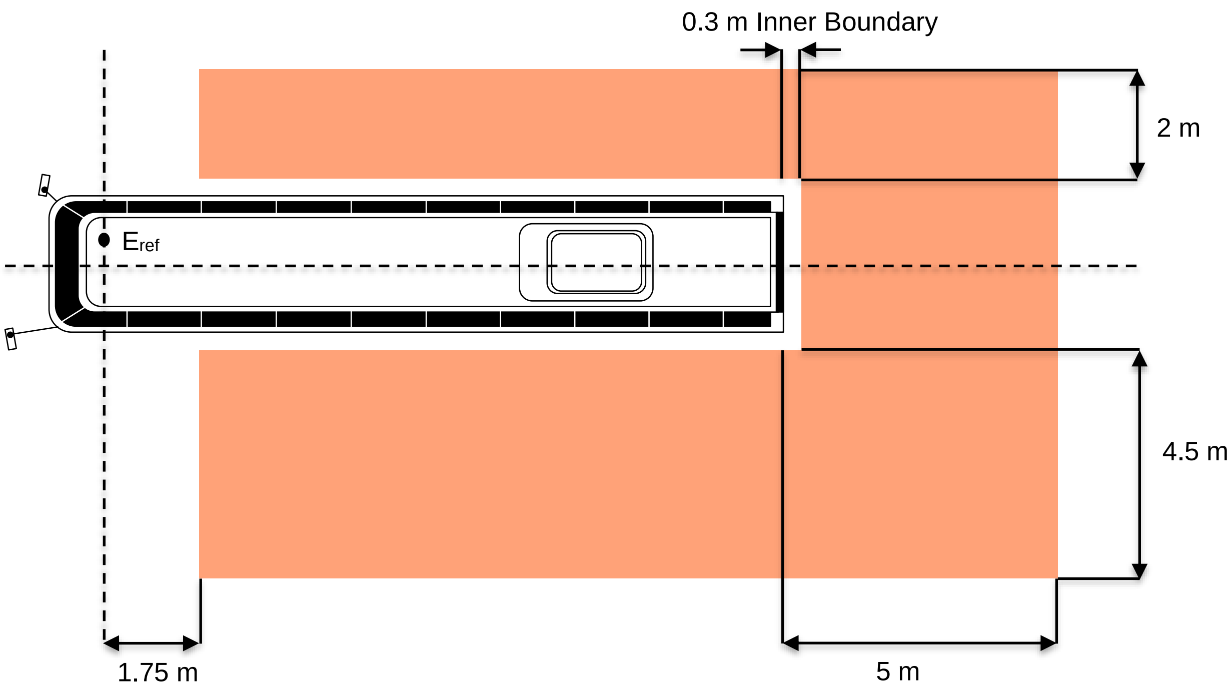


Figure 19_11: Plan view of rearward close proximity assessment zone

Figure 19_12: Side view of rearward close proximity assessment zone

6.15 Wide-Angle Zone

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 19_13 and 19_14 and described below:

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

i. The fore boundary of the assessment zone is defined by a YZ plane, located 1.5 m rear (-X axis) of the reference eye point (E_{ref}).

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

iii. The outer boundary of the assessment zone is defined by a XZ plane, located 15 m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure and a Z plane between 1.5 m rear (-X axis) of the reference eye point (E_{ref}) and 4.5 m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure and 10 m to the rear (-X axis) of the reference eye point (E_{ref}) and 15 m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure .

iv. The inner boundary of the assessment zone is defined by a XZ plane, located 4.5 m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure

v. Assessment Zone height as per Section 4.12, shown in Figure 19_14

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

i. The fore boundary of the assessment zone is defined by a YZ plane, located 1.5 m to the rear (-X axis) of the reference eye point (E_{ref})

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

iii. The outer boundary of the assessment zone is defined by a XZ plane, located 15 m outboard (-Y axis) from the most lateral aspect of the nearside of the vehicle structure and a Z plane between 1.5 m rear (-X axis) of the reference eye point (E_{ref}) and 4.5 m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure and 10 m to the rear (-X axis) of the reference eye point (E_{ref}) and 15 m outboard (+Y axis) from the most lateral aspect of the nearside of the vehicle structure

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

v. Assessment Zone height as per Section 4.12, shown in Figure 19_14

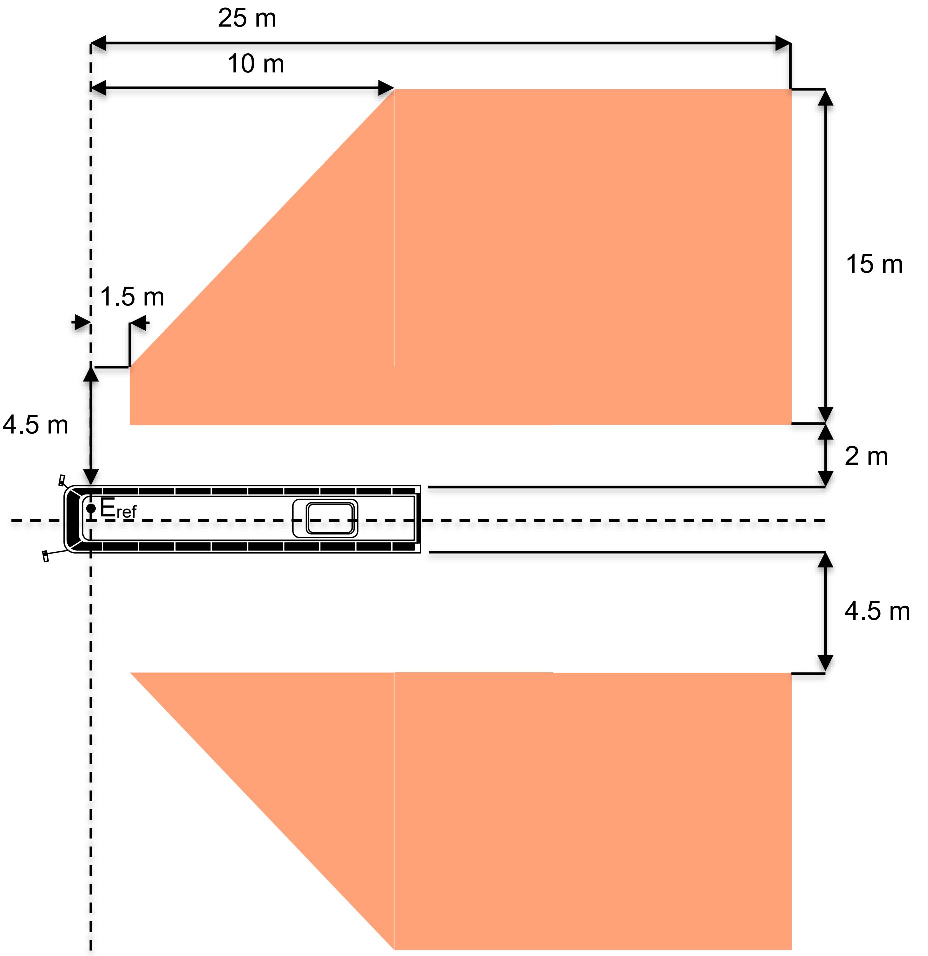


Figure 19_13: Plan view of wide-angle assessment zone

Figure 19_14: Side view of wide-angle assessment zone

6.16 Assessment Zone Elements

Each assessment zone volume shall be split into individual, 3 dimensional elements, approximately equal in both size and shape, with no single dimension exceeding 0.1m.

7 Vehicle preparation

7.1 CAD Model

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 (Figure). This can either be supplied by the OEM 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, 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 (e.g. bumper) and sides (e.g. wheel arches)
c) Exterior elements that may obstruct driver vision including; mirrors and mirror arms, wipers and any other OEM fit feature or equipment
d) Exterior mirrored surfaces that may reflect driver vision
e) Interior surfaces that may obstruct 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 obstruct driver vision including; ticket machines, rain sensors, monitors/screens or other controls or displays, etc.
g) Key elements of the driver packaging including; seats, steering wheel, etc, and the AHP.

Figure 19_15: Example CAD data required for bus vision standard assessment

7.2 Glazing Frit

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 below.

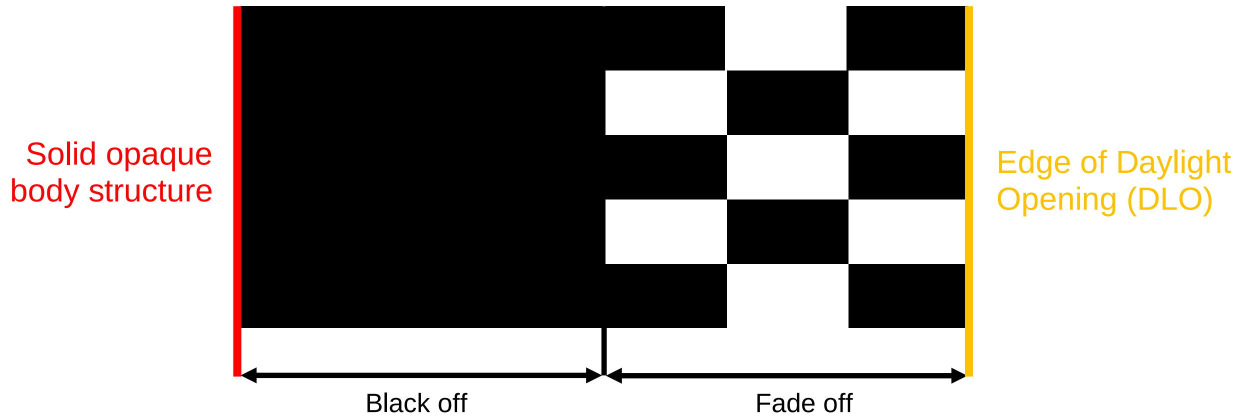


Figure 19_16: Definition of daylight opening (DLO) at window edges with black-off or fade-off areas

7.3 Tinting

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.

7.4 Glazing Angle

Where the angle of incidence (θ_I) between the surface of any section of glazing and the sightline from the eye is angled at greater than 74°, when looking at the surface from any angle, this area shall be considered opaque (Figure 19_17). The DLO boundary is therefore further defined by the boundaries of any glazed surfaces defined as opaque.

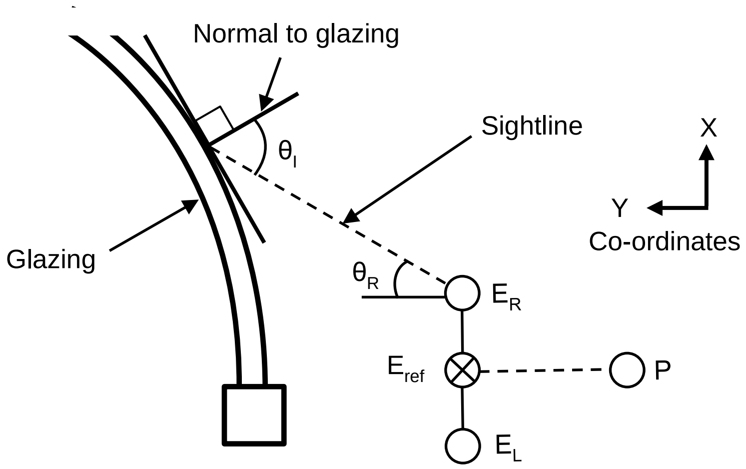


Figure 19_17: Illustration of angle of incidence between the sightline and glazing

7.5 Mirror Positioning

Accurate CAD models of mirror surfaces, mirror housings and mirror arms shall be included. Curved surfaces for non-planar mirrors shall be included. Mirror surfaces and mirror arm model information shall be recorded.

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

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, and Z-axes of the vehicle shall be recorded, alongside the position of the attachment to the mirror arm.

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

All mirrors, mirror housings and mirror arms shall be adjusted within OEM 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.

7.6 Camera-Monitor Systems (CMS)

Accurate CAD models of the exterior geometries for the camera, camera housing and monitor shall be included. Monitors shall be positioned in their OEM 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.

7.7 Accelerator Heel Point (AHP) Height

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 bodywork and mirror arrangements where the AHP is nearer to the ground. Alternatively, the OEM 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 OEM's recommendations
d) The fuel tank is filled to no greater than 10% of the capacity specified by the OEM
e) Other fluid levels, such as lubricants, coolants, etc., are set according to OEM's recommendations
f) The driver seat is occupied with a driver of 68 kg mass
g) No additional payload or passenger ballast is added

7.8 Steering Wheel Position

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

7.9 Driver Seat Position

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

7.10 Accelerator Heel Point (AHP)

The CAD data shall 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.

7.11 Other Vehicle Components

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.

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.

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

Technically, it is possible to undertake this assessment using CAD software alone. However, it is considered that it would be very complex and time consuming. It is, therefore, recommended that the CAD models of both the vehicle and assessment zone are assessed using an automated computer programme.

An example of the sightlines to be assessed can be found in the breakdown of the neck pivot point and eye point angles provided in Appendix B.

8.1 Sightline Projection

Sightline projections shall be made and analysed according to the following procedure for a combination of different neck pivot point angles (β), measured at 10º increments, and eye point angles(θ), within the ranges defined in Section 4.

Sightline projections shall also be made and analysed for camera field of vision angles (α, λ), within the ranges specified by the OEM..

Each sightline shall be projected from a point of origin located at the cyclopean eye point or camera point location to be assessed.

The angle between each sightline, whether projected from the eye point or a camera, shall be such that each of the assessment zone elements may be intersected where no obstruction exists. For example, where elements of 0.1m have been used at a distance of 3m from the Eye point, angular increments of 1.5° or less should be used.

Each sightline shall be increased in length in increments of 0.1 m, 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 not defined as a mirrored surface. In this case, the projection of the sightline shall be terminated at the obstruction point.

b) 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.

c) The end of the assessment zone.

8.2 Determining the Direct Vision Volume (V_D)

The determination of the Direct Vision Volume must be conducted before other vision volumes to ensure the Bus Vision Score weighting calculations are correctly applied.

All assessment zone elements intersected by a sightline originating from the cyclopean 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).

The assessment procedure must ensure that any assessment zone element which is counted as part of the Direct Vision Volume is prevented from being counted again as part of the Indirect Vision Volume. This is to prevent the double counting of any individual element which may produce a biased result.

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

8.3 Determining the Indirect Vision Volume (V_I)

8.3.1 Indirect Vision Volume (V_I)

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}).

Thus, for each assessment volume:

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

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

8.3.2 Mirrors (V_{I_M})

All assessment zone elements intersected by a sightline originating from the cyclopean eye point (i.e. not at a camera point) after having been reflected from a mirrored surface shall be designated as visible through the indirect field of vision of the driver using a mirror.

Any elements that have been found to be visible via the direct field of vision must not be included in this assessment to avoid "double counting" any elements..

The volume of these individual elements shall be summed to form the indirect vision volume for mirrors (V_{I_M}).

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

All assessment zone elements intersected by a sightline originating from a camera point, but that have not been found to be 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}).

8.4 Determining the Total Driver Vision Volume (V_T)

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).

Thus, for each assessment volume:

$$V_T = V_D + V_I$$

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

8.5 Determining the Blind Spot Volume (V_B)

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).

Thus, for each assessment volume:

$$V_B = V_A - V_T$$

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)

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 relevant direct vision volume (V_D) by the assessment zone volume (V_A) .

Thus, for each assessment volume:

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

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

9.2 Indirect Vision Performance Score (IVS)

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 relevant indirect vision volume (V_I) by the assessment zone volume (V_A) .

Thus, for each assessment volume:

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

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

9.3 Total Driver Vision Performance Score (TVS)

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 relevant total driver vision volume (V_T) by the assessment zone volume (V_A) .

Thus, for each assessment volume:

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

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)

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.

[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 _1.

Table 19_1: 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

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

$$Zone\ BVS = W_C(\text{DVS} \times W_D) + (\text{IVS} \times W_I)$$

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.

Table 9_2 shows hypothetical results as a worked example.

Table 19_2: 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

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

10.1 Performance Data

Table 19_3: Performance data template for test report shows the performance data to be produced for each vehicle assessed.

Table 19_3: Performance data template for test report

Performance Measure	Forward Close Proximity Zone	Rearward Close Proximity Zone	Wide Angle Zones
Assessment Zone Volume (V_A) /mm³			
Direct Vision Volume (V_D) /mm³		-	-
Indirect Vision Volume for Mirrors (V_{I_M}) /mm³			
Indirect Vision Volume for Cameras (V_{I_C}) /mm³			
Indirect Vision Volume (V_I) /mm³			
Total Driver Vision Volume (V_T) /mm³			
Blind Spot Volume (V_B) /mm³			
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) /%			

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 19_18.

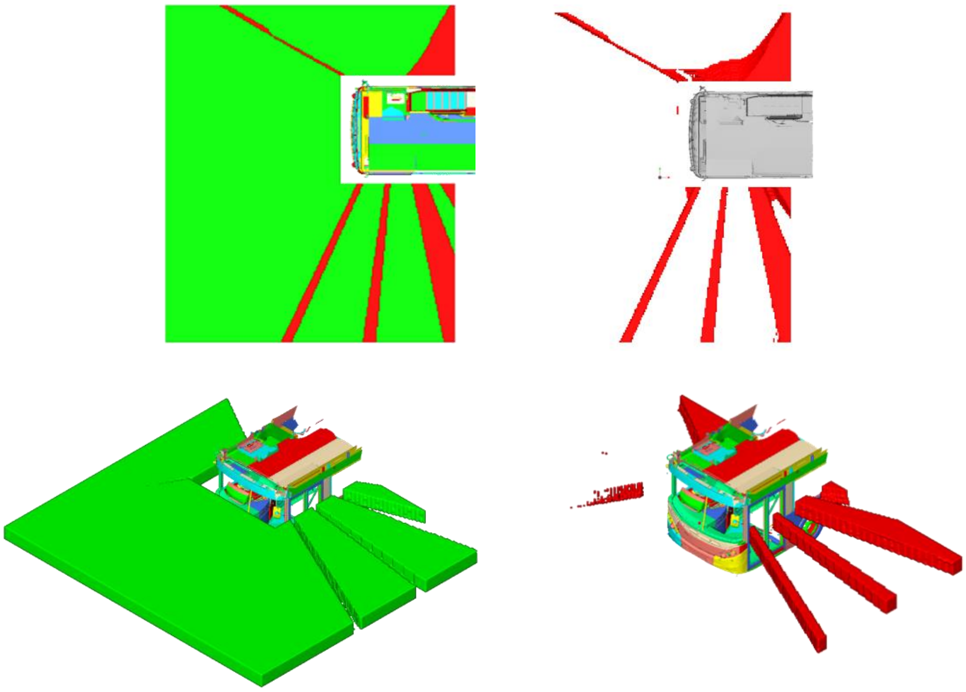


Figure 19_18: Example images showing Direct Vision Volume (green) and Blind Spot Volume (red) for the forward close proximity assessment zone

10.2 Protocol Compliance

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 OEM 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.

10.3 Reference Information

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
m) Test date(s)

Appendix A - 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

Appendix B - Example 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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

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 OEM and/or the aftermarket supplier.

2.2 Requirement interpretation and application guidance

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 allow the driver to recognise a potentially dangerous situation while undertaking 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 and associated protocol recognises that current buses already have very good direct vision relative to other large vehicles and so sets a minimum criteria that ensures that standard is maintained in the face of other competing pressures in future. It allows for improvements over and above this minimum standard but also recognises that the opportunities for improvement are relatively small.

In addition to this, the Bus Vision Standard defines a minimum standard for the overall level of vision, whether implemented via direct or indirect vision. It is not prescribed how this should be achieved and allows for vision performance over and above the minimum standard. This leaves OEMs and operators to choose the solutions that work best with their designs and operations. In making those choices, OEMs 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 vehicle via direct vision. In particular any area significantly rearward of the driver’s 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, as previously discussed, experimental evidence has shown the ability of drivers to recognise hazards can be more difficult when reliant on indirect vision rather than via direct vision. The following should be considered when implementing indirect vision:

- **Adjustment:** Poor adjustment of mirrors, camera views and monitors can substantially reduce the available view from the device. Operators should request guidance from the OEM or aftermarket supplier regarding the correct adjustment of the mirror or CMS.
- **Conflicts with direct vision:** Mirrors or monitors placed in areas around windows will can 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 also 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.
- **Image size:** Hazards seen in mirrors or monitors will are 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.

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 OEMs and operators should aim to select the best solutions they can bearing in mind these factors and their other operational constraints.

A camera monitor system which is intended to replace mirrors may resolve some of the potential conflicts by varying the views displayed on its 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. 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 Services

The recommended method to complete the assessment involves the use of CAD and finite element (FE) modelling. Therefore, the respective test service conducting an assessment should have the relevant expertise to implement such techniques.

Test services accredited to undertake approval tests to UNECE Regulation 46 will be considered suitable to undertake performance tests if they can also prove the necessary CAD and FE expertise. Test services without such accreditation will be required to demonstrate to TfL at their own expense that they can achieve the same standard of testing as an accredited organisation.

3.2 Bus Drivers

Drivers should be trained to correctly adjust mirrors and/or CMS to provide the required field of view, in accordance with the guidance from the OEM or aftermarket supplier.

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 ensure drivers correctly adjust mirrors and/or CMS to provide the required field of view and 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 OEM’s guidance. This should include understanding 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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

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 Considerations for the utilisation of Blind spot mirrors

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, experimental evidence has shown the ability of drivers to recognise hazards can be more difficult when reliant on indirect vision rather than via direct vision. The following should be considered when utilising indirect vision:

- **Adjustment:** Poor adjustment of blind spot mirrors can substantially reduce the useful available view from the device. Operators should request guidance from the OEM or aftermarket supplier regarding the correct adjustment of the mirror.

- **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. They can however also produce distorted the 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.
- **Image size**: Hazards seen in mirrors will are typically be smaller than life size and their relative motion in regard to the vehicle less easy to identify in peripheral vision. Thus, larger mirrors may be preferable to smaller devices.

A wide range of differences in approach are still possible within these constraints and OEMs 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 provide the required field of view, in accordance with the guidance from the OEM or aftermarket supplier.

3.2 Shift Supervisors

Supervisors should ensure drivers 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 failing 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.

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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

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 OEM and/or the aftermarket supplier.

Considerations for the utilisation of Camera Monitoring System 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, experimental evidence has shown the ability of drivers to recognise hazards can be more difficult when reliant on indirect vision rather than via direct vision. The following should be considered when utilising indirect vision:

- **Adjustment:** Poor adjustment can substantially reduce the useful available view from the device. Operators should request guidance from the OEM or aftermarket supplier regarding the correct adjustment of the CMS.
- **Conflicts with direct vision:** Monitors placed in areas around windows will can 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 however also 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.
- **Image size:** Hazards seen in monitors will are 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.

A wide range of differences in approach are still possible within these constraints and OEMs and operators should aim to select the best solutions they can bearing in mind these factors and their other operational constraints.

A camera monitor system which is intended to replace mirrors may resolve some of the potential conflicts by varying the views displayed on its 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. 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 Bus drivers

Drivers should be trained to correctly adjust the CMS to provide the required field of view , in accordance with the guidance from the OEM or aftermarket supplier.

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 ensure drivers correctly adjust CMS to provide the required field of view and 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 or monitors are deemed to be faulty or failing 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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

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 OEM and/or the aftermarket supplier. The compliance is with regard to the technical quality of view only.

2.2 Considerations for the utilisation of Rear View CMS

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, experimental evidence has shown the ability of drivers to recognise hazards can be more difficult when reliant on indirect vision rather than via direct vision. The following should be considered when utilising indirect vision:

- **Adjustment:** Poor adjustment can vary substantially greatly and therefore reduce the useful available view from the device. Operators should request guidance from the OEM or aftermarket supplier regarding the correct adjustment of the CMS.
- **Conflicts with direct vision:** Monitors placed in areas around windows will can 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 however also 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.
- **Image size:** Hazards seen in monitors will are 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.

A wide range of differences in approach are still possible within these constraints and OEMs 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, in accordance with the guidance from the OEM or aftermarket supplier.

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 ensure drivers correctly adjust CMS to provide the required field of view and 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 or monitors are deemed to be faulty or failing 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 (BSW) Assessment Protocol

1 Introduction

Blind Spot Warning (BSW) systems are used to provide additional information to drivers to inform them about the potential hazards presented by vulnerable road users in close proximity to the bus to support safe execution during low speed, driving tasks.

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

For full understanding of this Attachment it should be read in conjunction with the Attachment 25: Blind Spot Warning (BSW) Guidance Notes and New Bus Specification, Section 4.3.4.5.

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 M3; Class I.

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).

3 Purpose

The aim of the Blind sport warning assessment protocol is to provide objective assessments that can be used to enforce minimum standards for systems installed on vehicles to assist the driver and reduce the likelihood of collisions with vulnerable road users at low vehicle speeds. This protocol only covers collision situations related to low speed, close proximity manoeuvring. It does not consider forward collision warnings or automated emergency braking systems of the type relevant at higher speeds with the vehicle travelling in a straight line, such as those scenarios covered by TfL’s AEB assessment protocol

Over many years blind spots in a driver’s vision have been identified as a contributory factor in collisions between vehicles and pedestrians and cyclists which resulted in death or seriously injury. The Bus Vision Standard assessment (Attachment 19) has been defined to reduce likelihood of these type of collisions, however it is clear that better vision alone does not eliminate risk. Collisions where pedestrians and cyclists are killed or seriously injured when positioned in close proximity to a moving bus do still occur, with specific collisions identified where the vehicle turned left and hit a vulnerable road user at the nearside or front.

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 and collision warning systems therefore have a role to play in helping to 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, will define a minimum pass/fail standard only and covers information signals and not necessarily collision warning or intervention systems.

4 Normative References

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

- London Bus Service Limited New Bus Specification Section 4.3.4.5
- London Bus Service Limited New Bus Specification - Attachment 25: Blind Spot warning guidance
- 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
- UN ECE 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.
- UN ECE 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’
- UN ECE 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*
- ISO 19206: Road vehicles. Test devices for target vehicles, vulnerable road users and other objects for assessment of active safety systems

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.
- **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 OEM or their authorised dealer.

- **Blind spot** - The volume of space around the vehicle under test 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. 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 and is at risk of an imminent collision. The system may achieve the function through intervention in throttle, gear selection, braking, or other means. The system shall be type approved for use by the OEM.

- **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 OEM 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 vehicle under test and the sightline
- **OEM: Original Equipment Manufacturer –** The company responsible for the manufacture of a complete bus, delivered to a bus operator
- **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 with overall dimensions measuring approximately 2 m tall by 1 m wide. A proportionally scaled image of the Euro NCAP adult pedestrian dummy shall be displayed on the advertising hoarding (Figure 24_1). The image shall be positioned such that the dummy faces towards the trajectory of the VUT. 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 24_1: 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 crowd control barriers, an example of which is shown in Figure 24_2. These shall be constructed from a metal easily detected by RADAR. The height of the barrier shall be approximately 1.1m height. The diameter of the vertical rail shall be no less than 10 mm. Vertical rails approximately 125 mm apart. The feet of the railing may extend laterally towards the Kerb but shall not exceed 200mm from the centre-line of the railing.

Figure 24_2: 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:

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.

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

- **Vulnerable Road Users (VRU)**: Means pedestrians or cyclists.

6 Reference system

6.1 Local co-ordinates

A local co-ordinate system (x,y,z) for the VUT shall be defined such that the x-axis points toward the front of the bus, the y-axis towards the left and the z-axis upwards, as shown in Figure 24_3.

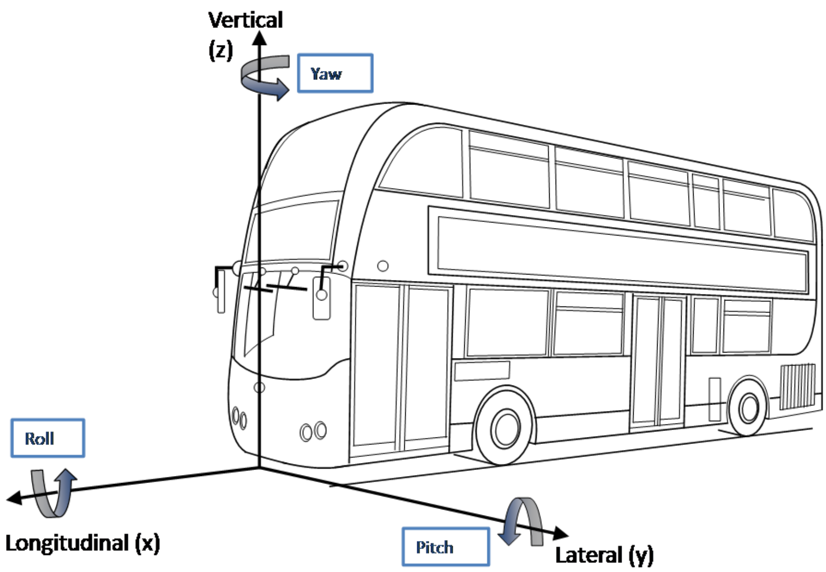


Figure 24_3: Local coordinate system and notation for VUT

6.2 Global co-ordinates

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

6.3 Test Target coordinates

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 coordinate system shall lie on the ground plane, at the intersection of the test target centreline and a line perpendicular to the centreline passing through the test target hip point, as shown in Figure 24_4.

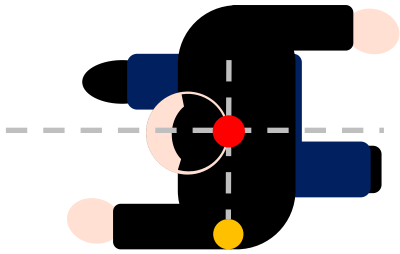


Figure 24_4: Origin of local coordinate systems for EPTa and EPTc test targets, illustrating centrelines (grey), local coordinate system origin (red) and test target hip point (orange),

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 24_5.

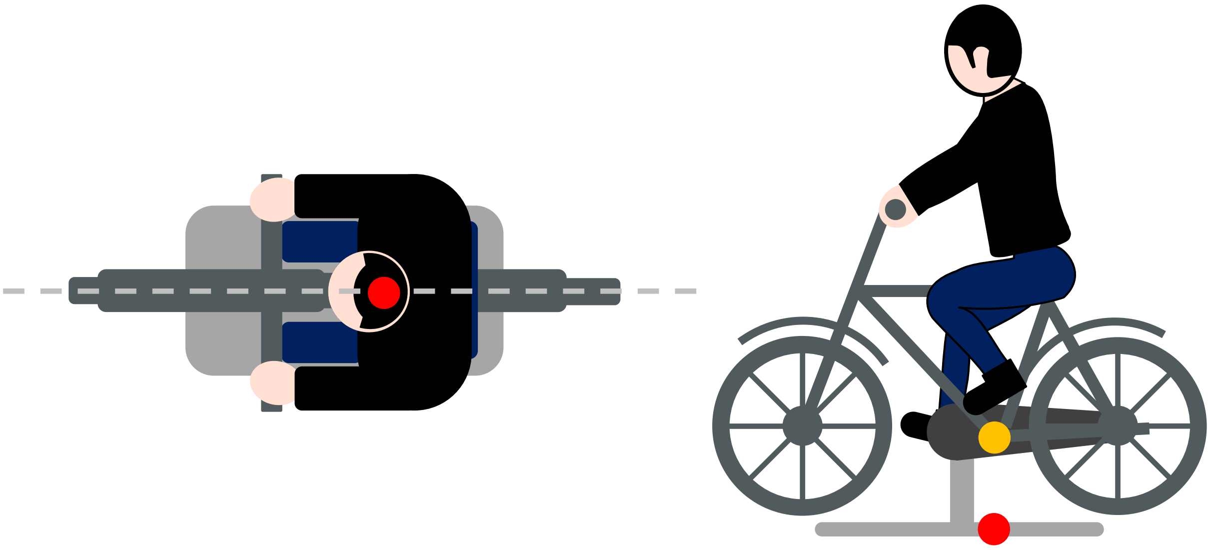


Figure 24_5: Origin of local coordinate systems for EBT test target, illustrating test target centreline (grey), local coordinate system origin (red) and centre of the bottom bracket (orange)

7 Measurements and variables

7.1 Variables to be measured

The variables which shall be measured continuously throughout testing can be seen in Table 24_1, along with the minimum operating ranges and measurement accuracy required.

Table 24_1: 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 vehicle under test (VUT_X, VUT_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 vehicle under test (V_{VUT})	0mph to 20mph	0.1mph
Speed of VRU test target (V_{TT})	0mph to 12.5mph	0.1mph
Heading (yaw) angle (θ) relative to global X-axis (θ_{TV}, θ_{TT})	0˚ to 360˚	0.1˚
Longitudinal acceleration of vehicle under test (A_{VUT})	± 15m/s^2	0.1m/s^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 24_2, along with minimum operating ranges and maximum overall permitted measurement errors.

Table 24_2: 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	0m/s to 20m/s	± 0.2m/s
Ambient Illumination	0lux to 150,000lux	± 10%

7.2 Measuring equipment

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

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 at least 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.

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

In addition to the data recording described above, the VUT shall be equipped with one or more video cameras positioned such that for each and every test, the TT can be clearly seen at the moment of impact, at impact points ranging from 1% to 99% of the vehicle width. When conducting test the video feed shall be synchronised to the data recordings, with a a delay of less than 50ms. 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.

8 Test Conditions

8.1 Test Track

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 VUT when the test ends.

8.2 Surroundings

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 VUT path, and within a longitudinal distance of 30m ahead of the VUT when the test ends.

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.

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

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.

8.3 Weather Conditions

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 0.5 miles.

d) Wind speeds shall be below 6m/s average, gusting to 10m/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 VUT, 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.

8.4 Test Targets

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 VUT by a low-profile platform.

The system will be capable of moving the vulnerable road user at speeds of up to at least 12.5mph, to accelerate at 3 m/s^2 or more, and maintaining constant speed within a tolerance of 0.25mph. Lateral deviation from an intended straight path shall be no more than 0.05m.

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.

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.

The distance between the lower edge of the VRU and the road surface shall be less than 75 mm.

9 Vehicle preparation

9.1 Aftermarket systems

For aftermarket systems, the system shall be installed on a standard VUT of category M_3 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

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 testing with the relevant VUT shall be required to guarantee satisfactory performance.

9.2 OEM systems

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 VUT will be whatever vehicle is supplied by the OEM for test, with this recorded in the Test Report.

9.3 Dealer fit systems

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

9.4 Blind Spot Safety System

9.4.1 Installation

The blind spot safety system to be tested shall be installed on the VUT in accordance with the OEM's instructions.

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 the scope of this document. The exact configuration of the system tested must be recorded in the Test Report.

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 VUT 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.

9.4.2 Settings

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 24_3, 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 24_3: 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>

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 sensitivity setting below the midpoint.

9.5 Tyres

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

9.6 Vehicle under test, Mass

BSW shall be operative at all states of Load.

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

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

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

8 Test scenarios

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 the bus is in motion. Within each collision scenario, more than one specific test method may be defined to fully assess the blind spot system performance in that collision scenario. The method of evaluating the specific results of each individual test and assessment are presented across this section. In all conditions, the accelerator pedal should be depressed to 100% travel, excluding any kick-down limit switches.

8.1 Moving-Off Scenarios

8.1.1 General Test Scenario Configuration

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 VUT and VRU test target starting positions and intended motions are illustrated in Figure 24_6, alongside positioning information for the standardised environmental clutter.

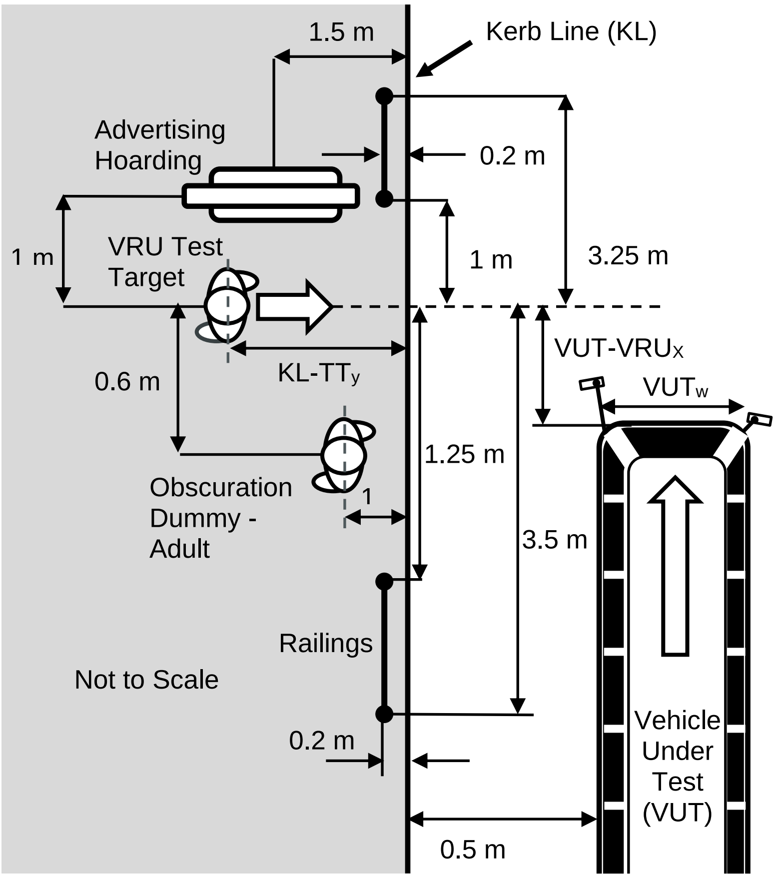


Figure 24_6: General test configuration for vehicle under test (VUT), test target (VRU) and standardised environmental clutter positions at time T_0 with intended motions for moving-off test scenarios

All test scenario configuration dimensions illustrated in Figure 24_6. Fixed dimensions are enumerated, whilst dimensions that vary with each test scenario are described by their acronym:

a) Vehicle under test width (VUT_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 VUT to KL = 0.5m

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

e) Longitudinal distance from front of VUT to centreline of VRU ($VUT\text{-}TT_x$)

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

8.1.2 Moving-Off Proximity Information signal (MOPI) Scenario

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 VUT, test targets and standardised environmental clutter shall be set up as specified in Section 8.1.1 with additional test scenario specific parameters as detailed in Table 24_4.

Table 24_4: Definition of test scenario specific parameters for the Moving-Off Proximity Information signal (MOPI) scenario

Parameter	Test Scenario		
	Adult Close (True Positive)	Child Mid (True Positive)	Adult Far (False Positive)
$KL\text{-}TT_Y$	1.2m	1.2m	1.2m
$VUT\text{-}TT_X$	0.3m	[2.5]m	[4.0]m
VRU Test Target	EPTa	EPTc	EPTa
VRU Speed (V_{TTy})	2 mph ± 0.5mph	3.2mph ± 0.5mph	3.2 mph ± 0.5mph

For all test scenarios, a constant acceleration of 1 m/s^2 ± 0.2 m/s^2 (A_{TTy}) shall be applied to the VRU test target in the direction of the negative Y-axis until the steady state VRU speed (V_{TTy}) is met, at which A_{TTy} 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 VUT.

The VUT ignition shall be switched to the fully on position with the vehicle gear/Drive selected and parking brake off, as if ready to move off. The VUT speed in both the x-axis and y-axis (V_{VUTx}, V_{VUTy}) shall be maintained at 0 mph through all test scenarios.

The motion of the VUT and VRU are enumerated below:

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

b) $V_{VUTx} = V_{VUTy}$ = 0 mph.

The start of each test (T_0) shall be taken as the point where the acceleration (A_{TTy}) 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 VUT, defined as if the VUT moved purely in the x-axis.

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.

Each specified test scenario shall be undertaken once.

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

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 VUT, test targets and standardised environmental clutter shall be set up as specified in Section 8.1.1 with additional test scenario specific parameters as detailed in Table 24_5.

VRU test targets shall be positioned directly in front of the VUT at lateral positions, 25%, 50%, and 75% of the width of the VUT (i.e. 0.25*VUT_W-0.75*VUT_W at 0.25*VUT_W intervals).

Table 24_5: Definition of test scenario specific parameters for the Moving-Off collision Warning and motion Inhibit (MOWI) scenario

Parameter	Test Scenario		
	EPTa Close (Motion Inhibit)	**EPTc Close (Motion Inhibit)**	**EPTa Far (Motion Inhibit or Collision Warning)**
VUT-TT_Y (% VUT_W)	25%, 50%, 75%	25%, 50%, 75%	25%, 50%, 75%
VUT-TT_X	0.3m	0.3m	[4.0]m
VRU Test Target	EPTa	EPTc	EPTc

VRU test target speeds in the x-axis and y-axis (V_{TTx}, V_{TTy}) shall be maintained at 0 mph throughout all test scenarios.

The VUT 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) Fully depress accelerator

d) Accelerate to no more than 10mph

The start of each test (T_0) shall be taken as the point where the VUT accelerator pedal is first depressed.

The completion of each test (T_1) shall be taken as either the point at which the VUT motion inhibit function is activated or the point at which contact with the VRU is made.

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 VUT 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.

Each specified test scenario shall be undertaken once.

Should the motion inhibit function be activated, the driver may use the over-ride function to move the vehicle.

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 not typical 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

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

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

The motion inhibit over-ride function shall deactivate before either reaching the finish point or 10 seconds after activation, whichever is a greater time period.

8.2 Bus in motion Scenarios

8.2.1 General Test Scenario Configuration

The general test scenario configuration is designed to be representative of collisions with VRUs in an urban area. Two categories of test scenario are assessed: the first where a bicyclist cycles alongside the nearside of a bus driving forward or performing a nearside turn and the second where a pedestrian crosses the road on the nearside of a bus whilst driving forward or performing a nearside turn.

Representative VUT and VRU test target starting positions and intended motions are illustrated in Figure 24_7, alongside positioning information for the standardised environmental clutter.

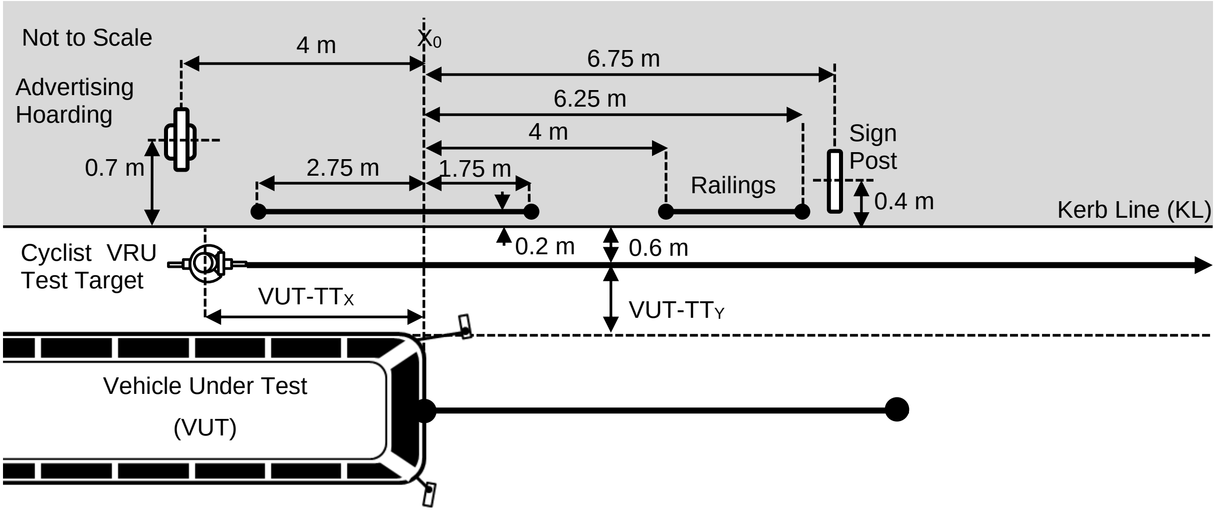


Figure 24_7: General test configuration for vehicle under test (VUT), test target (VRU) and standardised environmental clutter positions at time T_0 with intended motions for nearside turn test scenarios

All test scenario configuration dimensions illustrated in Figure 24_7 are described in greater detail below. Fixed dimensions are enumerated, whilst dimensions that vary with each test scenario are described by their acronym:

a) Vehicle under test, length (VUT_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) Turn Point (TP) is the X-position of the foremost point of the VUT at the moment that it commences steering

d) Longitudinal distance from AP to centreline of cyclist VRU ($VUT\text{-}TT_X$)

e) Lateral distance from nearside of VUT to centreline of cyclist VRU ($VUT\text{-}TT_Y$)

f) Lateral distance from KL to centreline of cyclist VRU = 0.6 m

g) Longitudinal distance from X_0 to centreline of pedestrian VRU = 8.5 m

h) Lateral distance from nearside of VUT to centreline of cyclist VRU = 2.0 m

i) Lateral distance from KL to centreline of cyclist VRU = 1.0 m

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

k) Longitudinal distance from X_0 to leading edge of foremost railing = 6.25 m

l) Longitudinal distance from X_0 to trailing edge of foremost railing = 4.0 m

m) Longitudinal distance from X_0 to leading edge of rearmost railing = 1.75 m

n) Longitudinal distance from X_0 to trailing edge of rearmost railing = 2.75 m

o) Lateral distance from KL to centreline of Advertising Hoarding = 0.7m

p) Longitudinal distance from AP to centreline of Advertising Hoarding = 4.0 m

q) Lateral distance from KL to centreline of signpost = 0.4 m

r) Longitudinal distance from X_0 to centreline of signpost = 6.75

8.2.2 Cyclist Undertaking Bus Proximity Information Signal (CUPI) Scenario

This test assesses the ability of a system to detect a cyclist manoeuvring along the nearside of a bus and provide an effective VRU proximity information signal. The vehicle under test, test target and standardised environmental clutter shall be set up as specified in Section 8.2.1 with additional test scenario specific parameters detailed in Figure 24_8 and Table 24_6.

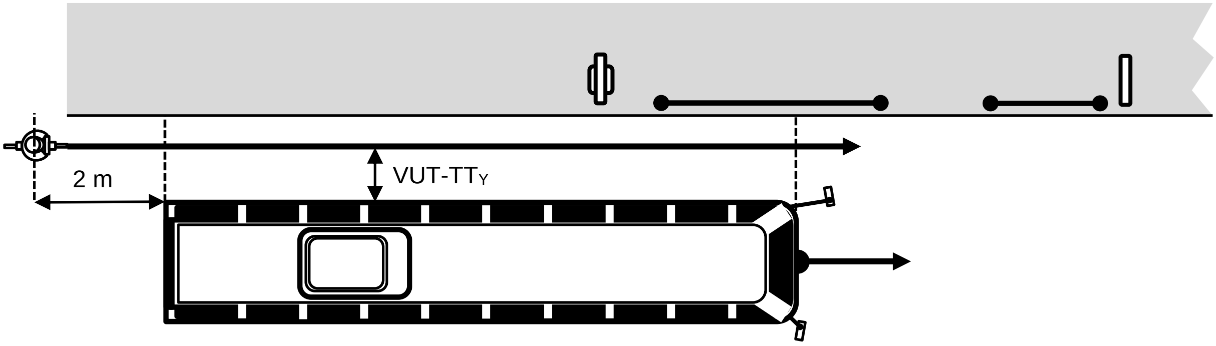


Figure 24_8: Test target positions at time T_0 for Cyclist Undertaking Bus Proximity Information signal (CUPI) scenario

Table 24_6: Definition of test scenario specific parameters for the Cyclist Undertaking Bus Proximity Information signal (CUPI) scenario

Parameter	Test Scenario		
$VUT\text{-}TT_Y$	0.5m	1.0m	1.5m
$VUT\text{-}TT_X$ start (T_0)	VUT_{rear} - 4m	VUT_{rear} - 4m	VUT_{rear} - 4m
$VUT\text{-}TT_X$ end (T_1)	VUT_{front} + 4m	VUT_{front} + 4m	VUT_{front} + 4m
VRU Test Target	EBT	EBT	EBT

For all test scenarios, the VUT shall maintain a constant speed of 6.5mph ±0.5mph in the X-axis. The VUT speed shall be maintained as constant until the completion of the test (T_1).

The VRU test target speed shall be 10.0mph ±0.5mph, maintained as constant from the point 2 m rearward of the rearmost point of the VUT to a point 2 m forward of the front most point of the vehicle, excluding wingmirrors.

Start positions and initial accelerations for the VUT and the VRU test target shall be at the discretion of the Test Service, required to ensure the compliance with position requirements.

The start of each test shall be taken as T_0 (position X_0), where the VRU test target is 2m behind the rear of the VUT.

The completion of each test shall be taken as T_1, where the VRU test target is 2m in front of the VUT.

The status of the blind spot information and warning signals shall be recorded, along with VRU test target position, from time T_0 to T_1.

The evaluation distance shall be taken as between the point where the VRU is 1 m rearward of the rearmost point of the VUT to the point where the VRU is in line with the frontmost point of the VUT, excluding wingmirrors.

Each specified test scenario shall be undertaken once.

8.2.3 Bus Overtaking Cyclist Proximity Information signal (BOPI) Scenario

This test assesses the ability of a system to detect a cyclist manoeuvring at a low relative speed along the nearside of a bus and provide effective VRU proximity information signal.

The vehicle under test, test target and standardised environmental clutter shall be set up as specified in Section 8.2.1 with additional test scenario specific parameters as detailed in Figure 24_9 andTable 24_7.

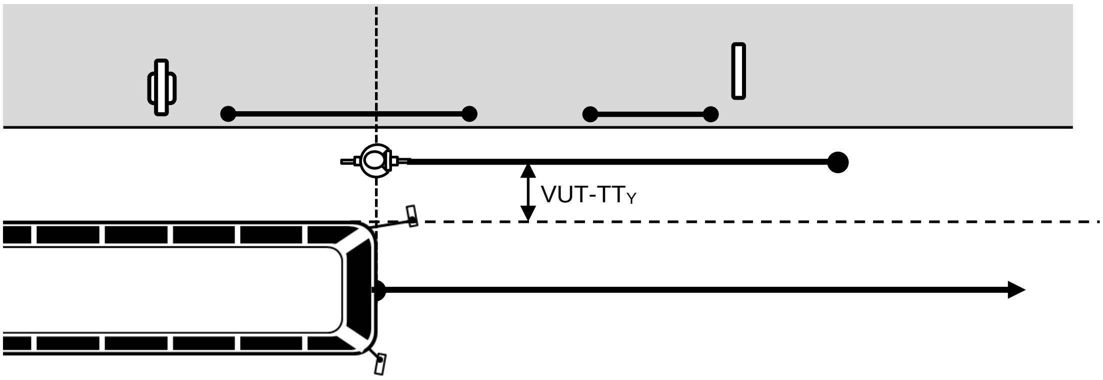


Figure 24_9: Vehicle under test and test target position at time T_0 for Bus Overtaking Cyclist Proximity Information signal (BOPI) scenario

Table 24_7: Definition of test scenario specific parameters for the Bus Overtaking Cyclist Proximity Information signal (BOPI) scenario

Parameter	**Test Scenario**		
$TV\text{-}TT_Y$	0.5m	1.0m	1.5m
$TV\text{-}TT_X$ at T_0	VUT_{rear} - 2m	VUT_{rear} - 2m	VUT_{rear} - 2m
$TV\text{-}TT_X$ at T_1	VUT_{front} + 0m	VUT_{front} + 0m	VUT_{front} + 0m
$TV\text{-}TT_X$ at T_2	VUT_{front} + 2m	VUT_{front} + 2m	VUT_{front} + 2m
VRU Test Target	EBT	EBT	EBT

For all test scenarios, the VUT shall maintain a constant speed of 10mph ± 0.5mph in the X-axis. The VUT speed shall be maintained as constant until the completion of the test (T_1).

The VRU test target shall maintain a constant speed of 6.5mph ± 0.5 mph in the X-axis, along a line parallel to the VUT, at the specified distance of separation in the Y-axis to the LH side of the bus.

The VUT and VRU shall travel at their constant test speeds from T_0 until the T_2.

Start positions and initial accelerations for the VUT and the VRU test target shall be at the discretion of the Test Service, required to ensure the compliance with position requirements.

The start of each test shall be taken as T_0, where the VUT is 2 m rearward of the VRU.

The completion of each test shall be taken as T_2, where the VRU is 2 m rearward of the rearmost point of the VUT.

The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and VUT positions, from time T_0 to T_1.

The proximity signal evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and the point where the VRU is in line with the front most point of the VUT, excluding wing mirrors, (T_1)

Each specified test scenario shall be undertaken once.

8.2.4 Cyclist Nearside turn Collision Warning (CTCW) Scenario

This test assesses the ability of a system to detect a cyclist manoeuvring along the nearside whilst the bus performs a nearside turn and provide effective VRU proximity information and collision warning signals.

The vehicle under test and test target shall be set up as specified in Section 8.2.1, without need for street furniture. Additional test scenario specific parameters as detailed in Figure 24_10 and Table 24_8. The test scenario has been designed to replicate the relative approach of the VUT and test target with the VUT traveling tangential to the arc of its turn at the point of collision. This has been chosen to ensure a comparable, reproducible and repeatable test.

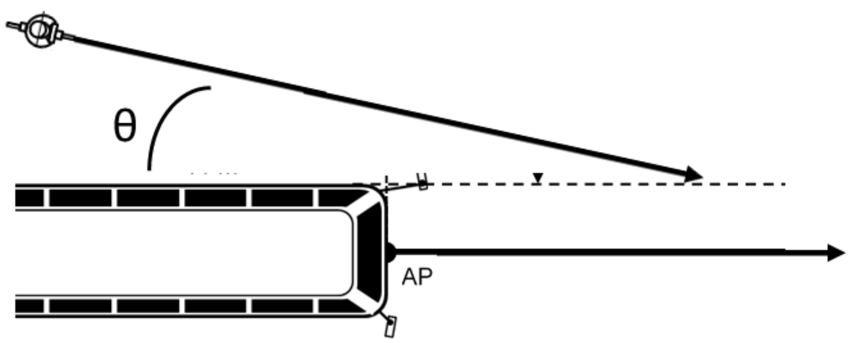


Figure 24_10: Vehicle under test and test target paths for Cyclist Nearside Turn Collision Warning (CTCW) scenario

For all test scenarios, the VUT shall maintain a constant speed of 10mph ± 0.5 mph in the X-axis until the completion of the test (T_1).

The VRU test target shall maintain a constant speed of 12 mph ± 0.5 mph at the specified angle, θ, from the X-axis of the VUT.

Start positions and initial accelerations for the VUT and the VRU test target shall be at the discretion of the Test Service, required to ensure the compliance with position requirements.

Start time, T_0, shall be taken as time for each scenario when TTC is 5 seconds.

The completion of each test, T_1 shall be defined as the point at which TTC = 0.75 seconds. At T_1, the VRU test target is to be decelerated to 0 mph to avoid unnecessary damage to the test target.

Tests shall be conducted so as to achieve a collision point at nearside outermost edge of the VUT at positions 25%, 50% and 75% of the vehicle length.

Table 24_8: Definition of test scenario specific parameters for the Cyclist Nearside Turn Collision Warning (CTCW) scenario

Parameter	Test Scenarios to be repeated at; 25%, 50%, 75% of the vehicle length		
V_{TT} at T_0	12mph	12mph	12mph
V_{VUT} at T_0	10mph	10mph	10mph
θ	10°	15°	20°
Collision point	25%, 50% and 75%	25%, 50% and 75%	25%, 50% and 75%
VRU Test Target	EBT	EBT	EBT

The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and VUT positions, from time T_0 to end of test, T_1.

The collision warning evaluation distance shall be taken as the difference between the VRU test target positions at T_0 and T_1.

Each specified test scenario shall be undertaken once.

8.2.5 Nearside Turn Crossing Pedestrian Collision Warning (NPCW) Scenario

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 vehicle under test, test target and standardised environmental clutter shall be set up as specified in Section 8.2.1 with additional test scenario specific parameters as detailed in Figure 24_11. The test shall be conducted on a EuroNCAP specification junction.

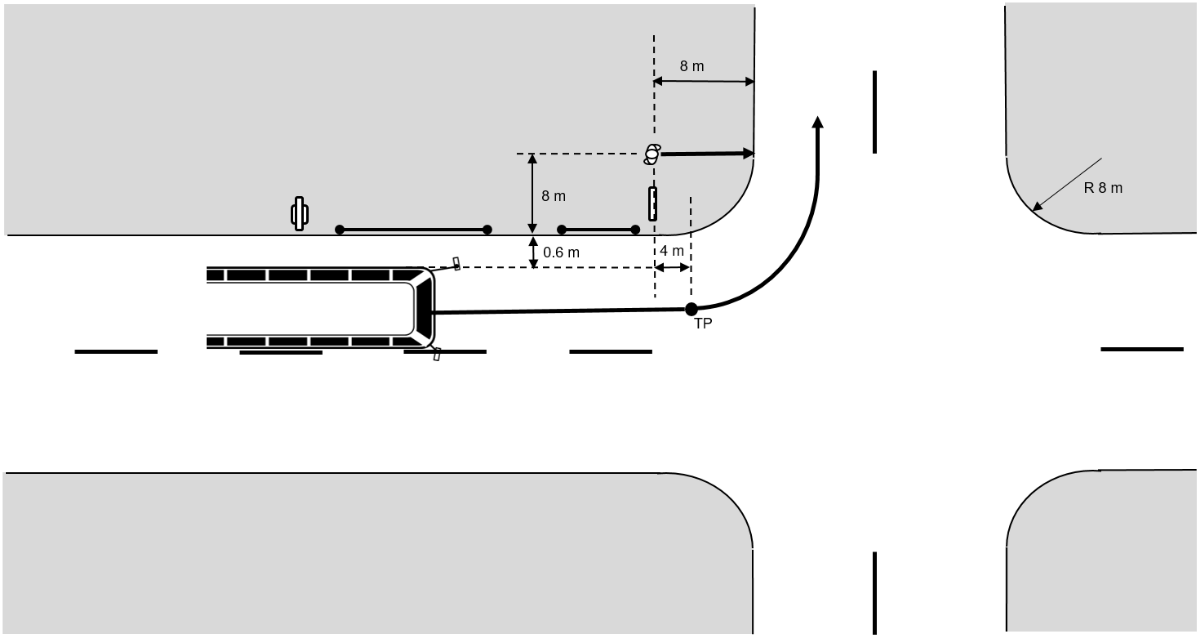


Figure 24_11: Vehicle under test and test target paths for Nearside Turn Crossing Pedestrian Collision Warning (NPCW) scenario

The VUT shall maintain a constant speed of 6.5mph ± 0.5mph from a point 10 m prior to the turn point (TP), at (T_0), until the completion of the test (T_3).

At the TP, steering shall be applied to the VUT such that the foremost point of its centreline follows the arc of a circle with a radius (R) of 10 m.

The VRU test target shall be located a distance of +8.0 m in the Y-axis direction from the road edge, such that it enters the road at the first point at which the bus straightens after completing the turning manoeuvre. The VUT shall be located a distance of -0.5 m in the Y-axis from the road edge.

The VRU test target shall be accelerated in the direction of the positive X-axis to a nominal steady state speed of 2.5mph ± 0.5mph within a distance of 2 m. The VRU test target shall commence acceleration at the moment in time such that when the constant speed is maintained for a distance of 4 m, the VRU would collide with a point 50% down the length of the bus were the VRU to maintain a constant speed.

When the VRU is a distance of 1.5m from the collision point it shall decelerate, achieving a complete stop at a distance 0.5m from the collision point. The moment in time that the VRU starts decelerating shall be defined as T_1, and the point at which the VRU stops shall be defined as T_2.

The speed of the VRU test target may be varied in response to the actual speed and path achieved by the VUT to ensure compliance with the above criteria.

The start of each test shall be taken as T_0.

The completion of each test (T_3) shall be defined as T_2 + 3 seconds.

The status of the blind spot information and warning signals shall be recorded, along with the VRU test target and VUT positions, from time T_0 to T_3.

Proximity signal evaluation distance shall be defined as the difference between the VRU test target positions T_1 – 2 seconds and T_1.

Collision Warning evaluation distance shall be taken as the difference between positions at TP and T_1.

This test scenario shall be undertaken once.

8.2.6 Nearside Turn No Test Target (NTNT) Scenario

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 NTNT scenario shall be conducted in exactly the same manner as the NPCW scenario. Instead of a VRU test target, as used for the NPCW scenario, an obscuration dummy shall be used. The dummy shall be positioned in the same location as that defined in the NPCW scenario for the test target at T_0. The VUT and standardised environmental clutter shall be set up as specified in Section 8.2.1, with additional test scenario specific parameters as detailed in Figure 24_11.

This test scenario shall be undertaken once.

9 Assessment of results

9.1 Moving-Off Proximity Information signal (MOPI) Scenario

Test Scenario Performance Evaluation

The evaluation of the system performance during the Moving-Off Proximity Information Signal (MOPI) test scenarios shall be assessed according to Table 24_9.

Where percentage of evaluation distance is stated the results metric generated shall be a sliding scale between the maximum and minimum stated values.

Table 24_9: 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 Close (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	100% Active: [1] . . . 0% Active: [0]	
Child Mid (True Positive)	0 to 1		100% Active: [1] . . . 0% Active: [0]	

Adult Far (False Positive)	-1 to 0		0% Active: [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	

9.1.1 HMI Performance Evaluation

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 24_10.

Table 24_10: 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 using a visual mode	0 to 3	Visual: [3] Tonal or Haptic or Speech: [0]	
Visual proximity information signal located within a horizontal field of view angle between ±30° from XZ plain, without causing an obstruction to direct or indirect vision	-1 to 1	In zone: [1] Out of zone: [0] Causing obstruction to vision: [-1]	
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 < [1.0] sec: [1] Ceases > [1.0] sec: [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

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 24_11.

Where percentage of evaluation distance is stated the results metric generated shall be a sliding scale between the maximum and minimum stated values.

Table 24_11: 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 Close (Motion Inhibit)	0 to 1	The vehicle remains stationary despite the driver actions	Stationary: [1] Motion: [0]	
Child Close (Motion Inhibit)	0 to 1		Stationary: [1] Motion: [0]	
Adult Far (Motion Inhibit or Collision Warning)	0 to 1	The vehicle remains stationary despite the driver actions	Stationary: [1] Motion: [0]	
	0 to 1	Percentage of evaluation distance for which collision warning was active	100% Active: [1] . . . 0% Active: [0]	
Max. Points	**3**		**Total Score**	
			Total Score/Max. Points	

9.2.2 HMI Performance Evaluation

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 24_12.

Table 24_12: 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 using visual and one other mode	0 to 1	Multi-mode inc. visual: [1] Single mode: [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Audible/Haptic Mode: [1] No Audible/Haptic Mode: [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 located within a horizontal field of view angle between ±30° from XZ plain, without causing an obstruction to direct or indirect vision	0 to 1	In zone: [1] Out of zone: [0] Causing obstruction to vision: [-1]	
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	0 to 1	Tonal: [1] Speech: [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	s/n ratio >1.3: [1] s/n ratio ≤1.3: [0]	
Collision warning signal automatically ceases in less than [1] second after T_1	0 to 1	Ceases < [1.0] sec: [1] Ceases > [1.0] sec: [0]	
Max. Points	**10**	**Total Score**	
		Total Score/Max. Points	

9.3 Cyclist Undertaking Bus Proximity Information signal (CUPI) Scenario

9.3.1 Test Scenario Performance Evaluation

The evaluation of the performance of the blind spot system during the Cyclist Undertaking Bus Proximity Information signal (CUPI) test scenarios shall be assessed in accordance with Table 24_13.

Where percentage of evaluation distance is stated the results metric generated shall be a sliding scale between the maximum and minimum stated values.

Table 24_13: Evaluation of test performance for the Cyclist Undertaking Proximity Information signal (CUPI) 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 0.5m (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	100% Active: [1] . . . 0% Active: [0]	
Cyclist 1.0m (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	Active: [1] . . . Inactive: [0]	
Cyclist 1.5m (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	100%Active: [1] . . . 0% Active: [0]	
All Scenarios (False Positive)	-2 to 0	Collision warning status in any test scenario	Inactive: [0] Active: [-2]	
Max. Points	**3**		**Total Score**	
			Total Score/Max. Points	

9.3.2 HMI Performance Evaluation

The evaluation of the performance of the blind spot system HMI across all Cyclist Undertaking Proximity Information signal (CUPI) test scenarios shall be assessed according to Table 24_14.

Table 24_14: Evaluation of human-machine interface (HMI) performance for the Cyclist Undertaking Bus Proximity Information signal (CUPI) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual: [3] Tonal/Haptic/Speech: [0]	
Visual proximity information signal located within a horizontal field of view angle between ±30° 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] Causing obstruction to vision [-1]	
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	

9.4 Bus overtaking Cyclist Proximity Indicator (BOPI) Scenario

9.4.1 Test Scenario Performance Evaluation

The evaluation of the performance of the blind spot system during the Bus overtaking cyclist proximity indicator (BOPI) test scenarios shall be assessed in accordance with Table 24_15.

Where percentage of evaluation distance is stated the results metric generated shall be a sliding scale between the maximum and minimum stated values.

Table 24_15: Evaluation of test performance for the Bus overtaking cyclist Proximity Indicating (BOPI) 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 0.5m (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	Active: [1] . . . Inactive: [0]	
Cyclist 1.0m (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	Active: [1] . . . Inactive: [0]	
Cyclist 1.5m (True Positive)	0 to 1	Percentage of evaluation distance for which proximity information signal was active	Active: [1] . . . Inactive: [0]	
All Scenarios (False Positive)	-2 to 0	Collision warning status in any test scenario	Inactive: [0] Active: [-2]	
Max. Points	**3**		**Total Score**	
			Total Score/Max. Points	

9.4.2 HMI Performance Evaluation

The evaluation of the performance of the blind spot system HMI across all Bus overtaking cyclist Proximity indicator (BOPI) test scenarios shall be assessed according to Table 24_16.

Table 24_16: Evaluation of human-machine interface (HMI) performance for the Bus overtaking cyclist Proximity Indicator (BOPI) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual: [3] Tonal/Haptic/Speech: [0]	
Visual proximity information signal located within a horizontal field of view angle between ±30° 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] Causing obstruction to vision [-1]	
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 Cyclist Nearside Turn Collision Warning (CTCW) Scenario

9.5.1 Test Scenario Performance Evaluation

The evaluation of the performance of the blind spot system during the Cyclist Nearside Turn Collision Warning (CTCW) test scenarios shall be assessed in accordance with Table 24_17.

Where percentage of evaluation distance is stated the results metric generated shall be a sliding scale between the maximum and minimum stated values.

Table 24_17: Evaluation of test performance for the Cyclist Nearside Turn Collision Warning (CTCW) test scenarios

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Collision 25% of vehicle length (Collision Warning)	0 to 2	Percentage of collision test evaluation distance for which collision warning was active	100% Active [2] . . . 0% Active [0]	
Collision 25% of vehicle length (Premature Collision Warning)	-1 to 0	Collision warning status before T_0 in any test scenario	Inactive: [0] Active: [-1]	
Collision 50% of vehicle length (Collision Warning)	0 to 2	Percentage of collision test evaluation distance for which collision warning was active	100% Active [2] . . . 0% Active [0]	
Collision 50% of vehicle length (Premature Collision Warning)	-1 to 0	Collision warning status before T_0 in any test scenario	Inactive: [0] Active: [-1]	
Collision 75% of vehicle length (Collision Warning)	0 to 2	Percentage of collision test evaluation distance for which collision warning was active	100% Active [2] . . . 0% Active [0]	
Collision 75% of vehicle length (Premature Collision Warning)	-1 to 0	Collision warning status before T_0 in any test scenario	Inactive: [0] Active: [-1]	
Max. Points	**6**		**Total Score**	
			Total Score/Max. Points	

HMI Performance Evaluation

The evaluation of the performance of the blind spot system HMI across all Cyclist Nearside Turn Collision Warning (CTCW) test scenarios shall be assessed according to Table 24_18.

Table 24_18: Evaluation of human-machine interface (HMI) performance for the Cyclist Nearside Turn Collision Warning (CTCW) test scenarios

HMI Criteria	Points Available	Result Criteria	Score
Collision warning signal is transmitted using visual and one other mode	0 to 1	Multi-mode inc. visual: [1] Single mode: [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Audible/Haptic Mode: [1] No Audible/Haptic Mode: [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]	
Collision Warning information signal located within a horizontal field of view angle between ±30° 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 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	s/n >1.3: [1] s/n ≤1.3: [0]	
Collision warning signal automatically ceases in less than [2] seconds after T_1	0 to 1	Ceases < [2] sec: [1] Ceases ≥ [2] sec: [0]	
Max. Points	**9**	**Total Score**	
		Total Score/Max. Points	

9.6 Nearside Turn Pedestrian collision warning (NPCW) Scenario

9.6.1 Test Scenario Performance Evaluation

The evaluation of the performance of the blind spot system during the Nearside Turn Pedestrian collision warning (NPCW) test scenario shall be assessed according to Table 24_19.

Where percentage of evaluation distance is stated the results metric generated shall be a sliding scale between the maximum and minimum stated values.

Table 24_19: Evaluation of test performance for the Nearside Turn Pedestrian collision warning (NPCW) test scenario

Test Scenario	Points Available	Result Criteria	Result Metric	Score
Pedestrian (Proximity Information Signal)	0 to 1	Percentage of total proximity test evaluation distance for which proximity information signal was active	100% Active: [1] . . . 0% Active: [0]	
Pedestrian (Collision Warning)	0 to 2	Percentage of collision test evaluation distance for which collision warning was active	100% Active: [2] . . . 0% Active: [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	

9.6.2 HMI Performance Evaluation

The evaluation of the performance of the blind spot system HMI across all Nearside Turn Pedestrian Collision Warning (NPCW) test scenarios shall be assessed according to

Table 24_20.

Table 24_20: Evaluation of human-machine interface (HMI) performance for the Nearside Turn Pedestrian Collision Warning (NPCW) test scenario

HMI Criteria	Points Available	Result Criteria	Score
Proximity information signal transmitted over the visual mode only	0 to 3	Visual: [3] Tonal/Haptic/Speech: [0]	
Visual proximity information signal located within a horizontal field of view angle between ±30° 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 using visual and one other mode	0 to 1	Multi-mode inc. visual: [1] Single mode: [0]	
Collision warning signal is transmitted over at least one of audible/haptic modes	0 to 1	Audible/Haptic Mode: [1] No Audible/Haptic Mode: [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]	
Collision Warning information signal located within a horizontal field of view angle between ±30° 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 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	s/n >1.3: [1] s/n ≤1.3: [0]	
Collision warning signal automatically ceases in less than [2] seconds after T_1	0 to 1	Ceases < [2] sec: [1] Ceases ≥ [2] sec: [0]	
Max. Points	**15**	**Total Score**	
		Total Score/Max. Points	

9.7 Nearside Turn No test Target (NTNT) Scenario

9.7.1 Test Scenario Performance Evaluation

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 24_21. No assessment of the HMI performance shall be performed for the Nearside Turn No test Target (NTNT) test scenario.

Table 24_21: 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	

9.8 General HMI Evaluation

Formal independent tests need not be undertaken in respect of the additional HMI requirements specified in Table 24_22. Assessment may be based on documentary evidence provided by the system supplier and demonstration of functionality.

Table 24_22: Requirements for warning systems

HMI Criteria	Points Available	Result criteria	Score
The device automatically switches off above a speed of 18.5mph	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	Brightness ≥ 6000 cd/m^2 : [1] Brightness <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	

Motion inhibit systems shall be over-rideable by the driver to continue making progress in the event of a false positive.

9.9 Quality, Durability and Installation Requirements

Additional score will be awarded if the system or vehicle supplier can demonstrate documentary evidence of compliance with the requirements in Table 24_23.

Table 24_23: 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	

9.10 Overall Rating

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 24_24.

Table 24_24: 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	
Cyclist undertaking Bus Proximity Information signal (CUPI)	Performance		90%	15%	20%	75%	0.030	
	HMI					25%	0.007	
Bus Overtaking Cyclist Proximity Information signal (BOPI)	Performance		90%	15%	30%	75%	0.020	
	HMI					25%	0.010	
Cyclist Nearside Turn Collision Warning (CTCW)	Performance		90%	15%	30%	75%	0.030	
	HMI					25%	0.010	
Nearside Turn Crossing Pedestrian Collision Warning (NPCW)	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

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

The minimum performance data required is the completion of each table of results listed in this document.

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.

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

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. 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.

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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

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 OEM 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 communicates the type of hazard to the driver such that it maximises the chance of a 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.

2.7.1 Vehicle Moving

At the time of drafting the BSW requirements, there were no systems available which automated emergency braking systems during low speed manoeuvres (i.e. <10 km/h), particularly during left or right turns, 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. Systems which would prevent a collision by use of brakes or other means, whilst the vehicle is moving at low speed, have therefore not been included in the bus safety standard. Systems are not prohibited and if they become available should be analysed, assessed and considered.

2.7.2 Vehicle moves off from rest

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 of the vehicle, a collision warning may be issued too late for the driver to react and stop before the collision occurs, though it may still prevent run-over by the wheels.

A system may prevent moving off from rest when a VRU is detected in front of the vehicle. This may be achieved by, for example, disabling the response to application of the accelerator pedal. This would result in the vehicle remaining stationary which is seen as a low risk.

In the event of a spurious activation, preventing the vehicle from moving off whilst in a safe condition, a driver over-ride shall be provided to prevent the vehicle being ‘marooned’. This over-ride 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. Once the system determines that the detected hazard has been avoided the over-ride function should deactivate to enable system to prevent moving off from rest in future. .

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.

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.3.5.2, Section 4.3.5.3 and Attachment 27 – Pedal Application Error Guidance Notes

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.

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.

3 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.

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 New Bus Specification: Section 4.3.5.2
- London Bus Services Limited New Bus Specification: Section 4.3.5.3

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- London Bus Services Limited New Bus Specification: Attachment 27 – Pedal Application Error Guidance Notes
- 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).

5 Definitions

For the purpose of this Protocol:

- **ALS: Accelerator Light System** – a light system to inform the driver which pedal is currently being pressed.
- **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 passenger doors have opened or the passenger ramp has been extended.
- **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 passenger doors are open or the bus ramp is extended).
- **New Build** – a vehicle that has been built by the OEM with the system to be assessed fitted during the assembly process prior to first registration of the vehicle.
- **OEM: Original Equipment Manufacturer** - The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **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 speed of the bus as determined by pedal usage, in order to help the driver recover from a pedal application error incident.
- **Pedal Application Error** – an incident where a driver mistakenly presses the accelerator pedal instead of the brake pedal.
- **Retrofit** – fitment of the system to be assessed after the first registration of the vehicle. Installation is to be completed by the OEM 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.

6 Test conditions

6.1 Test Track

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.

The road surface shall be a uniform, solid-paved surface with a consistent slope in any direction of between 0% and 1%, and 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).

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.

6.2 Weather and lighting

Testing shall be conducted in weather conditions such that testing can be safely conducted at the discretion of the Test Service and temperatures no lower than 5°C and not higher than 40°C.

Testing shall be conducted in the following lighting conditions:

a) 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.

7 Vehicle preparation

The VUT shall be prepared according to the following requirements:

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 OEM; and

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 that engages when the bus passenger doors are opened and when the passenger ramp is extended or the bus is kneeling

e) Be driven by a qualified driver

Be empty of passengers or any persons other than the driver and required qualified test personnel.

8 Test procedure

8.1 Brake Toggle System

Apply the Brake Toggle System checklist as defined in Appendix A for both Drive and Reverse gears in the following sequence:

a) Put the VUT into the specified state
b) Execute step action and observe the result
c) Compare the observed result to required result
d) Record if observed result matches required result ("Pass" or "Fail")

Note: Bus state refers to whether the vehicle 'ignition' is on, and the vehicle is in a driveable state.

8.2 Accelerator Light System

Apply the Accelerator Light System checklist as defined in Appendix B in the following sequence:

a) Put the VUT into the specified state
b) Execute step action and observe the result
c) Compare observed result to required result
d) Record if observed result matches required result ("Pass" or "Fail")

The assessment of the ALS shall be completed under the following lighting conditions:

a) Daylight

See section 6.2 for definition of lighting conditions.

Apply the lamp installation/illumination checklist as defined in Appendix C

The activation time of the lamps shall be assessed using high speed video analysis.

a) The frame rate for the video shall be at least 30 frames per second.
b) The high-speed video shall be synchronised with the CANBus signal from the pedals.

The delay between the first movement of the pedal and the lamp achieving 90% of its steady state output shall be recorded.

Note: Bus state refers to whether the vehicle 'ignition' is on, and the vehicle is in a driveable state.

8.3 Pedal Acoustic Feedback

Apply the Pedal Acoustic Feedback checklist as defined in Appendix D.

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.

9 Assessment of Results

The following criteria will be used to assess if the Brake Toggle System and Accelerator Light System have passed or failed the assessment.

9.1.1 Brake Toggle System

In order to receive a "Pass" certification the system must receive a "Pass" grade for each of the requirements in the Drive and Reverse assessment checklists in Appendix A.

The system shall be deemed to have failed the assessment if it received a single "Fail" grade in the Drive or Reverse assessment checklists in Appendix A.

9.1.2 Accelerator Light System

In order to receive a "Pass" certification the system must receive a "Pass" grade for each of the requirements in the Accelerator Light System assessment checklist in Appendix B.

The system shall be deemed to have failed the assessment if it received a single "Fail" grade on the Accelerator Light System assessment checklist in Appendix B.

9.1.3 Lamp Installation/illumination Checklist

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

The system shall be deemed to have failed the assessment if it received a single "Fail" grade on the assessment checklist in Appendix C.

The lamp activation time shall be 100ms or less.

9.1.4 Pedal Acoustic Feedback Checklist

Evidence shall be submitted by the OEM, or a bus inspected. The test engineer shall assess whether the bus passes or fails each check.

9.1.5 Overall Assessment

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.

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.

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%.

10 Test report

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

a) Completed Brake Toggle System checklist;
b) Completed Accelerator Light System checklist;
c) Completed lamp installation/illumination checklist;
d) Lamp activation assessment;
e) Pedal Acoustic Feedback checklist; and
f) Reference information.

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).

Appendix A - Brake Toggle System checklist – Drive and Reverse Scenarios

Step	Bus State (On/Off)	Gear	Park Brake	Bus Passenger Doors	Action	Required Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
1	On	Drive	On	Closed	Open any bus passenger doors	Halt brake engages		
2	On	Drive	Off	Open	Close bus passenger doors and then depress accelerator	Halt brake remains engaged, and bus remains stationary		
3	On	Drive	Off	Closed	Depress brake pedal to level that triggers brake lights on, and then release brake pedal	Bus remains stationary.		
4	On	Drive	Off	Closed	Apply accelerator > 10% AND ≥ 10s after completing Step 3	Bus remains stationary		
5	On	Drive	Off	Closed	Depress brake pedal to level that triggers brake lights on, then release brake pedal and apply accelerator ≤ 10s after releasing brake pedal	Bus moves forward (The vehicle must remain stationary regardless of vehicle orientation against track gradient until Step 5 Action is completed correctly)		
Bring Vehicle to Rest using Foot Brake								
6	On	Drive	Off	Closed	Open any bus passenger doors	Halt brake engages		
7	On	Drive	Off	Open	Close bus passenger doors and then depress brake pedal to level that triggers brake lights on, then release brake pedal and apply accelerator ≤ 10s after releasing brake pedal	Bus moves forward (The vehicle must remain stationary regardless of vehicle orientation against track gradient until Step 7 Action is completed correctly)		
						Total Required Score Outcome		7

Step	Bus State (On/Off)	Gear	Park Brake	Bus Passenger Doors	Action	Required Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
1	On	Reverse	On	Closed	Open any bus passenger doors	Halt brake engages		
2	On	Reverse	Off	Open	Close bus passenger doors and then depress	Halt brake remains engaged, and bus remains stationary		
3	On	Reverse	Off	Closed	Depress brake pedal to level that triggers brake lights on, and then release brake pedal	Bus remains stationary.		
4	On	Reverse	Off	Closed	Apply accelerator > 10% AND ≥ 10s after completing Step 3	Bus remains stationary		
5	On	Reverse	Off	Closed	Depress brake pedal to level that triggers brake lights on, then release brake pedal and apply accelerator ≤ 10s after releasing brake pedal	Bus moves backwards (The vehicle must remain stationary regardless of vehicle orientation against track gradient until Step 5 Action is completed correctly)		
Bring Vehicle to Rest using Foot Brake								
6	On	Reverse	Off	Closed	Open any bus passenger doors	Halt brake engages		
7	On	Reverse	Off	Open	Close bus passenger doors and then depress brake pedal to level that triggers brake lights on, then release brake pedal and apply accelerator ≤ 10s after releasing brake pedal	Bus moves forward (The vehicle must remain stationary regardless of vehicle orientation against track gradient until Step 7 Action is completed correctly)		
						Total Required Score Outcome		7

Appendix B - 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 noticeable 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 noticeable 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 noticeable delay in light turning off		
9	On	Drive	Off	Closed	Accelerator pedal pressed	No noticeable delay in light illuminating		

Total	
Required Score	9
Outcome	

Appendix C - 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 ≥80%	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 ≥80%	Lights meet requirements of ISO 2575:2004 Section 4 and Section 5		
3	On	Neutral	On	Closed	Accelerator pedal pressed ≥80%	Lights meet UN ECE Regulation121		
4	n/a	n/a	n/a	n/a	n/a	The light symbol is: 		
5	n/a	n/a	n/a	n/a	n/a	The icon must be displayed on a minimum pixel matrix of 32x32.		
						Total		
						Required Score		5
						Outcome		

Appendix D - 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 OEM to prevent increasing the noise levels inside the saloon of the bus	Pass		
The level set by the OEM 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 OEM's 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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.3.5.2, Section 4.3.5.3, Section 4.3.5.4, Section 4.3.7 and Attachment 26 – Pedal Application Error Assessment Protocol

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 confusion 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 passenger doors are opened (as well as when the passenger ramp is extended or the bus is kneeling). 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 passenger doors have been opened or the passenger ramp has been extended or the bus is kneeling, with the brake toggling 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 toggle system and standard bus operation is detailed in Table 27_1 and Table 27_2 below, for when the vehicle is left in Drive or taken out of Drive.

Table 27_1. Comparison of task order between standard operation and the brake toggle system – vehicle left in gear - D (drive)

Standard Bus Task Order	Brake Toggle Task Order
Open passenger door/ extend ramp/kneel bus – halt brake on	Open passenger door/ extend ramp/kneel bus – halt brake on
Close passenger door/retract ramp/raise bus – halt brake remains on	Close passenger door/retract ramp/raise bus – halt brake remains on
	Release park brake - halt brake remains on
	Press brake - halt brake remains on
Release park brake – halt brake remains on	Release brake - halt brake remains on
Apply accelerator to release halt brake and move off	Apply accelerator ≤ [10] seconds of releasing brake to release halt brake and move off

Table 27_2. Comparison of task order between standard operation and the brake toggle system – vehicle taken out of gear-D

Standard Bus Task Order	Brake Toggle Task Order
Open passenger door/ extend ramp/kneel bus – halt brake on	Open passenger door/ extend ramp/kneel bus – halt brake on
Close passenger door/retract ramp/raise bus – halt brake remains on	Close passenger door/retract ramp/raise bus – halt brake remains on
Press brake - halt brake remains on	Release park brake - halt brake remains on
Change gear to “D” – halt brake remains on	Press brake - halt brake remains on
Release brake - halt brake remains on	Release brake - halt brake remains on
Release park brake – halt brake remains on	
Apply accelerator to release halt brake and move off	

Note: if the Standard Bus Task Order differs for the scenario in Table 27_2, then the Brake toggle Task Order in Table 27_1 shall be implemented.

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:

Identification:

a) Where possible a symbol designated for the purpose in ISO 2575:2010 - Road vehicles — Symbols for controls, indicators and tell-tales, shall be used

b) To identify a tell-tale or indicator not included in the Regulation or ISO 2575:2004 the OEM 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 an OEM the principles of Paragraph 4 of ISO 2575:2010 shall be followed.

d) Any additional symbol used by the OEM shall not cause confusion with any symbol specified in the Regulation.

Colour:

a) Indicators and tell-tales not included in the Regulation or ISO 2575:2010 may be of any colour chosen by the OEM, 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 OEMs 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 System

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 that any software updates that are made to the bus do not alter the logic of the 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 OEM shall be followed.

Advice should be sought from the supplier 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 System

If a failure occurs to the brake toggle system due to a software error, then an appropriate software fix shall be implemented. The 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 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 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

A Runaway Bus Prevention system is required for all buses in service in London to automatically stop the bus from moving from a stationary position in the event that a driver has left the driving seat without applying the park brake.

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 a "runaway bus".

For full understanding of this Attachment it should be read in conjunction with the Attachment 29: Runaway Bus Prevention Guidance Notes and New Bus Specification, Section 4.3.6 and Section 5.2.

Supporting documents are located on the TfL BVS Database HERE. These documents will help in the understanding, developing and testing of Runaway Bus Prevention Systems.

2 Scope

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

3 Purpose

The purpose of this protocol is to allow an assessment against the required level of performance for systems that intend to prevent runaway bus occurrences.

4 Normative References

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

- London Bus Services Limited New Bus Specification: Section 4.3.6
- London Bus Services Limited New Bus Specification: Section 5.2
- Runaway Bus Prevention Supporting Documents

- London Bus Services Limited New Bus Specification: Attachment 29 Runaway Bus Prevention Guidance Notes

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
- **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 OEM 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
- **RaBPS: Runaway Bus Prevention System -** The system implemented in conjunction with the Park Brake to prevent a Runaway Bus scenario
- **RaBPS$_{TT}$ -** Runaway Bus Trigger Time; the time taken for RaBPS to apply the Park Brake once Trigger conditions have been met
- **Test Mark** – Start point/position of front wheels of VUT at beginning of each test, used to measure roll distance
- **Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority
- **Trigger Conditions** - Conditions where the driver is deemed to be NOT present, causing RaBPS to apply the Park Brake
- **VUT: Vehicle Under Test** – The vehicle tested according to this protocol

6 Test conditions

6.1 Test track

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. It shall be at the discretion of the Test Service to determine whether the Test Track surface conditions allow testing.

There are 3 different gradients that are to be used for testing as per Appendix B:

1. For ‘flat’ tests, the Test Track gradient shall be <1%
2. For positive and negative gradient tests, the Test-Track shall have a gradient of between 1% and 3%

3. For Worst Case tests, the test track gradient shall be 20%

A clear zone shall be defined around the VUT. The clear zone shall extend at least one bus length in front and one bus length behind the VUT, and one bus width to either side of the VUT. This is to give sufficient room for any rolling that occurs as a result of the testing.

6.2 Weather and lighting

Testing shall be conducted in weather conditions such that testing can be safely conducted at the discretion of the test service and temperatures no lower than -5°C and not higher than 40°C

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 at risk of being hit by the bus during testing.

7 Vehicle preparation

The RaBPS shall:

a) Have been installed during manufacture of the VUT

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 passenger doors are opened, when the passenger ramp is extended or the bus kneels

e) Have checked all bus passenger doors 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

i) Be empty of passengers or any persons other than the driver and required qualified test personnel

NOTE: the OEM shall ensure that all monitored Primary and Secondary signals are made available for logging by the Test Service at a suitably high raster in order to determine Runaway Bus Prevention System Trigger Time ($RaBPS_{TT}$)

As a minimum the OEM shall supply:

- A relevant .dbc file, that shall enable the Test Service to monitor and record the CANBus channels used for Primary and Secondary Driver Detection Input signals
- Locations of all required physical take off/measurement points to the Test Service for accessing and connecting logging equipment to the CANBus

8 Test Procedure

The assessment of the RaBPS is carried out in two stages. The Auxiliary Release system checklist shall be completed prior to commencing the RaBPS checklist.

Assessments shall be conducted and recorded for:

- For vehicles without a creep function, 18 tests, chosen at random by the Test Service, with a minimum of 2 tests chosen per test section from sections 1-9
    - Note: Section 9 tests are conducted on a 20% gradient. These tests shall only be conducted if all other previous tests have been undertaken and achieved a Pass
- If the vehicle is determined to have a creep function, it shall undergo a further test, selected at random by the Test Service from Section 10 for a total of 19 tests completed

NOTE: If any test is failed, then the OEM has 2 options:

1. Provided the OEM **DOES NOT** make any changes to the RaBPS then:
    a. The failed test shall repeated
    b. The remaining tests shall be completed
    c. A further 9 tests, chosen by the Test Service, made up of 1 test not yet tested per test section from sections 1-9, shall also be completed
    d. The Section 9 Tests shall be completed
2. If the OEM makes ANY changes to the RaBPS, then a full retest shall be undertaken as per the test procedure above.

8.1 Auxiliary Release System Checklist

Apply the Auxiliary Release system checklist as defined in Appendix A in the following sequence:

a) Put the VUT into the specified state and gear

b) Execute the actions for the requisite step and 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

f) Reset the gear to neutral

Note: Bus state refers to whether the vehicle ‘ignition’ is on, and the vehicle is in a driveable state.

8.2 RaBPS checklist

Only if all requirements of the Auxiliary Release system checklist are satisfied shall the testing continue. Apply the RaBPSchecklist as defined in Appendix B in the following sequence:

Stationary Tests (Test Matrix Test Section 1, 2 & 8; Runaway Bus scenario)

a) Ensure the vehicle is on (ignition ON, vehicle can drive)

b) Put the vehicle into the specified gear as per the Test Number selected at random by the test service

c) Drive the vehicle as per the relevant gear (forwards for Drive, in reverse for Reverse) so that the front wheel is aligned with the with the test mark

d) Keep foot brake depressed, do NOT apply the Park Brake

e) Trigger RaBPs according to the relevant Trigger number for that test (Trigger 'i' see note below)

f) Record results and if observed result matches required result ("Pass" or "Fail")

Note: Refer to Section 4.3.6.3 – System Hierarchy, Point 4 for details of 'RaBPs Trigger'

Note: For Section 8 tests, the Test Track gradient must be 20%

Stationary Tests (Test Matrix Test Section 6; Runaway Bus – Vehicle Shut Off scenario)

a) Ensure the vehicle is on (ignition ON, vehicle can drive)

b) Put the vehicle into the specified gear as per the Test Number selected at random by the test service

c) Drive the vehicle as per the relevant gear (forwards for Drive, in reverse for Reverse) so that the front wheel is aligned with the with the test mark

d) Keep foot brake depressed, do NOT apply the Park Brake

e) While remaining in the driver's cab and driver's seat, take all necessary steps to switch the vehicle off (vehicle shutdown)

f) Record results and if observed result matches required result ("Pass" or "Fail")

Note: Refer to Section 4.3.6.3 – System Hierarchy, Point 2 for details of 'vehicle shutdown requirements

Dynamic Tests (Test Matrix Test Section 3, 4 & 5; Driver Misuse scenario)

a) Switch the vehicle on
b) Put the vehicle into the specified gear as per the Test Number selected at random by the test service
c) Drive the vehicle as per the relevant gear (forwards for Drive, in reverse for Reverse), at the relevant speed
d) Trigger RaBPs according to the relevant Trigger number for that test (Trigger ‘ii’ or ‘iii’, see note below)
e) Record result and if observed result matches required result (“Pass” or “Fail”)

Note: Refer to Section 4.3.6.3 – System Hierarchy, Point 4 for details of ‘RaBPs Trigger’

False Positive Tests (Test Matrix Test Section 7; Driver Misuse scenario)

For this test, the Test Service shall begin and then abort either Trigger ‘ii’ or Trigger ‘iii’, selected at random and recorded by the Test Service, to ensure the RaBPS only triggers when all conditions are met.

a) Switch the vehicle on
b) Put the vehicle into the specified gear as per the Test Number selected at random by the test service
c) Drive the vehicle as per the relevant gear (forwards for Drive, in reverse for Reverse), at the relevant speed
d) Begin to Trigger RaBPs according to the relevant Trigger number for that test (Trigger ‘ii’ or ‘iii’, see note below)
e) Abort triggering of RaBPs before Trigger Driver Detection Conditions are met
f) Record result and if observed result matches required result (“Pass” or “Fail”)

Note: Refer to Section 4.3.6.3 – System Hierarchy, Point 4 for details of ‘RaBPs Trigger’

Creep Tests (Test Matrix Test Section 9; Creep scenario)

a) Switch the vehicle on
b) Put the vehicle into Drive
c) Remove application of both footbrake and accelerator pedal and allow vehicle to ‘creep’. Record the vehicle/’creep’ speed
d) Trigger RaBPs according to the relevant Trigger number for that test (Trigger ‘i’, see note below)
e) Record observed results (“Pass” or “Fail”)

Note: Refer to Section 4.3.6.3 – System Hierarchy, Point 4 for details of ‘RaBPs Trigger’

Idle Shutdown Tests (Test Matrix Test Section 10; Idle Shutdown scenario)

a) Switch the vehicle on

b) Put the vehicle into Drive

c) Trigger RaBPs according to the relevant Trigger number for that test (Trigger 'i', see note below)

d) Wait 2.5 minutes

e) Record observed results ("Pass" or "Fail")

Note: Refer to Section 4.3.6.3 – System Hierarchy, Point 4 for details of 'RaBPs Trigger'

9 Assessment of results

The following criteria will be used to assess if the RaBPS has passed or failed the assessment.

9.1 Assessment of the Auxiliary Release System

a) In order to receive a "Pass" certification the system must meet the expected outcome when tested against each of the requirements on Appendix A - Auxiliary Release system assessment checklist.

b) The system shall be deemed to have failed the assessment if it does not meet any single expected outcome in Appendix A.

9.2 Assessment of the RaBPS

a) In order to receive a "Pass" certification the system must meet the expected outcome when tested, for each of the requirements of Appendix B – RaBPS Test Matrix.

b) The system shall be deemed to have failed the assessment if it does not meet any single expected required outcome Appendix B – RaBPS Test Matrix.

9.3 Overall Assessment

a) In order to receive an overall "Pass" certification the system must receive a "Pass" grade for each assessment. .

b) 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%

c) A system that fails to meet these pre-requisites shall not be recommended

10 Test report

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

a) Completed Auxiliary Release system checklist

b) Completed RaBPS checklist

c) Vehicle Reference information

The reference information required shall include as a minimum:

1. Vehicle Make
2. Vehicle Model
3. Vehicle Model Variant
4. RaBPS installed
5. Evidence of meeting vehicle preparation requirements (e.g. MOT certificate, service history)
6. Details of the Test Service
7. Test date(s)

Appendix A - Auxiliary Release system checklist

Auxiliary Release			General Braking Mechanisms		Break Down	Expected Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
Bus State (On/Off)	Gear	Seat Pressure / Driver Input	Park Brake	Passenger Door	Auxiliary Release			
Off	Neutral	Yes	On	Closed	Disengaged	No roll		
Off	Neutral	No	Off	Closed	Engage	Roll		
On	Neutral	Yes	On	Closed	Disengaged	No roll		
On	Neutral	No	Off	Closed	Engage	Roll		
On	Reverse	Yes	On	Closed	Disengaged	No roll		
On	Reverse	No	Off	Closed	Engage	Roll		
On	Drive	Yes	On	Closed	Disengaged	No roll		
On	Drive	No	Off	Closed	Engage	Roll		
						Total		
						Required Score		8
						Outcome		

Appendix B - Runaway Bus Prevention System Test Matrix

The full RaBPS test Matrix is located on the TfL BVS Database HERE

Section	Test Number	Test Procedure (RaBPS Scenario)	RaBPS trigger	RaBPS Condition	VUT Gear	Gradient	VUT Dynamic	Expected Outcome	RaBPS Trigger Delay (seconds)		Vehicle to Rest Time (seconds)		Measured Roll Distance (m) (for info)	Result (Pass/Fail)
									Target	Actual	Target	Actual		
1	1	Runaway Bus	i	Ideal	Neutral	Positive	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	2	Runaway Bus	i	Ideal	Drive	Positive	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	3	Runaway Bus	i	Ideal	Reverse	Positive	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	4	Runaway Bus	i	Ideal	Neutral	Negative	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	5	Runaway Bus	i	Ideal	Drive	Negative	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	6	Runaway Bus	i	Ideal	Reverse	Negative	Stationary	Application of RaBP	≤ 0.5		≤ 2			
2	7	Runaway Bus	i	FailSafe	Neutral	Positive	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	8	Runaway Bus	i	FailSafe	Drive	Positive	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	9	Runaway Bus	i	FailSafe	Reverse	Positive	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	10	Runaway Bus	i	FailSafe	Neutral	Negative	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	11	Runaway Bus	i	FailSafe	Drive	Negative	Stationary	Application of RaBP	≤ 0.5		≤ 2			
	12	Runaway Bus	i	FailSafe	Reverse	Negative	Stationary	Application of RaBP	≤ 0.5		≤ 2			
3	13	Driver Misuse	ii	Ideal	Drive	Positive	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	14	Driver Misuse	iii	Ideal	Drive	Positive	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	15	Driver Misuse	ii	Ideal	Reverse	Positive	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	16	Driver Misuse	iii	Ideal	Reverse	Positive	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	17	Driver Misuse	ii	Ideal	Drive	Negative	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	18	Driver Misuse	iii	Ideal	Drive	Negative	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	19	Driver Misuse	ii	Ideal	Reverse	Negative	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
	20	Driver Misuse	iii	Ideal	Reverse	Negative	Steady Speed ≤ 5.5 kph	Application of RaBP	≤ 0.5		≤ 2			
4	21	Driver Misuse	ii	Ideal	Drive	Flat	Steady Speed > 5.5 kph	Audible Alert	≤ 0.5					
	22	Driver Misuse	iii	Ideal	Drive	Flat	Steady Speed > 5.5 kph	Audible Alert	≤ 0.5					
	23	Driver Misuse	ii	Ideal	Reverse	Flat	Steady Speed > 5.5 kph	Audible Alert	≤ 0.5					
	24	Driver Misuse	iii	Ideal	Reverse	Flat	Steady Speed > 5.5 kph	Audible Alert	≤ 0.5					
5	25	Driver Misuse	ii	Ideal	Drive	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	26	Driver Misuse	iii	Ideal	Drive	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	27	Driver Misuse	ii	Ideal	Reverse	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	28	Driver Misuse	iii	Ideal	Reverse	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
6	29	Runaway Bus	Vehicle Shut down (Vehicle 'key off')	Ideal	Neutral	Positive	Stationary	Application of RaBP OR Application of Park Brake by Driver	≤ 0.5		≤ 2			
	30	Runaway Bus	Vehicle Shut down (Vehicle 'key off')	Ideal	Drive	Positive	Stationary	Application of RaBP OR Application of Park Brake by Driver	≤ 0.5		≤ 2			
	31	Runaway Bus	Vehicle Shut down (Vehicle 'key off')	Ideal	Reverse	Positive	Stationary	Application of RaBP OR Application of Park Brake by Driver	≤ 0.5		≤ 2			
	32	Runaway Bus	Vehicle Shut down (Vehicle 'key off')	Ideal	Neutral	Negative	Stationary	Application of RaBP OR Application of Park Brake by Driver	≤ 0.5		≤ 2			
	33	Runaway Bus	Vehicle Shut down (Vehicle 'key off')	Ideal	Drive	Negative	Stationary	Application of RaBP OR Application of Park Brake by Driver	≤ 0.5		≤ 2			
	34	Runaway Bus	Vehicle Shut down (Vehicle 'key off')	Ideal	Reverse	Negative	Stationary	Application of RaBP OR Application of Park Brake by Driver	≤ 0.5		≤ 2			
7	41	False Positive	False Positive	False Positive	Drive	Flat	Steady Speed ≤ 5.5 kph	NO Action	∞					
	42	False Positive	False Positive	False Positive	Drive	Flat	Steady Speed > 5.5 kph	NO Action	∞					
	43	False Positive	False Positive	False Positive	Drive	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	NO Action	∞					
	44	False Positive	False Positive	False Positive	Reverse	Flat	Steady Speed ≤ 5.5 kph	NO Action	∞					
	45	False Positive	False Positive	False Positive	Reverse	Flat	Steady Speed > 5.5 kph	NO Action	∞					
	46	False Positive	False Positive	False Positive	Reverse	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	NO Action	∞					
	47	False Positive	False Positive	False Positive	Neutral	Flat	Steady Speed ≤ 5.5 kph	NO Action	∞					
	48	False Positive	False Positive	False Positive	Neutral	Flat	Steady Speed > 5.5 kph	NO Action	∞					
	49	False Positive	False Positive	False Positive	Neutral	Flat	Delta Speed; > 5.5 kph to ≤ 5.5 kph	NO Action	∞					
8	35	Runaway Bus	i	Worst Case	Drive	Positive	Stationary	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	36	Runaway Bus	i	Worst Case	Drive	Negative	Stationary	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	37	Runaway Bus	i	Worst Case	Neutral	Positive	Stationary	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	38	Runaway Bus	i	Worst Case	Neutral	Negative	Stationary	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	39	Runaway Bus	i	Worst Case	Reverse	Positive	Stationary	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
	40	Runaway Bus	i	Worst Case	Reverse	Negative	Stationary	Audible Alert then Application of RaBP	≤ 0.5		≤ 2			
9	50	Creep	i	Creep	Drive	Flat	Steady Speed ≤ 5.5 kph	Vehicle speed < 5.5 kph then Application of RaBP	≤ 0.5		≤ 2			
	51	Creep	ii	Creep	Drive	Flat	Steady Speed ≤ 5.5 kph	Vehicle speed < 5.5 kph then Application of RaBP	≤ 0.5		≤ 2			
	52	Creep	iii	Creep	Drive	Flat	Steady Speed ≤ 5.5 kph	Vehicle speed < 5.5 kph then Application of RaBP	≤ 0.5		≤ 2			
10	53	Idle Shutdown	i	Ideal	Drive	Positive	Stationary	Application of RaPBS then Idle Shutdown after 2.5 mins						
	54	Idle Shutdown	i	Ideal	Drive	Negative	Stationary	Application of RaPBS then Idle Shutdown after 2.5 mins						
	55	Idle Shutdown	i	Ideal	Reverse	Positive	Stationary	Application of RaPBS then Idle Shutdown after 2.5 mins						
	56	Idle Shutdown	i	Ideal	Reverse	Negative	Stationary	Application of RaPBS then Idle Shutdown after 2.5 mins						

Attachment 29: Runaway Bus Prevention Guidance Notes

1 Introduction

A Runaway Bus Prevention System (RaBPS) is required for all buses in service in London to automatically stop the bus from moving from a stationary position in the event that a driver has left the driving seat without applying the park brake.

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

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

2 Selection of buses/test services

Any bus that meets the TfL Bus Vehicle Specification.

An assessment of the RaBPS shall be conducted using a new build bus.

The testing of the RaBPS shall be carried out by a TfL approved test service

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 OEM 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 OEM 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 OEM 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 Prevention Assessment Protocol (LBSL Attachment 28)

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2.2 Towing and recovery

The RaBPS 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.

UNECE Regulation 13 requires an auxiliary release system for the brakes to allow towing. These are often mechanical. Auxiliary release is only intended for use in full breakdown/recovery circumstances and should only be undertaken when the vehicle is held stationary by some other external means, e.g. wheel chocks or recovery vehicles etc.. 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 RaBPS are aimed at reducing the risk associated with the rare occurrences where the park brake 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 Runaway Bus Prevention system's auxiliary release.

In the event that the system has been engaged and the driver or engineer is not able to release it, the shift supervisor shall have ability to rectify 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 require the bus to roll whilst in a state where the runaway prevention system would otherwise inhibit that movement.

4 Maintenance

The supplier of the Runaway Bus Prevention System or the vehicle OEM are required to provide the operator with suitable instructions and schedules for required checks and maintenance activities.

Operators are to ensure instructions and schedules provided by the system supplier or OEM are incorporated into the vehicle maintenance plans along with any associated costs.

5 Repair

If during system maintenance checks (Section 4) any of the sensors are deemed to be faulty or failing they must be replaced immediately. The runaway prevention 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. TfL has designed a unique Urban Bus Sound to be used by quiet running buses in London and buses belonging to other organisations at TfL's discretion.

The aim of these systems is to make a vehicle fitted with a quiet running powertrain (e.g. hybrid or electric) as conspicuous to a pedestrian as a typical diesel engine.

For full understanding of this Attachment it should be read in conjunction with the Attachment 31: Acoustic Conspicuity Guidance Notes and New Bus Specification, Section 4.4.1.

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.

UNECE Regulation 138 requires the addition of an Acoustic Vehicle Alerting System (AVAS) on all new quiet running vehicles. The regulation came into effect for all new vehicle models of this type manufactured after 01/07/2019 and applies to all vehicles manufactured after 01/07/2021.

3 Purpose

The purpose of this protocol is to allow an assessment against the required level of performance for Acoustic Vehicle Alerting Systems (AVAS).

4 Normative References

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

- London Bus Services Limited New Bus Specification: Section 4.4.1
- London Bus Services Limited New Bus Specification: Attachment 31 Acoustic Conspicuity Guidance Notes

- UN ECE Regulation 138; Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility

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. This is the entire system including both hardware & firmware/software and the Urban Bus Sound when installed on a bus, as per Regulation 138.
- **AVAS Hardware** - Complete playback system used to reproduce the AVAS
- **Beacon sound** - Part of the Urban Bus Sound. A Distinct rhythmic pulse, intended to raise acoustic conspicuity
- **Core sound** - Part of the Urban Bus Sound. An underlying sound component that is played continuously when the bus is in operation
- **Existing Fleet** – A vehicle that is quiet running and is installed with a pre-2022 version of the AVAS.
- **Front plane of the vehicle** - A vertical plane tangential to the leading edge of the vehicle
- **Idle operation** – AVAS operation when a vehicle is in idle mode, either following arrival or awaiting departure. Core sound operation only.
- **Intelligent Speed Assistance (ISA)** – Through TfL Digital Speed Map bus selects localised speed limits
- **$L_{AMAX, FAST}$** – The maximum sound pressure in a 5 second period, A-weighted, Fast time weighting
- **$L_{Aeq, 10\ seconds}$** – The equivalent continuous sound pressure level for a 10 second period, A-weighted
- **L_{SIL}** – The Speech Interference Level of noise, calculated as the arithmetic mean of the $L_{eq,10\ seconds}$ in four octave bands 500 Hz, 1 kHz, 2 kHz and 4 kHz
- **Moving operation** – AVAS operation when a vehicle is in motion (above 0 km/h). Core and Beacon sound operation.
- **New Build** – A vehicle that has been built by the Vehicle OEM with the system to be assessed fitted during the assembly process prior to first registration of the vehicle.
- **Non-Responsive AVAS** – An AVAS configuration that has a fixed sound output level and is non-dependent on location and time of day.
- **Quiet running vehicle** - Any vehicle which does not require the continuous operation of an internal combustion engine to propel the vehicle
- **Rear plane of the vehicle** - A vertical plane tangential to the trailing edge of the vehicle

- **Responsive AVAS** – An AVAS configuration that adapts its sound output level depending on the vehicles GPS location and time of day via ISA.
- **Retrofit** – A vehicle as defined in the TfL AVAS Retrofit Programme.
- **Sound Pressure Level (L_{pA}) -** The sound pressure expressed in Decibels, A-weighted
- **Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority.
- **Urban Bus Sound** - The uniquely identifiable AVAS sound designed and owned by TfL, consists of two components
- **VUT: Vehicle Under Test** – Means a vehicle that is being tested to this protocol.

6 Test Conditions

Requirements for testing as defined in Regulation 138.

6.1 Test Track (Outdoors)

Testing shall be conducted on a dry surface, free from absorbing materials (powdery snow, or loose debris)

The test track shall meet the requirements of ISO 10844:2014.

6.2 Test Track (Indoors)

The test facility shall meet the requirements of ISO 26101:2012.

6.3 Weather and lighting

Testing shall be conducted in 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.

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

The AVAS shall have been installed during manufacture in the case of a new-build vehicle.

The VUT shall:

a) 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

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) 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

e) Be empty of passengers or any persons other than the driver

8 Test procedure

The assessment of the AVAS is carried out using the checklists found in Appendix A and B.

The AVAS checklist shall be assessed based on documentation submitted by the bus OEM.

Testing of the AVAS shall be conducted in a manner conforming to UN ECE Regulation 138.

All observed results shall be recorded in the checklist.

9 Assessment of results

The following criteria will be used to assess if the AVAS system has passed or failed the assessment.

In order to receive a "Pass" certification, the system must meet the expected outcome for each of the requirements on the assessment checklist.

The system shall be deemed to have failed the assessment if it does not meet any single expected outcome on the AVAS assessment checklist. A system that fails to meet these pre-requisites shall not be recommended.

10 Test report

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

a) Completed AVAS checklist;

b) Reference information.

The reference information required shall include as a minimum:

a) Vehicle Make

b) Vehicle Model

c) Vehicle Model Variant

d) AVAS system installed (including unit serial number)

e) Evidence of meeting vehicle preparation requirements (e.g. technical inspection, service history)

f) Details of the Test Service

g) Test date(s)

Appendix A - AVAS checklist

Acoustic Vehicle Alerting System (AVAS)	Expected Outcome	Actual Outcome	Outcome match? (Yes=1, No=0)
Sounder/s located on the front of the vehicle below the windshield	True		
TfL Urban Bus Sound is in appropriate format	True		
The AVAS has a working functionality self-check with driver notification	True		
The AVAS sound is Regulation 138 compliant, and a valid test certificate submitted	True		
The reversing requirement of Regulation 138 is compliant	True		
The AVAS sound achieves the minimum frequency profiles for Idle and Moving operation as defined in Appendix B for AVAS Step 1	True		
The AVAS sound achieves the overall amplitude defined for each AVAS Step for Idle and Moving operation as defined in Appendix B with a tolerance of ±1.5 dB (Step 3 only if Non-Responsive AVAS)	True		
The AVAS sound does not exceed the maximum sound pressure levels in the Driver's cabin as defined in Appendix C	True		
The AVAS unit number is recorded in relation to the vehicle number and can receive local updates	True		
The AVAS can receive an updated sound file in the future	True		
	Total		
	Required Score		10
	Outcome		

Appendix B – AVAS Sound Level Requirements

Minimum sound level requirements per third octave band are provided for *Idle operation* and *Moving operation*. *Idle operation* playback consists of the Core sound only. *Moving operation* playback shall consist of Core and Beacon sounds.

The overall amplitude for AVAS Steps 2-4 shall be achieved by a uniform increase across all third octave bands to achieve overall level for each Step, as shown in Table B1. Sounder technologies for harsh operating environments are continually evolving. Manufacturers are encouraged to develop enhanced frequency response at low and high frequencies for suitable weatherproof sounders in order to improve fidelity of the Urban Bus Sound operating across the TfL bus fleet. The minimum frequency profile in Table B1 shall be updated at regular intervals to respond to improvements in weatherproof sounder performance and improve fidelity of the Urban Bus Sound operating across the TfL bus fleet.

Minimum sound level requirements for Idle and Moving operation are included in Tables B1 and B2.

Moving Operation

Moving operation playback shall consist of Core and Beacon sounds.

Measurement Positions: Regulation 138 positions: 2m left and right of the vehicle centreline, at the front plane of the vehicle, plus a further measurement along the vehicle centreline, 2m ahead of the front plane of the vehicle.

Vehicle Speed Operation: Performances shall be achieved at all speed operations below 22 km/h, tested as per Regulation 138.

Table B*1 – Minimum sound levels for the AVAS Step levels while in Moving operation.*

Frequency (Hz)		A-weighted Sound Pressure Level ($L_{AMAX,\ FAST}$ (dB))			
		Step 1	Step 2	Step 3	Step 4
Overall amplitude		60	63	66	69
1/3 Octave bands	160	30			
	200	35			
	250	38			
	315	44			
	400	41			
	500	47			
	630	51			
	800	53			
	1,000	52			
	1,250	53			
	1,600	49			
	2,000	47			
	2,500	49			
	3,150	51			
	4,000	40			
	5,000	37			

Idle Operation

Idle operation playback consists of the Core sound only.

Measurement Positions: Regulation 138 positions: 2m left and right of the vehicle centreline, at the front plane of the vehicle, plus a further measurement along the vehicle centreline, 2m ahead of the front plane of the vehicle.

Vehicle Speed Operation: Performances shall be achieved at 0 km/h.

Table B2 – *Minimum sound levels for the AVAS Step levels while in Idle operation.*

Frequency (Hz)		A-weighted Sound Pressure Level ($L_{AMAX, FAST}$ (dB))			
		Step 1	Step 2	Step 3	Step 4
Overall amplitude		60	63	66	69
1/3 Octave bands	160	29			
	200	36			
	250	35			
	315	29			
	400	37			
	500	46			
	630	46			
	800	49			
	1,000	55			
	1,250	48			
	1,600	50			
	2,000	46			
	2,500	47			
	3,150	49			
	4,000	37			
	5,000	32			

Appendix C – Cabin Sound Level Requirements

Drivers Cabin

Measurement Position: 1.2m above the cab floor, directly between the steering wheel and the driver's seat.

Table C1 – Maximum sound levels in the Drivers Cabin as a result of AVAS Sounder operation only.

Frequency (Hz)	Sound Pressure Level ($L_{Aeq,10\ second}$ (dB))
	Maximum
New Build vehicles	55 (45 L_{SIL})
Existing Fleet and Retrofit vehicles	60 (50 L_{SIL})

Manufacturers are encouraged to further reduce the level of sound ingress to the Cabin from the AVAS sounders by system configuration, placement, equipment, sound insulation, or other means, below the maximum levels set out in Table C1.

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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

2 Selection of buses/systems

2.1 Buses requiring Acoustic Conspicuity measures

Regulatory requirements are in force for Whole Vehicle Type Approval (WVTA), in the form of Regulation 138[1]. This requires:

- From September 2019 all new bus models (new designs requiring type approval) in vehicle category
- 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 requires all new buses conforming to the description above, 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)

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,

[1] UN ECE Regulation 138; Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility.

systems meeting Regulation 138 are required to active at speeds between 0 km/h to 22 km/h inclusive, and are intended to replace engine noise cues to pedestrians and vulnerable road users (VRUs) that a vehicle is approaching.

The sound sources should be installed at the front of the bus such that they provide a fuller directional component towards the kerbside (see Bus specification 4.4.1.5 for details of source height and direction). This should also be done in conjunction with the supplier of the AVAS equipment

TfL have developed a specific sound file which the vehicle will be required to generate, known as the Urban Bus Sound (UBS). Availability of the UBS will be provided by TfL upon request.

Vehicles using AVAS shall be shown to 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.

The pace/playback speed and frequency content of the Urban Bus Sound must increase and decrease as the bus accelerates and decelerates, at a rate of 0.8% per km/h.

The values defined in ‘Attachment 30, Appendix B - AVAS Minimum Sound Level Requirements’ are TFL’s minimum requirements for the playback of the Urban Bus Sound. TFL would encourage innovation and seek suppliers to develop AVAS sounders that exceed these minimum requirements to produce an enhanced low frequency presence and detailed high frequency to reproduce the highest quality Urban Bus Sound and have supplied ideal values in ‘Attachment 30, Appendix C Ideal Sound Level Requirements.’

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 suppliers 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 supplier of the equipment.

Attachment 32: Slip Prevention Assessment Protocol

1 Introduction

To reduce the risk to occupants of slips or falls whilst travelling the floor of all buses in service in London will be expected to be covered with materials which provide an effective level of resistance to slip.

This document presents a procedure for the characterisation of the slip resistance properties of flooring materials for buses.

For full understanding of this Attachment it should be read in conjunction with the Attachment 33: Slip Prevention Guidance Notes and New Bus Specification, Section 4.5.6.

2 Scope

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

3 Purpose

The purpose of 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.

4 Normative References

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

- London Bus Services Limited New Bus Specification: Section 4.5.6
- London Bus Services Limited New Bus Specification: Attachment 32 Slip Prevention Guidance Notes
- 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.

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.
- **IRHD: 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.

6 Test equipment and conditions

6.1 Test equipment

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)

6.2 Test conditions

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).

Tests shall only be made under wet conditions, having a thin, consistent film of water covering the entirety of the test area. This requirement supersedes Section 3.6 of the UKSRG guidelines (The UK Slip Resistance Group, 2016).

7 Test samples

Testing may be conducted at various levels of wear or aging for continued life assessment. Definition of the level of wear, stated as number of passengers, and age of the material shall be provided to the test service along with the sample/s.

Ideally the assessment of materials will be carried out on in-service vehicles however, should this not be possible, testing may be conducted upon representative material coupons within a laboratory. Testing shall be conducted following the procedure stated in section 8 for either In-vehicle or Laboratory testing.

a) In-vehicle: Testing of the floor covering shall be performed at a number of locations. These should include, but are not limited to; the area inside the front door, the area inside any other passenger doors located down the body, the wheelchair area, the bottom of the stairs (double-deck vehicles), and any areas where passengers may stand on or travel over.

b) Materials laboratory: Testing shall be performed using representative coupons of the floor covering material. The coupon size should be as specified by the test machine manufacturer.

8 Test procedure

The following procedure shall apply to measurements taken either using an in-service vehicle or material coupons within a laboratory.

Apply the UKSRG guidelines for measuring slip resistance using the PSRT, with the following amendments:

Tests shall be carried out within a test environment with a temperature range of 5^{o}C to 40^{o}C. (Addition to UKSRG guidelines (The UK Slip Resistance Group, 2016))

Tests shall only be made under wet conditions where a thin, consistent film of water covers the entirety of the test area. (Supersedes Section 3.6 of the UKSRG guidelines (The UK Slip Resistance Group, 2016))

Where possible testing of each in-vehicle location / coupon shall be conducted at three angles relative to the vehicle longitudinal axis. These are:

- 0° (Longitudinal axis)
- 90° (Lateral axis)
- 45°

Due to vehicle design and size of the test equipment there may not be room for all three angles to be tested. In which case testing should be taken as close to the test location as possible with the intention to test in 45º increments.

Photographic evidence and written description of each test location should be recorded at the time of test.

Each measurement shall be repeated until the range for five consecutive PTV measurements is less than or equal to 3.0. The mean of these 5 consecutive measurements shall be given as the Mean PTV. (This Supersedes Section 3.6, Point 9 and 10 of the UKSRG guidelines (The UK Slip Resistance Group, 2016)).

For clarity, Table 32_1 shows an example test matrix.

Table 32_1: Example test matrix for supplied specimens

Test location/coupon	Test direction (degrees)	PTV for test number:										Mean PTV
		1	2	3	4	5	6	7	8	…	n	
1	0	45	52	50	49	51	48	49				49.4
	45											
	90											

9 Assessment of results

For all test locations / coupons the 'Mean PTV' calculated for each direction shall be assessed dependent upon the samples level of usage and age.

The level of slip shall be deemed a failure if any of the 'Mean PTV' values are found to be less than those stated in Table 32_2.

Table 32_2: Minimum 'Mean PTV' requirements

Usage	Age	PTV
New	New	36.0
Greater than 100,000 Passengers	Greater than 6 months	40.0

10 Test report

The Test Service shall provide a comprehensive test report which contains UKAS test certificates for testing performed. The following should also be provided as appropriate:

a) Material definition, including trade name

b) The vehicle details on which the assessed material was installed Test conditions

c) Coupon batch of manufacture for material

d) An approximation of the number of passengers transported by the vehicle at assessment stage

e) The amount of time that the flooring material type was in service for at assessment stage

f) Mean PTV values

g) Pass/Fail assessment

Attachment 33: Slip Prevention Guidance Notes

1 Introduction

To reduce the risk to occupants of slips or falls whilst travelling the floor of all buses in service in London will be expected to be covered with materials which provide an effective level of resistance to slip.

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

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

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 and various usage/age conditions. The Slip Prevention Assessment Protocol: Attachment 32, 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[1] 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”, the material will be deemed a failure if the mean Pendulum Test Value (PTV) is found to be less than 36.0.

[1] 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.

- After 100,000 persons have accessed the material, or after 6 months in service, whichever is sooner, the material will be deemed a failure if the mean PTV is found to be less than 36.0
- Flooring material shall be assessed annually for a period of 7 years from the point of entering service. Throughout this period the material shall provide a minimum slip resistance. The material will be deemed a failure is the mean Pendulum Test Value (PTV) is found to be less than 40.0.

Assessment of the skid resistance of the materials must be carried out in accordance with the assessment protocol defined in Attachment 32. The assessment of materials must be carried by persons accredited by UKAS for the operation of the Portable Skid Resistance Tester (PSRT). This includes individuals working for the material manufacturer, OEM, bus operator or third-party test service.

The certification of materials should, where appropriate take into account possible variations in material performance between manufactured batches. This may require the assessment of material samples 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 UKAS certificates which present as a minimum:

- The material type being assessed
- The vehicle details on which the assessed material was installed
- The Mean PTV of the material in each test direction
- An approximation of the number of passengers transported by the vehicle at the assessment stage
- The amount of time that the flooring material type was in service for at the 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’ materials
- Performance measured in the laboratory, for ‘new’ materials

Each of these options is described in more detail below.

Ideally the assessment of materials will be carried out on in-service vehicles. However, to encourage innovation, laboratory tests may be deemed acceptable.

4.1 Performance measured on buses

Materials may be certified by assessing their performance on current, in-service buses.

Materials shall be assessed at each of the requisite age/usage intervals as stated in section 4. Evidence for each of the assessment increments may be gathered quickly by using materials at various ages across multiple, in-service, vehicles.

New materials may be certified by assessing the performance of those materials on in-service buses. New flooring shall have been installed by appropriately trained individuals, as per section 3. Materials shall be assessed and reported at each of the requisite age/usage intervals stated in section 4. Should the material fail to achieve the criteria required at any stage then it must be replaced.

For certification to be achieved the performance of the materials should be assessed following the procedure defined in Attached 32 and meet the requirements specified in the London Bus Service Limited New Bus Specification Section 4.5.6.

4.2 Performance measured in the laboratory

Materials may be certificated by measuring the performance of representative samples within a laboratory.

Materials shall be assessed at each of the requisite age/usage stated in section 4.

Accelerated wear for a material coupon may be used to simulate the footfall experienced by the flooring materials at the required intervals. Additional evidence showing a strong correlation must be presented between the mean PTV for a coupon with accelerated wear against the equivalent in-service wear.

For certification to be achieved the performance of the materials should be assessed following the procedure defined in Attached 32 and meet the requirements specified in the London Bus Service Limited New Bus Specification Section 4.5.6.

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. 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
- 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 OEM's installation instructions should be followed precisely when replacing materials and, if available, training by the material supplier 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 OEMs recommended procedures. In cases where there are no OEM 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 product'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 product'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 inspection of a bus interior to identify potential injury hazards and the assessment and rating of hazards identified.

The categories of potential hazards include Handrails, Restraints, Partitions, inadequately constrained seated passengers, and General/other hazards such as sharp corners and protrusions.

For full understanding of this Attachment, it should be read in conjunction with the Attachment 35: Occupant Friendly Interiors Guidance Notes and New Bus Specification, Section 4.5.2, Section 4.5.3, Section 4.5.4 and Section 4.5.5.

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.

3 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.

4 Normative references

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

- London Bus Services Limited New Bus Specification: Section 4.5.4
- London Bus Services Limited New Bus Specification: Section 4.5.5
- London Bus Services Limited New Bus Specification: Attachment 35 Occupant Friendly Interiors Guidance Notes

5 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.
- **'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 in Figure 34_1.

Figure 34_1: Examples of seats with high occupancy rate immediately adjacent to a door and only accessible via a step.

- **Partition-like structure**: Is defined as a semi-continuous structure with apertures no greater than 100 mm and a lower edge not more than 100 mm above the floor where the passenger's feet rest for at least 66% of its length.
- **Passenger trajectory plane (PTP)**: Vertical planes which describe the likely directions of travel for a passenger who is thrown forward in the vehicle.
- **Position line (PL)**: Lines which represent a position from which a passenger could be thrown forward in the vehicle
- **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. **Note that hanging grab holds/straps shall not be defined as secondary handrails**
- **Test Service:** The organisation undertaking the testing and certifying the results to the Approval Authority
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **Vehicle under Test (VUT)**: Means the vehicle assessed according to this protocol.

6 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.

7 Test preparation

The following assessment envelopes/zones shall be defined by the Test Service in a universally compatible 3D CAD format e.g. *.IGES or *.STEP.

7.1 Standing passenger vertical handrail assessment space envelope.

A plan view of the envelope is shown in Figure 34_2.

Each of the boxes shall be 500mm x 500mm area

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, this should include any steps that are present. It is possible that the additional height of the steps may make it difficult for a passenger to stand in the associated box areas. In this case, these boxes would be excluded from further assessment, because only areas where passengers are likely to stand are assessed.

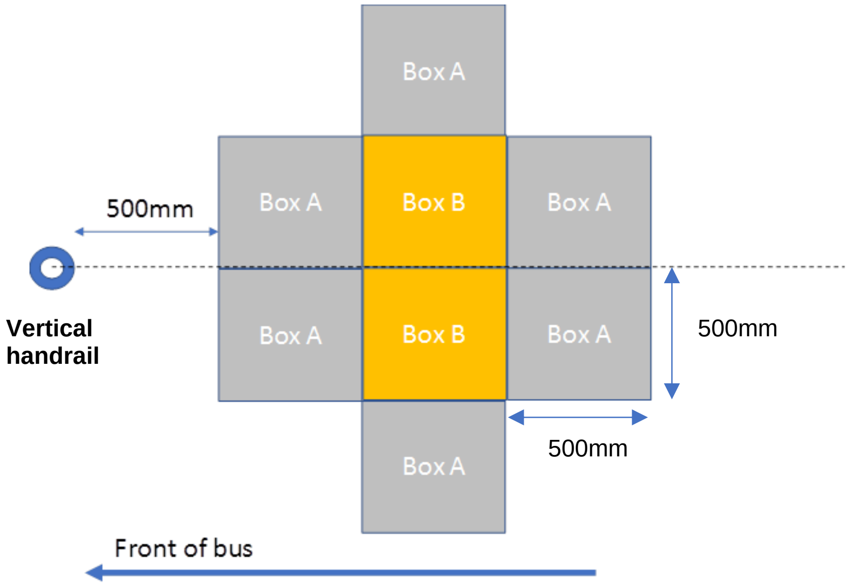


Figure 34_2: Plan view of the vertical handrail assessment space envelope.

7.2 Standing Passenger Head Impact Assessment Zones

The following two head impact zones are defined for standing passengers:

1. Zone for assessment of horizontal handrails (see Sections **Error! Reference source not found.** and **Error! Reference source not found.**):

The height of this zone is from 1160 mm to 1870 mm above the floor level of the VuT with a critical zone defined from 1340 mm to 1755 mm (Figure 34_3).

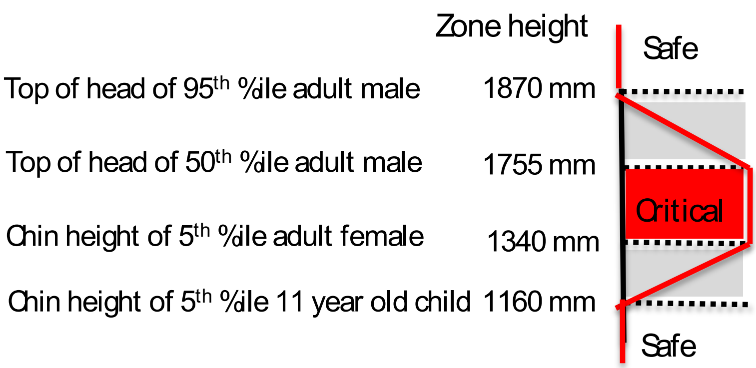


Figure 34_3: Zone for assessment of horizontal handrails

2. Zone for assessment of general / other hazards (See Sections **Error! Reference source not found.** and **Error! Reference source not found.**):

The height of the zone is defined as from floor level of VuT to 1870 mm (top of head of standing 95th percentile adult male) above floor level.

7.3 Seated Passenger Vertical Handrail Impact Assessment Zone

A side view of this zone relative to the seat being assessed is shown in Figure . The zone shall extend for the width of the seat being assessed.

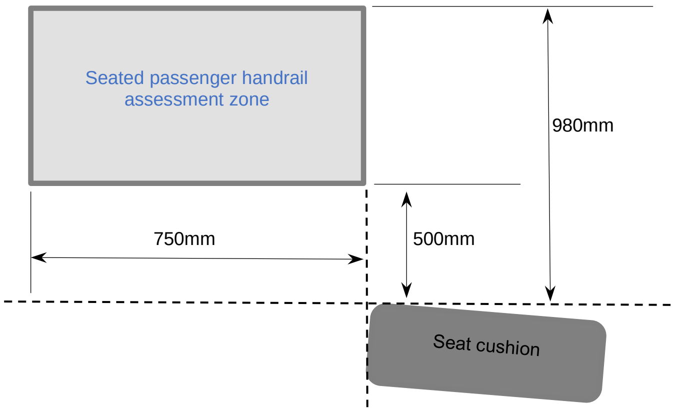


Figure 34_4: Side view of seated passenger handrail assessment zone

7.4 Seated Passenger Head and Body Impact Assessment Zones

Head (inner and outer) and body impact zones are defined for each seating position as illustrated in Figure 34_5.

Head impact zones - forward facing seat

- Height (inner and outer zones): bottom [500 mm], top 980 mm above front of seat cushion, (based on anthropomorphic data)
- Width:
  - Inner zone (high impact risk): 180 mm centred around seat centre
  - Outer zone (lower impact risk): aisle seat; seat aisle edge to seat bodyside edge, exclude inner zone; bodyside seat, aisle seat edge to bodyside window (to include window surround in zone), exclude inner zone
- Length (inner and outer zones): 1100 mm from seat back at front of seat cushion height (measured at seat centreline)

Head impact zones - rearward facing seat

- Height and width as per forward facing
- Length: 300 mm from seat back at front of seat cushion height (measured at seat centreline)

Body impact zone – (forward facing seat only)

This zone consists of a single zone across its width, i.e. it does not consist of inner and outer zones as for the head

- Height: Floor to bottom of head impact zones for forward facing seat
- Width: As for head but only extends to bus body side, i.e. excludes window surround

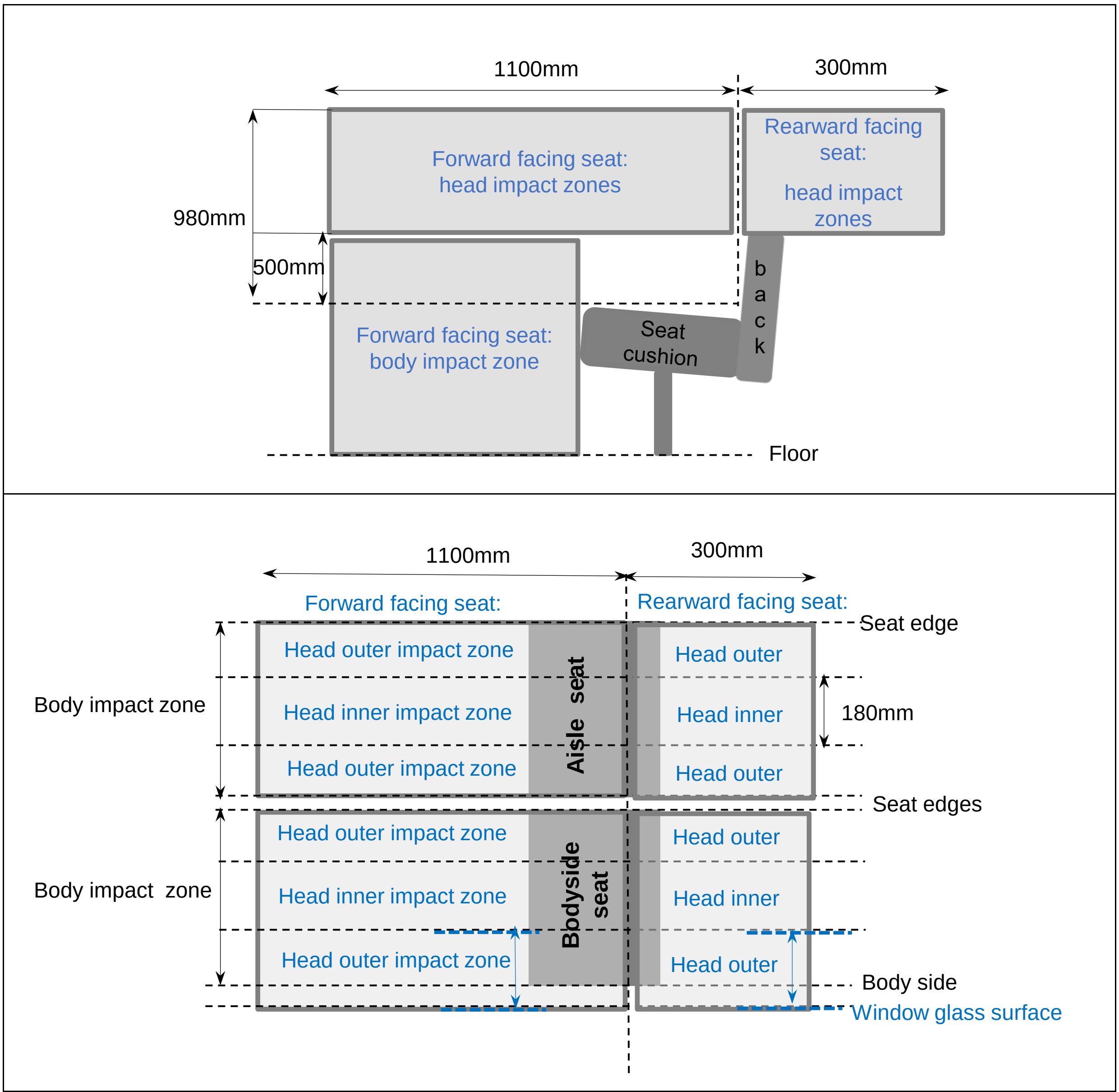


Figure 34_5: Side (top) and plan (bottom) views of seated passenger head (inner and outer) and body impact zones

8 Test Procedure

8.1 Standing Passengers

This part of the procedure only applies to the lower deck of the VUT on the basis that standing (for substantial periods) is prohibited on the upper deck.

8.1.1 Standing Passenger Handrails

Purpose:

- To encourage vertical handrails to be positioned where they are less likely to be hit by a standing passenger who falls.
- To discourage the placement of horizontal handrails at a height, level with a passenger's head, where they are likely to be impacted

The procedure considers vertical and horizontal handrails separately.

8.1.1.1 Vertical handrails

A vertical handrail is defined as 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.

Note: The London Bus Services Limited New Bus Specification Section 4.5.3, 'Occupant Protection - handrail/stanchion construction and installation', amongst other things, requires:

seat back to ceiling handrails (with bell push) at all forward facing seats in the lower saloon and at alternate seats in the upper saloon

which is generally above that required by the performance based regulatory requirement.

All vertical handrails shall be identified and the following process followed.

1. Apply the Vertical Handrail Assessment Space Envelope to each of the vertical handrails identified (see section 7.1). The centre of the handrail being assessed is the reference point for the template see example in.
2. Identify the boxes in which a passenger is likely to stand by applying the following criteria:
   - Identify encroaching structures for each of the boxes within the space envelope.
   - 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.

The example shown in Figure 34_6 identifies which boxes a passenger can stand in by using 250 mm diameter circles. 4x Box ‘A’s and 1x Box ‘B’ are identified (see the green arrows).

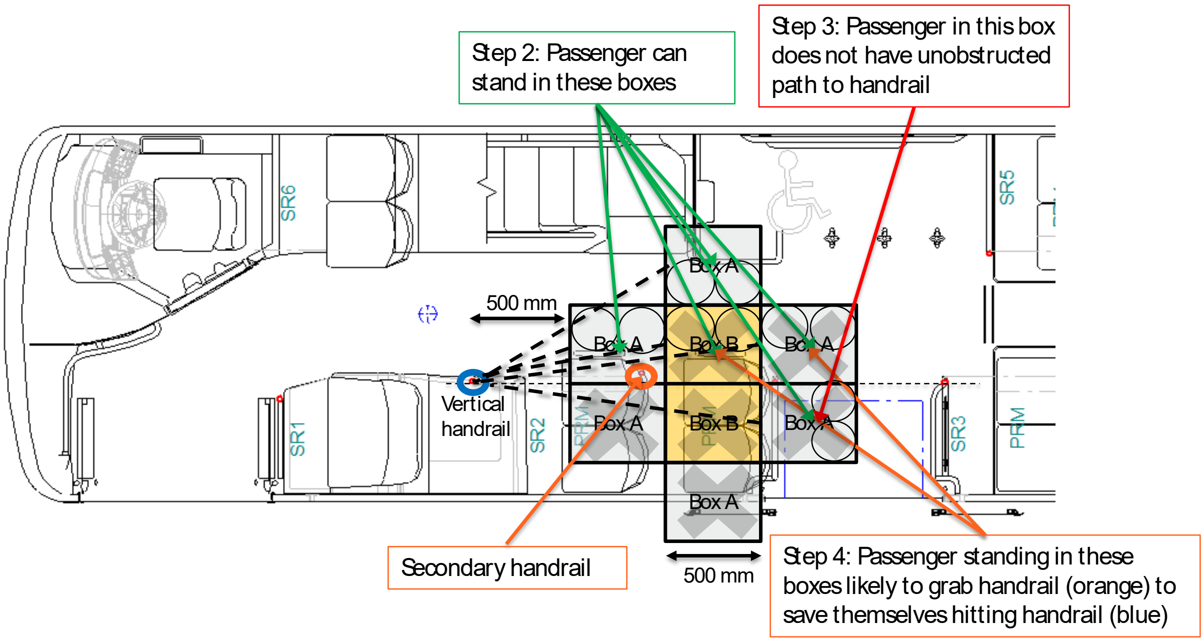


Figure 34_6: Example of assessment of vertical handrail positioned ahead of PRM seats in luggage storage area.

3. 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 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 bottom picture. When complete this will give 6 corridors; two corridors for each PL.

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.

The example shown in Figure 34_6**Error! Reference source not found.** shows that a passenger standing behind the seats in front of the middle doors does not have an unobstructed path to the handrail highlighted in blue (see red arrow). This reduces the number of relevant boxes to 3x Box 'A's and 1x Box 'B'.

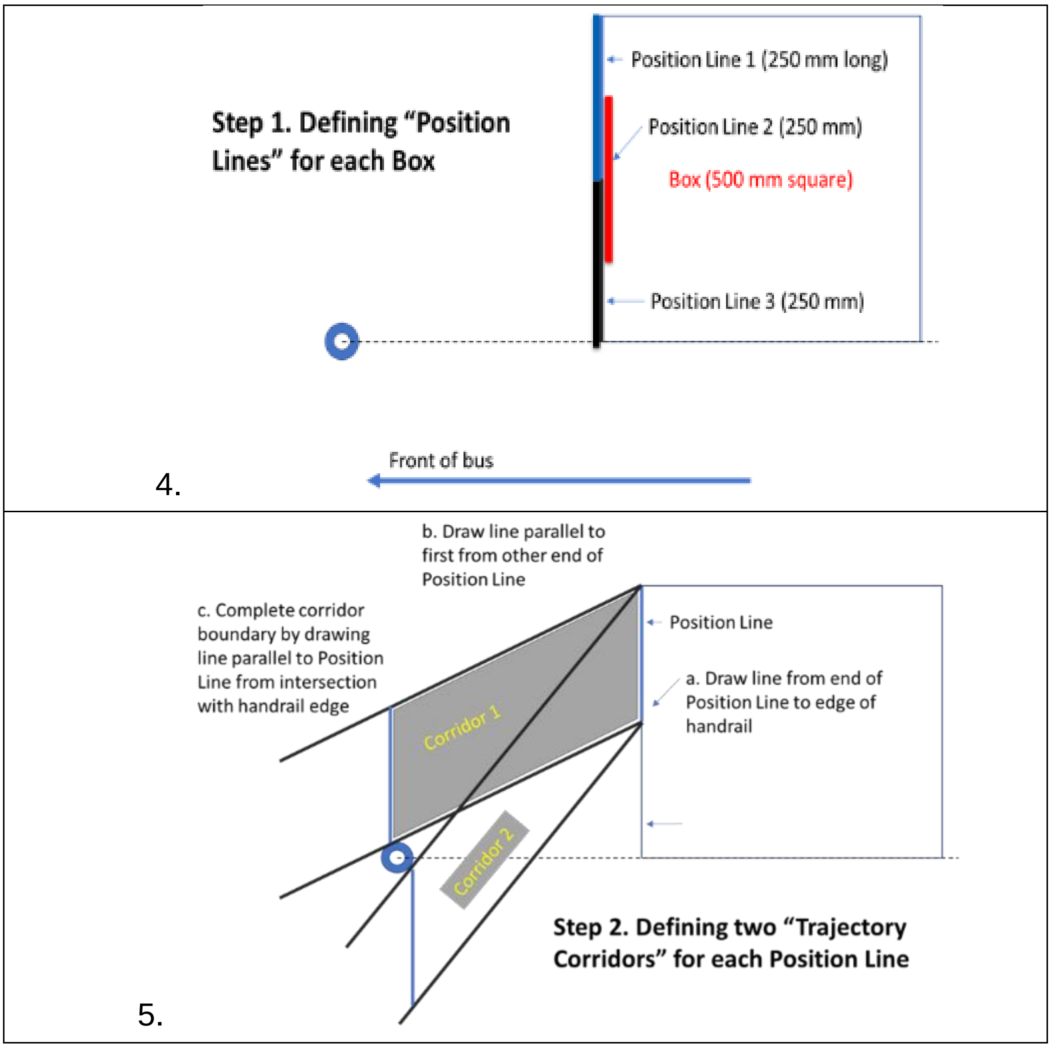


Figure 34_7: Procedure to assess presence of unobstructed corridor to vertical handrail.

4. Determine whether passengers have an opportunity to grab another handrail (secondary handrail) to prevent a collision with the primary handrail using the following method:

   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. In the case of curved handrails, the above measurements shall be taken at a height of [1384]mm from the floor height.

   Note: Hanging grab holds/straps shall not be defined as secondary handrails

For the example in Figure 34_6, the secondary (seatback to ceiling) handrail highlighted in orange will offer passengers standing in the Box B and Box A behind it indicated (see orange arrows), an opportunity to grab it and save themselves from hitting the vertical handrail being assessed. This reduces the number of relevant boxes (in which a passenger could stand and likely fall and hit the handrail being assessed) to 2x Box 'A's (ones without grey crosses in them).

8.1.1.2 Horizontal handrails

1. All horizontal handrails shall be identified.
2. The height of the middle of each handrail above the bus floor shall be measured.
3. The length of each handrail shall also be measured.

8.1.2 Standing Passenger Restraints

Purpose:

To encourage partitions that a passenger may stand behind to be of sufficient height to restrain the motion of a passenger in the event of emergency braking and / or a collision, i.e. they are not thrown over it.

1. Partitions that a passenger can stand behind shall be identified.

   This shall be achieved by measuring the space available for standing passengers behind all partitions. If this space extends at least 500 mm rearward across the width of the partition, has a width > 250 mm and is open to a height of 1870 mm, the partition shall be identified as one which can be stood behind.
2. The width of the partitions identified (as one which can be stood behind) shall be measured.

   If the partition width varies with height, it shall be measured at a height of 1060 mm or at the top of the partition if its height is lower

3. The average height of the partition above the VuT floor shall be measured. Guidance of how to do this for partitions which consist of multiple structures with a longitudinal offset and/or uneven top profiles, such as those shown in Figures 34_8 and 34_9, are given below.
   - Multiple structures (see Figure 34_8):
     - If the top of the forward most structure is less than [170 mm] longitudinally of the rearward most structure (measured from rear of rearward most structure to rear of forward most structure), the height of the partition shall be defined as the height of the higher structure.
     - If the top of the forward most structure is more than [170 mm] longitudinally of the rearward most structure (measured from rear of rearward most structure to rear of forward most structure), the height of

the partition shall be defined as the height of the rearward most structure.

- Exception: if the height of the forward most structure is more than 500 mm higher than the rearward most structure, the height of the partition shall be defined as the height of the forward most structure

- Uneven top profiles (see Figure 34_9):
  - Measure profile of top of partition taking height measurements, if necessary, up to every 50 mm along its width
    - For multiple structures, follow guidance above to measure max height of appropriate structure
  - Bridge any gaps in profile less than 100 mm wide and integrate to determine average height of partition

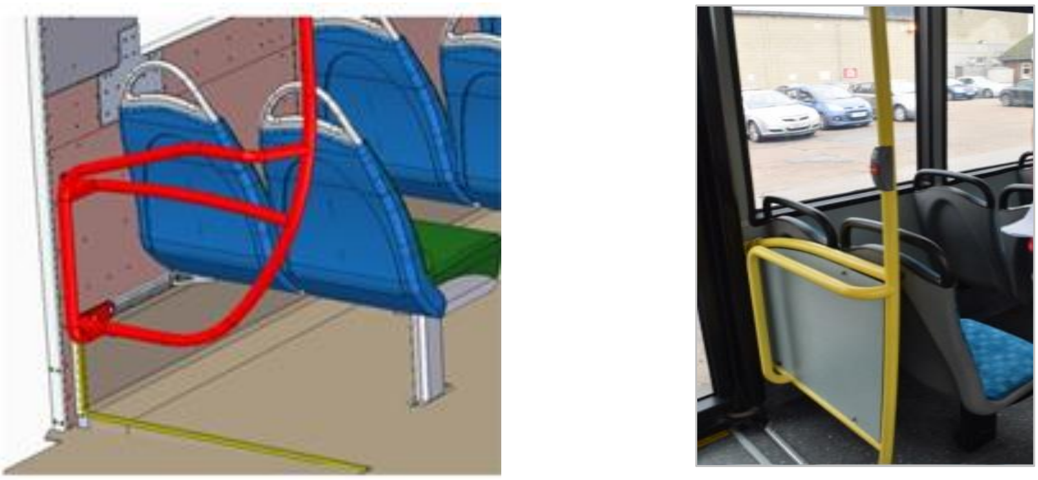


Figure 34_8: Example of partitions consisting of multiple structures

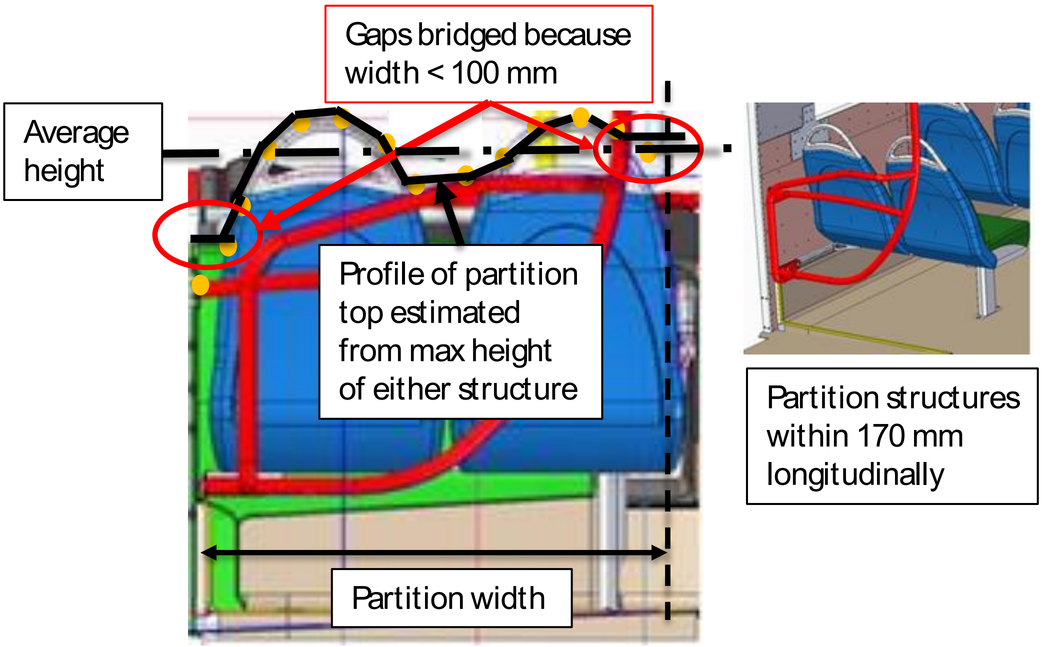


Figure 34_9: Measurement of width and average height for partition with multiple structures and uneven height

8.1.3 Standing Passenger General/other Hazards

Purpose:

To encourage the removal of features, such as sharp edges / corners and protrusions, that a standing passenger may hit when they fall, with focus on head impact.

1. Hazards meeting the following criteria shall be identified:
   - Edge or corner with predominant radius < 20 mm and protrusions with height from surrounding surface > 3.2 mm which are:
     - Located within the head impact zone (see Section **Error! Reference source not found.**, point 2)
     - Situated in a position such that bus interior furniture (seats) do not prevent it from being impacted by the head of a standing passenger (a standing passenger is not likely to be thrown sideways over a pair of seats to impact an object mounted on the bus's bodyside). Guideline for assessment is to include objects positioned < 0.5 m over interior furniture (seats) from where passengers permitted to stand and include objects within space where standing passengers could be thrown in the event of harsh braking or a collision (e.g. non-standing area in front of driver cab).

  - Can be contacted by 165 mm diameter sphere, i.e. is not shielded by another feature such as a handrail, partition or seat which prevents head contact
  - Made from material with a Shore A hardness[1] greater than 50
  - Attached to bus rigidly, i.e. displaces < 5 mm with application of 20N load
  - Note: components which have been designed to move (e.g. armrests) should be assessed in all normal in-use positions and worst case taken

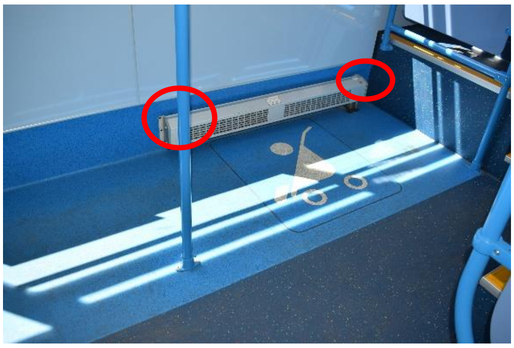
2. Exclude the following from hazards identified:
   - Handrails ….*because these are assessed separately*
   - Brackets / clamps which hold partition structures with no or small protrusions < 3.2 mm and blunted / radiused edges, ideally radii > 2.5 mm
   - Armrests with predominant radii > 5 mm
   - Step edges …*because these are required to prevent passenger slisp/trips/falls*
   - Stop buttons with standard rounded design OR exposed radii > 2.5 mm
   - Window surrounds with predominant radii > 5 mm
   - Handholds (on high backed seats) with predominant radii > 10 mm
   - Protrusions with height > 3.2 mm which meet UNECE Regulation No. 21 para 5.1.4 and/or 5.1.5 as appropriate – **The OEM is to provide documentary evidence**
     - Paragraph 5.1.4.: ….Features made of rigid material, which project 3.2 mm to 9.5 mm from the surrounding structure, shall have a cross-sectional area of not less than 2 cm^2, measured 2.5 mm from the point projecting furthest, and shall have rounded edges with a radius of curvature of not less than 2.5 mm
     - Paragraph 5.1.5 ….Features made of rigid material, which project more than 9.5 mm from the surrounding structure, shall be so designed and constructed as to be able, under the effect of a longitudinal horizontal force of 378 N delivered by a flat-ended ram of not more than 50 mm in diameter, either to retract into the surface of the structure until they do not project by more than 9.5 mm or to become detached; in the later case, no dangerous projections of more than 9.5 mm shall remain; a cross section not more than 6.5 mm from the point of maximum projection shall be not less than 6.5 cm^2 in area.
     - Note: for further detail see UNECE Regulation No 21[2]
3. Identify groups of hazards which can be contained in a rectangular area 10 cm x 10 cm.

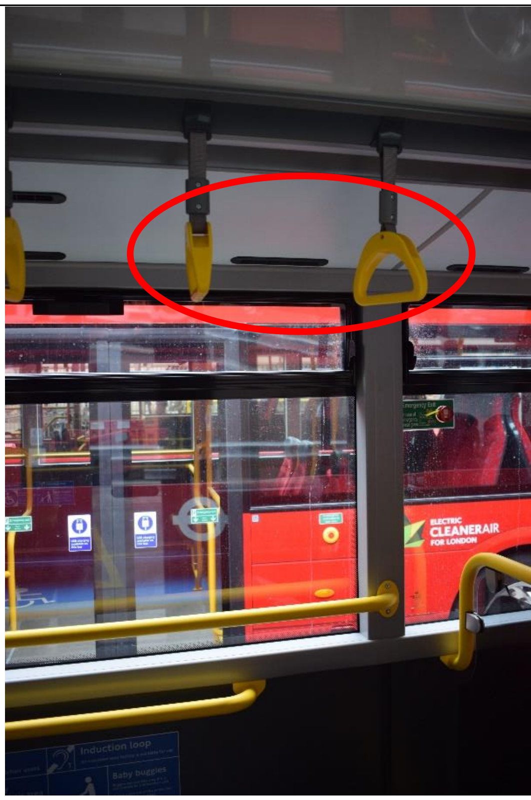
[1] Shore hardness is defined as a material's resistance to indentation when a static load is applied.
[2] UNECE Regulation No 21: https://op.europa.eu/en/publication-detail/-/publication/588aa860-5042-4063-ad75-8ae5e18af385/language-en

4. Count number of hazards identified; note that a group of hazards as defined in point 3 above shall be counted as one hazard only.
5. Determine and record edge orientation (transverse or longitudinal) and protrusion height as appropriate for each hazard and hazard group (see Section **Error! Reference source not found.** and Figure).

Examples of items which should be included and excluded as hazards are shown across the following pages in (Figure 34_10).

Include as general hazard	**Exclude as general hazard**
 Seat mount structure sharp corner (radius < 20 mm).	  Step edges with small radius in direction perpendicular to travel (because needed to prevent slips/trips on step and ensure functionality).

Include as general hazard	**Exclude as general hazard**
 Mirror (provided in head impact zone - < 1870 mm above floor - and rigidly attached.	 Stop button with rounded design
 Heating unit corner / edge	 Brackets / clamps holding partition-like structures – radii blunted, no protrusion > 3.2 mm Note: edges of glass partition also shielded from impact by partition rail structure

Include as general hazard	**Exclude as general hazard**
 Passenger Information System (PIS) corner	 Grab handles on straps attached to structures above 1870mm from the VUT floor

Include as general hazard	**Exclude as general hazard**
 Protruding driver compartment door hinges with sharp edges (note 2 hazards because more than 100 mm apart)	 Window surround with predominant radii > 5 mm
 Armrest with predominant radii < 5 mm	 Handhold (on high backed seats) with predominant radii > 10 mm

Include as general hazard	Exclude as general hazard
	 Armrest with predominant radii > 5 mm – note armrest shown fitted to train

Figure 34_10: Examples of features which should be identified as general hazards for standing passengers, and those which should be excluded

8.2 Seated Passengers

The assessment shall be completed for both the lower and upper decks for forward facing seats.

8.2.1 Seated Passenger Handrails

Purpose:

To encourage vertical handrails (mainly seat back to ceiling) to be positioned more inboard to reduce the risk of head impact for seated passenger.

1. Identify vertically orientated handrails positioned within the seated passenger head impact assessment zone. Examples of handrails in this zone are shown in Figure 34_11. Handrails can be straight or curved.

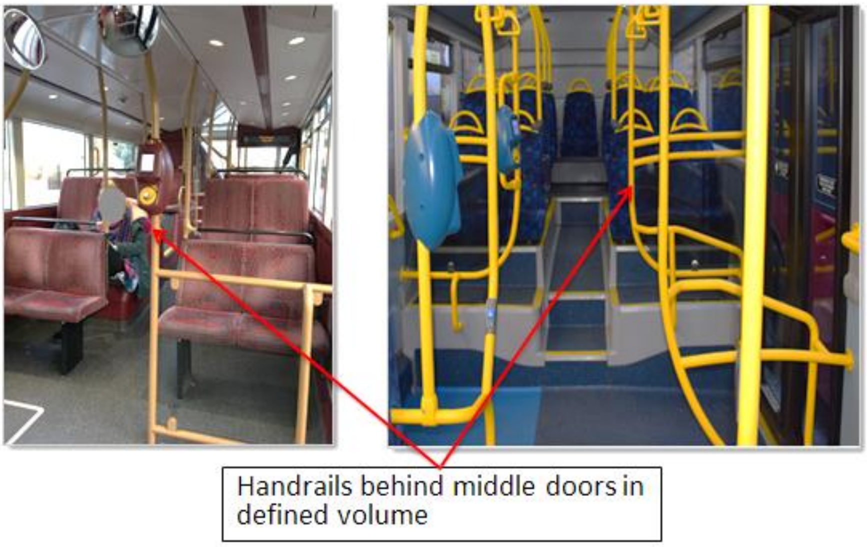


Figure 34_11: Examples of handrails positioned behind middle doors in trajectory of seated occupant that shall be identified for further assessment.

2. For each of the handrails identified, take the following measurements relative to the longitudinal centreline of the seat:
    - D_{LatHR} - Lateral (y-axis) distance from boundary (edge) of the handrail nearest to the seat centreline to the outer edge of the seat.
    - W_{seat} - The maximum width of the seat.
3. For curved handrails measure D_{LatHR} at 5 heights relative to head impact zone as follows: bottom, 25%, middle, 75%, top, as per Figure 34_12

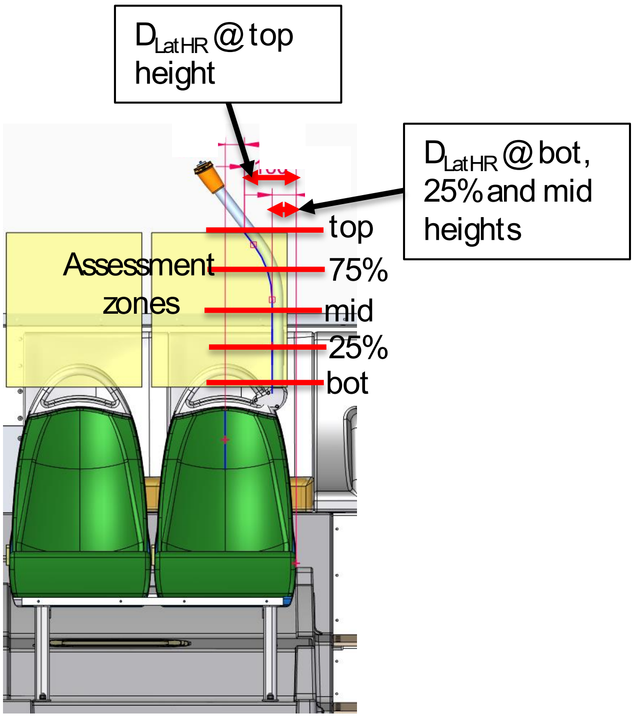


Figure 34_12: Measurement of D_{LatHR} for curved handrail at 5 heights, bot, 25%, mid, 75%, top

Note: Child/parent seats, which are wider than standard seats, should be assessed as standard adult seats. Reasons for this include:

- Child/parent seat is often occupied by one adult only.
- Assessment for adult will drive changes that are beneficial for when seat occupied by parent and child, i.e. encourage position of vertical (seatback to ceiling) handrails to be more inboard to reduce risk of head impact

4. Identify whether the handrails assessed are associated with ‘high occupancy / PRM’ seats.

Example shows assessment of vertical handrail positioned in front of seats behind luggage rack (Figure 34_13).

Figure 34_13: Assessment of vertical handrail positioned in front of seats behind luggage rack showing handrail > 750 mm longitudinally from front of seat cushion and therefore outside 'vertical handrail impact assessment zone'

Assessment shows vertical handrail positioned outside vertical handrail impact zone (see Section **Error! Reference source not found.**), therefore, vertical handrail does not score (i.e. scores zero).

Note: Luggage retention rail height below height of head impact zone so not assessed as potential head impact hazard (see Section **Error! Reference source not found.**).

8.2.2 Restraint

Purpose:

To encourage structures in front of seated passengers (partitions or seatbacks) to have sufficient height and width to constrain passenger motion during harsh braking or a collision type event, i.e. they are not thrown over or around side of structure.

Note: The London Bus Services Limited New Bus Specification Section 4.5.4 'Occupant Protection - guards for exposed seats', requires that:

as specified in the 06 series of amendments for UNECE Regulation No. 107, guards for exposed seats shall be fitted as per the performance requirements where any seated passenger is likely to be thrown forward into a designated wheelchair space, buggy (pram) space, or open area for standing passengers as a result of heavy braking.

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 – defined as two sets of two seats facing each other
   c) Some structure within a longitudinal distance of 1200 mm from seat back
2. Where a seat has some structure in front of it, take the following measurements as illustrated in Figure 34_14:
   - H_{feet}: The average height above the floor on which the passenger's feet rest for the seating position being assessed. Make measurement of average height for structure present in alignment with central 50% of seat width only.

     Notes:

     - If structure not present over 50% of seat width, make average measurement for structure present only – structure will be penalised separately on basis of its lack of lateral coverage, i.e. D_{LatRes}.
     - For structure with uneven top profile, measure average as described in Section **Error! Reference source not found.** 'Standing restraint', i.e. take height measurements up to every 50 mm, if necessary bridge gaps < 100 mm and integrate to determine average.
   - D_{LatRes}: Lateral (y-axis) not covered by restraint / partition-like structure. Measure the distance from the centre of the innermost seat to the boundary (edge) of the restraint structure nearest the centre of the bus.

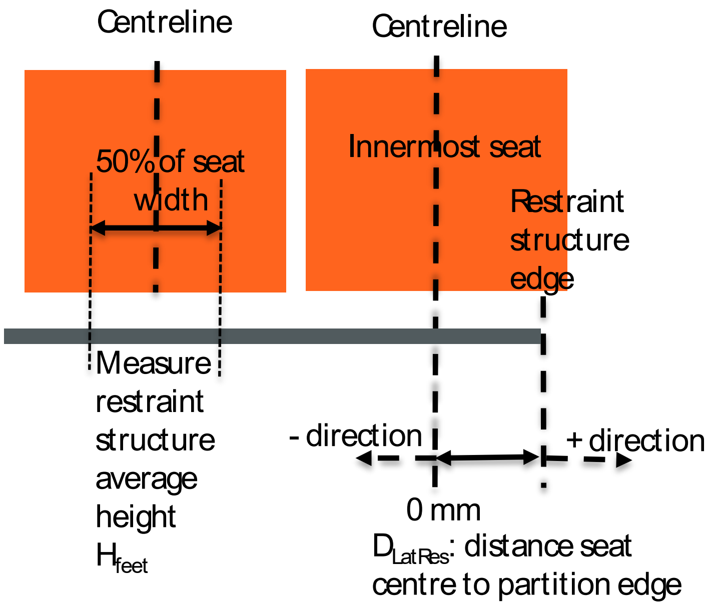


Figure 34_14: Measurement of H_{feet} and D_{LatRes}

3. For restraint structures with curved edges measure width at height of 500 mm (seat cushion / knee level) and 800 mm (or top of partition if height < 800 mm) and record minimum value of D_{LatRes} measured as illustrated in Figure 34_15.

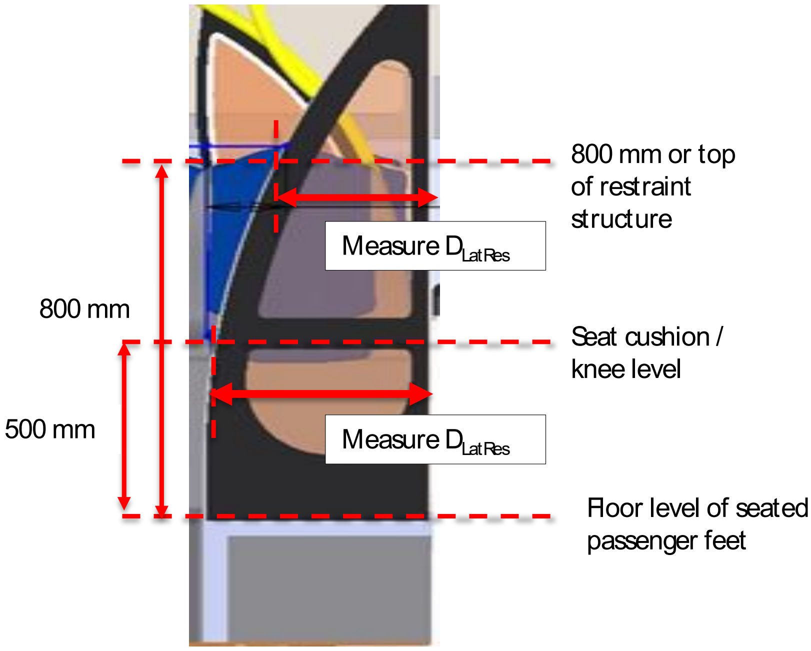


Figure 34_15: Measurement of D_{LatRes} for curved restraint structure

4. Identify whether or not the restraints assessed are associated with PRM seats.

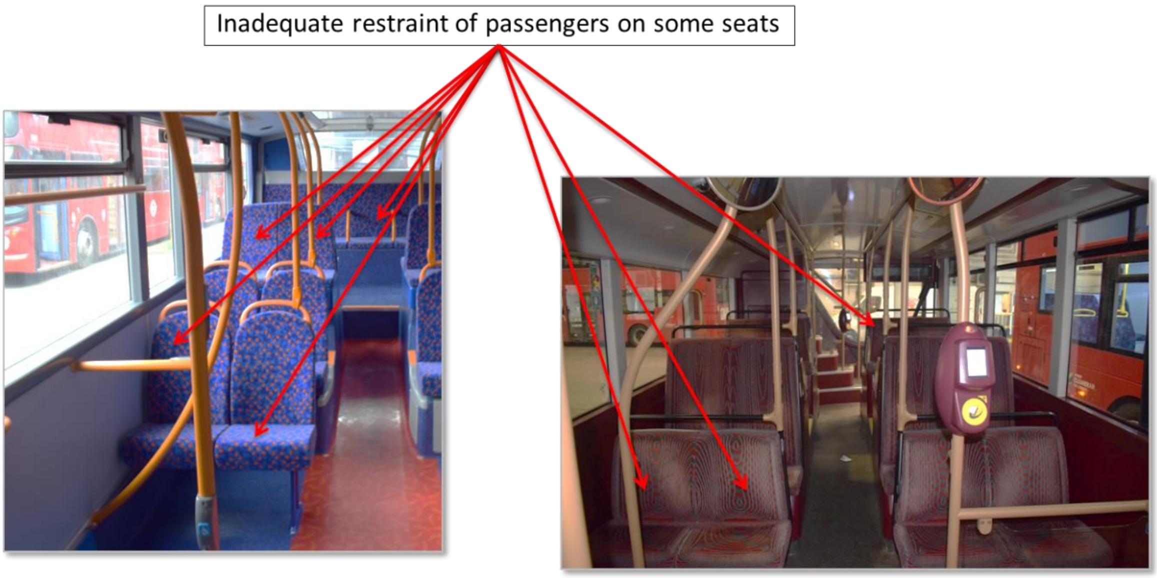


Figure 34_16: Examples of seats where there is inadequate restraint of seated passengers

Note: to help understanding of the process, an example of the assessment of the restraint provided by the wheel box / luggage area is shown in Section **Error! Reference source not found.**.

8.2.3 General hazards

Purpose: To encourage the removal of features, such as sharp edges / corners and protrusions, that a seated passenger may hit mainly when they are thrown forward during harsh braking or a collision type event.

1. Hazards meeting the following criteria shall be identified:
   a) Edge or corner with predominant radius < 20 mm or with predominant radius > 20 mm and protrusions with height from surrounding surface > 3.2 mm which are:
      - Located within the seated head (inner or outer) or body impact zone.
        - Zones defined in Section 7.4.
      - Can be contacted by 165 mm diameter sphere in head impact zone or 100 mm diameter sphere in body impact zone, i.e. is not shielded by another feature such as a handrail, partition or seat which prevents head (or body) contact
      - Made from material with a Shore A hardness[4] greater than 50
      - Attached to bus rigidly, i.e. displaces < 5 mm with application of 20N load

[4] Shore hardness is defined as a material's resistance to indentation when a static load is applied.

Note: Hazard identification shall be performed for all frequently used conditions, e.g. for USB port assess with lead plugged in and not plugged in.

2. Exclude the following from hazards identified:
   - In head impact zones:
     - Structures with large radii (> 200 mm) and area (> 400 cm^2), i.e. large flat type structures which include:
       - Full height glass panels for weather protection,
       - Partitions located behind driver cab,
       - Windscreen in front of upper deck front seats provided guard as required by UN Regulation 107 fitted
     - Handrails / handholds on the top of low backed seats provided their maximum height is < [1040] mm above level of floor where passenger seated behind places their feet and they have predominant radius > 10 mm
     - Vertical handrails assessed in 'seated / handrail' section, but note that this does not include brackets which hold seat to ceiling handrails to seat back.
     - Handrails and associated brackets which hold partition structures with no or small protrusions < 3.2 mm and blunted / radiused edges, ideally radii > 2.5 mm positioned in following head impact outer zones:
       - In-board seat, outer zone which is most inboard
       - Out-board seat, outer zone which is most outboard
     - Handholds (on high backed seats) in outer head impact zone with predominant radii > 10 mm
     - Stop buttons attached to seatback handrail with standard rounded design OR exposed radii > 2.5 mm
     - Window surrounds with predominant radii > 5 mm
     - Protrusions with height > 3.2 mm which meet UNECE Regulation No. 21 para 5.1.4 and/or 5.1.5 as appropriate – **manufacturer to provide documentary evidence**
       - Para 5.1.4.: ….Features made of rigid material, which project 3.2 mm to 9.5 mm from the surrounding structure, shall have a cross-sectional area of not less than 2 cm^2, measured 2.5 mm from the point projecting furthest, and shall have rounded edges with a radius of curvature of not less than 2.5 mm
       - Para 5.1.5 ….Features made of rigid material, which project more than 9.5 mm from the surrounding structure, shall be so designed and constructed as to be able, under the effect of a longitudinal horizontal force of 378 N delivered by a flat-ended ram of not more than 50 mm in diameter, either to retract into the surface of the structure until they do not project by more than 9.5 mm or to become detached; in the later case, no dangerous projections of more than 9.5 mm shall remain; a

cross section not more than 6.5 mm from the point of maximum projection shall be not less than 6.5 cm^2 in area.

- Note: for further detail see UNECE Regulation No 21[5]

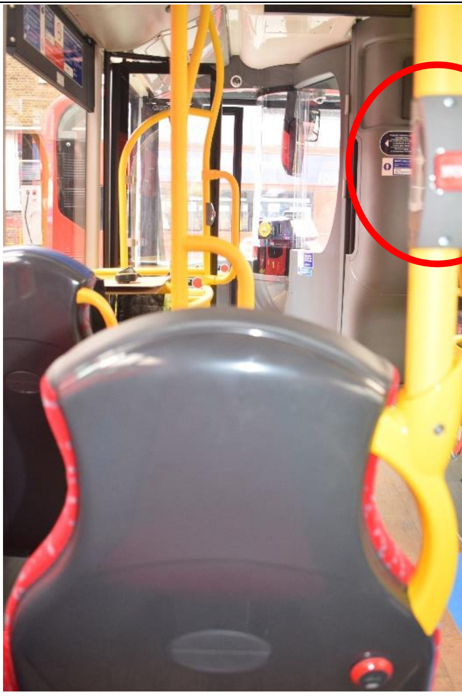
- In body impact zone:
  - Edge / corner with predominant radii > 5 mm
  - Handrails and associated brackets with radii > 2.5mm which hold partitions
  - Protrusions with height > 3.2 mm which meet UNECE Regulation No. 21 para 5.1.4 and/or 5.1.5 as appropriate – **manufacturer to provide documentary evidence**

3. Identify groups of hazards which can be contained in a rectangular area 10 cm x 10 cm.
4. Count number of hazards identified for each zone; head inner, head outer, body; note that group of hazards as defined above shall be counted as one hazard only

Examples of potential hazards that should be included and excluded are shown on the following pages (Figure 34_17).

[5] UNECE Regulation No 21: https://op.europa.eu/en/publication-detail/-/publication/588aa860-5042-4063-ad75-8ae5e18af385/language-en

Potential hazard included	**Potential hazard excluded**
 Sharp corner on Passenger Information System in head impact outer zone	 Full height glass partition in front of forward facing seats covering head impact zones
 Luggage rack rail in head impact inner zone for rear facing seats (counts as 1 hazard in head impact inner zone for both seats, i.e. 2 hazards in total)	 Window surround with predominant radii > 5 mm

Potential hazard included	Potential hazard excluded
 Group of bolt heads in lower body impact zone (counts as 1 hazard for body impact zone because within 10 cm of each-other)	 Stop button with rounded design
 Ends of handrails in head impact outer zone of window seat passenger	

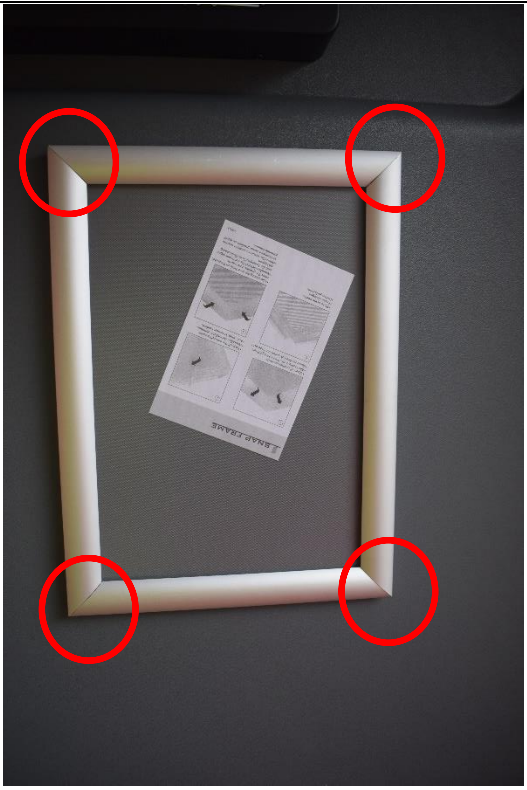
Potential hazard included	Potential hazard excluded
 Sharp corners on notice / picture frame in head impact zones of pasenger seat behind driver cab	

Figure 34_17: Examples of potential hazards for seated passengers to be included and excluded in assessment

9 Assessment of results

9.1 Standing passengers

9.1.1 Handrails

9.1.1.1 Vertical

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.

   Note: 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.

   Note: If any of these criteria are not met, the box is scored 0.

This results in maximum score of 1 for a handrail.

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.

9.1.1.2 Horizontal

1. Using the data collected, each handrail shall be assessed as follows:

   - For handrail height ≤ 1160 mm score 0.
   - For handrail height > 1160 mm and < 1340 mm, linearly score between 0 and 1 by application of formula below:

     Score = ('handrail height (mm)' – 1160 mm)/(1340 mm – 1160 mm)

   - For handrail height ≥ 1340 mm and ≤ 1755 mm, score 1
   - For handrail height > 1755 mm and < 1870 mm, linearly score between 1 and 0 by application of formula below:

     Score = (1870 mm - 'handrail height (mm)')/(1870 mm – 1755 mm)

   - For handrail height ≥ 1870 mm score 0.

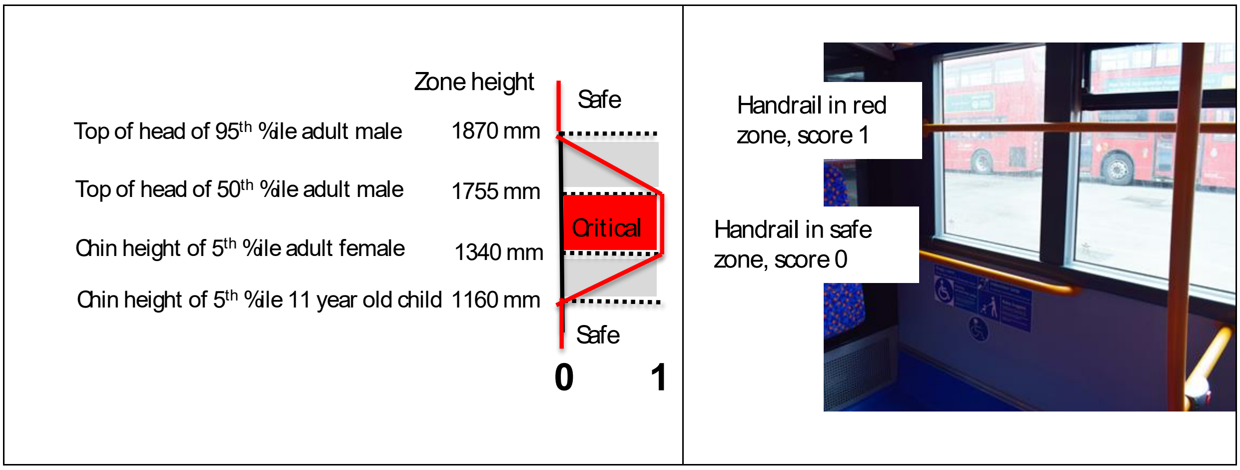


Figure 34_18: Illustration of assessment for horizontal handrails based on their height above the bus floor.

2. 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

9.1.2 Restraint

The partition is scored based on its average height and length as below:

1. Partition average height

- ‘Partition average height’ ≤ 750 mm score 1
- ‘Partition average height’ > 750 mm and < 1060 mm apply formula below: Score = (1060 mm - ‘Partition average height (mm)’)/310 mm) * (‘Partition length (mm)’/500 mm)
- Partition average height ≥ 1060 mm score 0

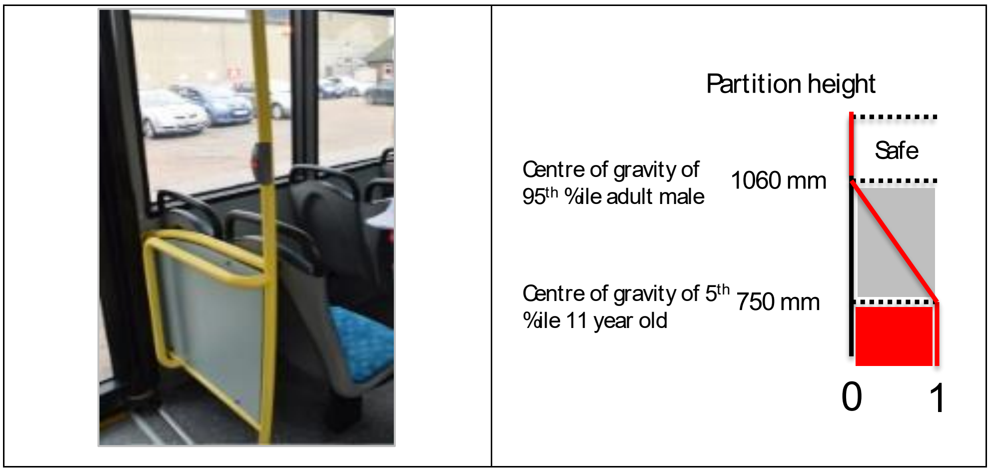


Figure 34_19: Illustration of assessment of restraint (partitions) for standing passengers.

2. The score for each partition shall be factored by its length by application of the formula below:

   Final score = ('Partition average height score')*(partition length mm)/500 mm

   Note: 500 mm chosen to represent approximate space required for one passenger to stand

9.1.3

9.1.3 General/other hazards

1. Each of the hazards and groups of hazards identified in Section **Error! Reference source not found.** shall be assessed as follows:

   If hazard or group of hazards has an edge or protrusion which meets the following criteria score 1 (otherwise score 0):

   - Edge (see Figure 34_20):
     - Orientated laterally across the VUT within +/- 45 deg and has predominant radius less than 20 mm
     - Orientated longitudinally along the VUT within +/- 45 deg and has predominant radius less than 10 mm
   - Protrusion:
     - Height greater than 3.2 mm (and not UNECE Regulation No. 21 para 5.1.4./5.1.5 compliant)

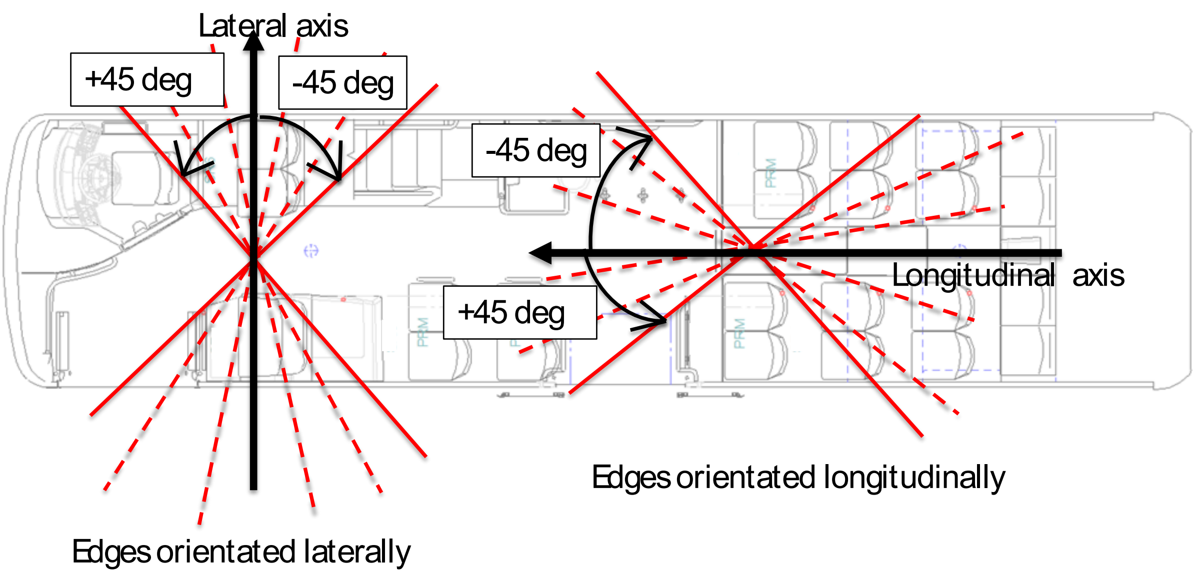


Figure 34_20: Illustration of laterally and longitudinally oriented edges (edges shown with dashed red lines, +/- 45 deg boundaries shown with solid red lines)

9.1.4 Weighting of hazards for standing passengers

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

9.2 Seated passengers

9.2.1 Handrails

1. The handrail shall be scored as illustrated in Figure 34_21 as follows:

i. If distance D_{LatHR} from the edge of the rail closest to the seat centre to the outer edge of the seat in the vehicles y-axis is ≤ 100 mm, handrail scores 0

ii. If distance D_{LatHR} from the edge of the rail closest to the seat centre to the outer edge of the seat in the vehicles y-axis is ≥ ((w_{seat}/2) – 90 mm), handrail scores 1

iii. For distances in between those defined above, use the formula below to calculate a score between 0 and 1:

$$\text{Score} = (D_{LatHR} - 100\text{ mm})/(w_{seat}/2 - 190\text{ mm})$$

2. For curved handrails:

- If D_{LatHR} measured at any height fulfils (ii) handrail scores 1 otherwise take average of D_{LatHR} measured at five heights and score as above for straight handrail, i.e. (i) or (iii)

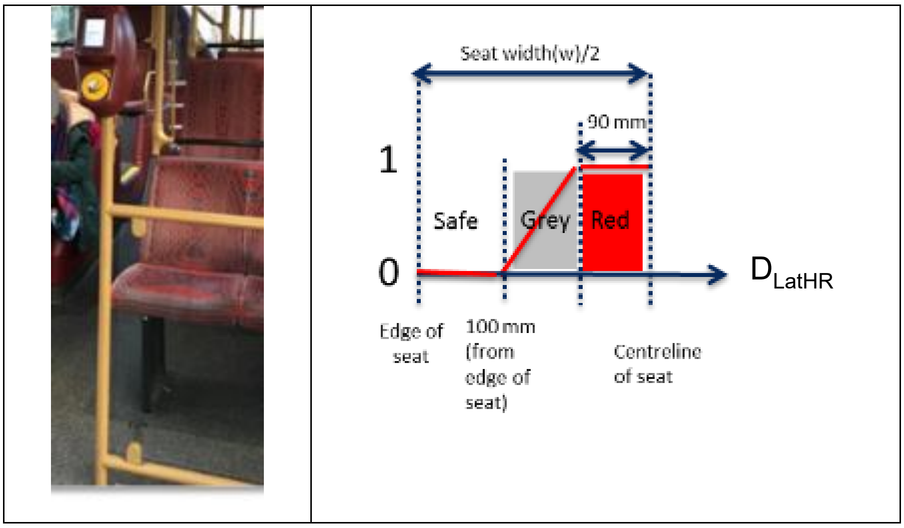


Figure 34_21: Procedure for assessment for handrails identified as a potential hazard for seated occupants

9.2.2 Restraint

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; note bay seat arrangement defined as defined as two sets of two seats facing each other – score for full arrangement (i.e. all 4 seats) is 0.75.

c) Seats with some structure (partition like structure or other seats) in front of them shall be assessed as follows:

(a) The lateral coverage of the structure C_{Lat} shall be scored based on D_{LatRes} measurement as follows (see Figure):

- If $D_{LatRes} \leq 0$ mm $C_{Lat} = 1$;
- If $D_{LatRes} > 0$ mm and < 100 mm, $C_{Lat} = (100 - D_{LatRes})/100$
- If $D_{LatRes} \geq 100$ mm $C_{Lat} = 0$;

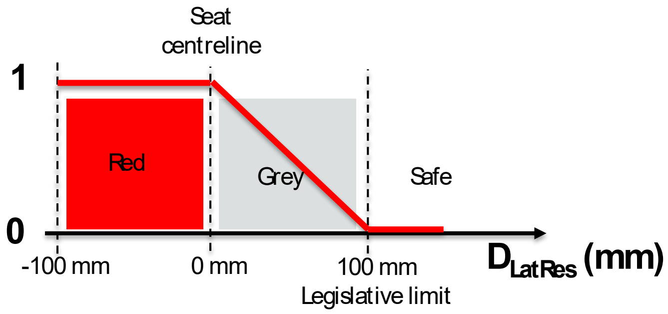


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Figure 34_22: Illustration of safe, grey and red zones for lateral coverage of restraint assessment

(b) The average height (H_{feet}) as follows (see Figure):

i. If the average height of the structure (H_{feet}) ≥ 800, the structure's height is in the safe zone, height factor score = 0

ii. If the average height of the structure (H_{feet}) ≤ 700 mm, the structure's height is in red zone, height factor score = 1.

iii. If average height of structure (H_{feet}) is between 700 mm and 800 mm, the formula below shall be applied to calculate score between 0 and 1:

Height factor score = $(800 - H_{feet})/100$

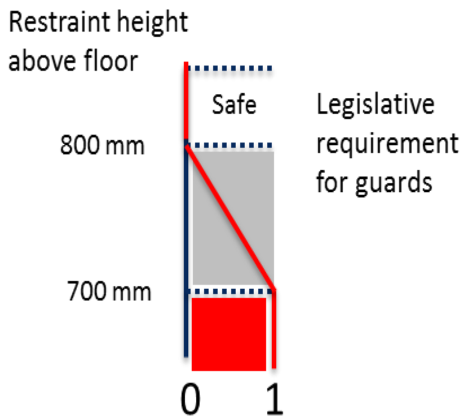


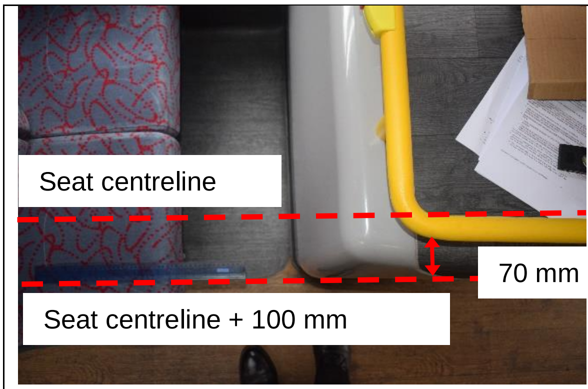
Figure 34_23: Illustration of safe, grey and red zones for height of restraint assessment

(c) The final score for the restraint shall be calculated based on its lateral coverage score (C_{Lat}) and its height factor score as follows:

Final Score = C_{Lat} + (Height factor score)

Note: Scores calculated to be greater than 1 should be capped at 1.

Example: Assessment of restraint provided by wheel box / luggage area.



Window seat:

D_{LatRes} = full seat width, i.e. ≥ 100 mm

H_{feet} = ~820 mm, i.e. ≥ 800 mm

Aisle seat:

D_{LatRes} @ 500 mm height = 100 mm

D_{LatRes} @ 800 mm height = 30 mm

H_{feet} = ~820 mm, i.e. ≥ 800 mm

Both seats are 'high occupancy / PRM seats'

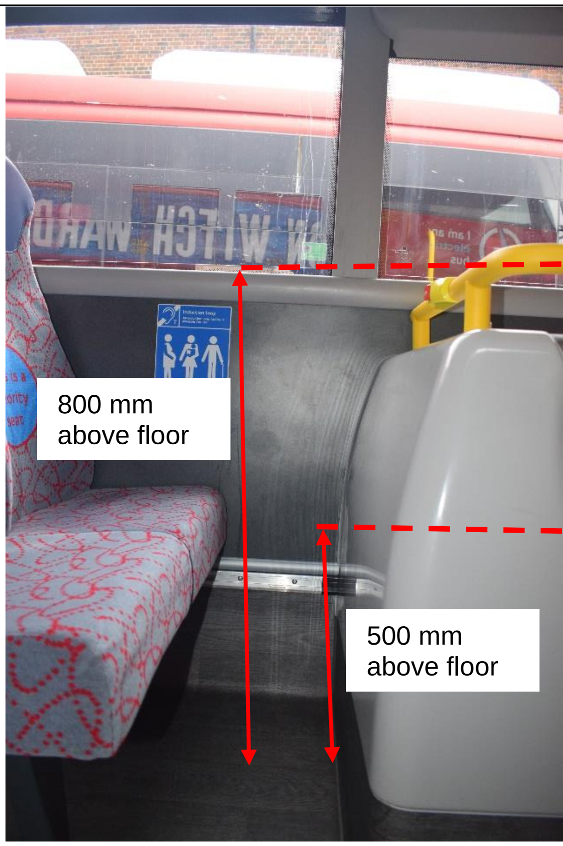


Figure 34_24: Assessment of restraint provided by wheel box / luggage area

Scoring of seats:

Window seat

- D_{LatRes} ≥ 100 mm, therefore C_{Lat} = 0
- H_{feet} ≥ 800, therefore score = C_{Lat} = 0

Aisle seat

- D_{LatRes} = 30 mm, therefore C_{Lat} = (100 - 30)/100 = 0.7
- H_{feet} ≥ 800, therefore score = C_{Lat} = 0.7

Note: Seat is 'high occupancy/ PRM seat', so weighting applied is 8 (see Section 9.2.4).

9.2.3 General/other hazards

For each seat position, an assessment of the injury potential and risk of impact shall be made for the hazards (and groups of hazards) identified and a score of up to 1.0 given, in accordance with the following criteria (see Figure for definition of impact zones, head inner, head outer and body):

Injury potential:

- Head impact categorise as high
- Other body region impact categorise as low

Risk of impact:

- Hazard located in head impact inner zone categorise as high
    i. Note: if any part of hazard in zone score it as high
- Hazard located in head impact outer zone categorise as low
- Hazard located in body impact zone categorise as low

Score:

- Injury potential low, risk of impact low; score 0.3
- Injury potential high, risk of impact low and vice versa; score 0.6
- Injury potential high, risk of impact high; score 1.0

9.2.4 Weighting of hazards for seated passengers

The following weightings shall be applied to assessment category scores not associated with 'high occupancy / PRM' seats:

a) Handrails – multiply by 5
b) Restraint – multiply by 4
c) General / other hazards – multiply by 4

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

10 Assessment template

Each of the scores shall be entered into an assessment template made up of the tables shown in Appendix A - Assessment Template.

The Total Actual Score is the sum of the weighted scores 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.

11 Normalising the score

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.

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.

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 score is 120 points for a single deck vehicle and 132 points for a double deck vehicle.

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.

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.

12 Test report

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

a) Confirmation of protocol compliance
b) Reference information.

To confirm protocol compliance, the Test Service shall include in the report the completed Occupant Friendly Interiors Assessment worksheet

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).

Appendix A - Assessment Template

Note: Values entered in the tables below are fictional values for illustrative purposes only.

Section 1. Standing Passengers

Handrails - vertical	Length factor	Box A's (Max 0.1 each)						Box B's (Max 0.2 each)		Total	Weighted
		Score	Score	Score	Score	Score	Score	Score	Score		20.46
Handrail 1	1.00	0.10								0.10	5
Handrail 2	1.00	0.10	0.10					0.20		0.40	
Handrail 3	1.23	0.10	0.10					0.20		0.49	
Handrail 4	1.00	0.10								0.10	
Handrail 5	1.00	0.10	0.10	0.10				0.20		0.50	
Handrail 6	1.00	0.10	0.10	0.10	0.10			0.20		0.60	
Handrail 7	1.00	0.10	0.10	0.10				0.20		0.50	
Handrail 8	0.00									0.00	
Handrail 9	1.00	0.10	0.10					0.20		0.40	
Handrail 10	1.00	0.10	0.10					0.20		0.40	
Handrail 11	1.00	0.10						0.20		0.30	
Handrail 12	1.00	0.10						0.20		0.30	
Handrail 13										0.00	
Handrail 14										0.00	
Handrail 15										0.00	
Handrail 16										0.00	
Handrail 17										0.00	
Handrails 18 (For more add rows)										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

Handrails - horizontal	Height factor	Length factor	Total	20.80
Handrail 1	1.00	4.16	4.16	5
Handrail 2			0.00	
Handrail 3			0.00	
Handrail 4			0.00	
Handrail 5			0.00	
Handrail 6 (For more add rows)			0.00	

Height factor - red zone (IF rail ≥ 1340 mm from floor AND rail ≤ 1755 mm) = 1
Height factor - upper grey zone (IF rail between 1755 mm and 1870 mm from floor) = (1870 - 'height of rail from floor in mm') /115
Height factor - lower grey zone (IF rail between 1160 mm and 1340 mm from floor) = ('height of rail from floor in mm' - 1160)/180
Height factor - safe zones (IF rail ≥ 1870 mm from floor OR ≤ 1160 mm from floor) = 0
Length Factor = (Length in mm)/500

Restraint	Average height factor	Length factor	Total	3.84
Restraint 1	0.48	2.00	0.96	4
Restraint 2			0.00	
Restraint 3			0.00	
Restraint 4			0.00	
Restraint 5			0.00	
Restraint 6 (For more add rows)			0.00	

Average height factor - red zone (IF partition average height ≤ 750 mm from floor) = 1
Average height factor - grey zone (IF partition average height between 750 mm and 1060 mm from floor) = (1060 - 'partition avearge height from floor in mm')/310
Average height factor - safe zone (IF partition average height ≥ 1060 mm from floor) = 0
Length Factor = (Length in mm)/500

General/other	Score (0 or 1)	Total	3.00
Hazard 1	1.00	1.00	3
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		0.00	
Hazard 9		0.00	
Hazard 10 (For more add rows)		0.00	

Section 2. Seated Passengers (Lower Deck)

Handrails -vertical	Lateral position factor	PRM/high occupancy seat? (Y/N)	Number of additional identical seats	Total	27.14
Handrail 1	1.00	Y	0	2.00	5
Handrail 2	0.00	Y	1	0.00	
Handrail 3	1.00	Y	0	2.00	
Handrail 4	0.71	N	1	1.43	
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 (For more add rows)				0.00	

Lateral position factor - red zone (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (DLatHR) ≥ ('half seat width in mm' (w/2) - 90) = 1
Lateral position factor - safe zone (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (DLatHR) ≤ 100) = 0
Lateral position factor - grey Zone (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (DLatHR) > 100 AND < ('half seat width in mm' (w/2) - 90) = (DLatHR – 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

Restraint	Exposed seat? (Y/N)	Bay seat? (Y/N)	Lateral coverage factor (CLat)	Height factor	PRM/high occupancy seat? (Y/N)	Number of additional identical seats	Total	18.00
Restraint 1	Y	N			Y		2.00	4
Restraint 2	Y	N			N		1.00	
Restraint 3	N	Y			N		0.75	
Restraint 4	N	Y			N		0.75	
Restraint 5							0.00	
Restraint 6 (For more add rows)							0.00	

Score 1 if seat facing directly into aisle or other empty space, i.e. exposed seat
Score 0.75 for set of 4 bay seats
If some restraint present, score lateral coverage and height factors as follows:
Lateral coverage factor - red zone (IF lateral coverage from seat centreline (DLatRes) ≤ 0 mm, CLat = 1
Lateral coverage factor - safe zone (IF lateral coverage from seat centreline (DLatRes) ≥ 100 mm, CLat = 0
Lateral coverage factor - safe zone (IF lateral coverage from seat centreline (DLatRes) > 0 and < 100 mm, CLat = (100 - DLatRes)/100
Height factor - red zone (IF average height of restraint above floor in mm (Hfeet) ≤ 700 mm) = 1
Height factor - safe zone (IF average height of restraint above floor in mm (Hfeet) ≥ 800 mm) = 0
Height factor - grey zone (IF average height of restraint above floor in mm (Hfeet) > 700 mm and < 800 mm) = (800 - Hfeet)/100
Final score = CLat + Height factor   Note final score capped at 1, i.e. if > 1 = 1

General/other	Score (0.3, 0.6 or 1)	PRM seat? (Y/N)	Number of additional identical seats		Total	0.00
Hazard 1	0.00				0.00	4
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 (For more add rows)					0.00	

Injury potential: Head impact high; Other body regions low
Risk of impact:
- Hazard located in head impact inner zone categorise as high
- Hazard located in head impact outer zone categorise as low
- Hazard located in body impact zone categorise as low

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 -vertical	Lateral position factor	Number of additional identical seats			Total	3.00
Handrail 1	0.00	7			0.00	5
Handrail 2	0.60	0			0.60	
Handrail 3					0.00	
Handrail 4					0.00	
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 (For more add rows)					0.00	

Lateral position factor - red zone (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (DLatHR) ≥ ('half seat width in mm' (w/2) - 90) = 1
Lateral position factor - safe zone (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (DLatHR) ≤ 100) = 0
Lateral position factor - grey Zone (IF distance edge of rail nearest to seat centreline to outer edge of seat in mm (DLatHR) > 100 AND < ('half seat width in mm' (w/2) - 90) = (DLatHR – 100)/(w/2 – 190)

Restraint	Exposed seat? (Y/N)	Bay seat? (Y/N)	Lateral coverage factor (CLat)	Height factor	Number of additional identical seats		Total	4.00
Restraint 1	Y	N			0		1.00	4
Restraint 2							0.00	
Restraint 3							0.00	
Restraint 4							0.00	
Restraint 5							0.00	
Restraint 6 (For more add rows)							0.00	

Score 1 if seat facing directly into aisle or other empty space, i.e. exposed seat
Score 0.75 for set of 4 bay seats
If some restraint present, score lateral coverage and height factors as follows:
Lateral coverage factor - red zone (IF lateral coverage from seat centreline (DLatRes) ≤ 0 mm, CLat = 1
Lateral coverage factor - safe zone (IF lateral coverage from seat centreline (DLatRes) ≥ 100 mm, CLat = 0
Lateral coverage factor - safe zone (IF lateral coverage from seat centreline (DLatRes) > 0 and < 100 mm, CLat = (100 - DLatRes)/100
Height factor - red zone (IF average height of restraint above floor in mm (Hfeet) ≤ 700 mm) = 1
Height factor - safe zone (IF average height of restraint above floor in mm (Hfeet) ≥ 800 mm) = 0
Height factor - grey zone (IF average height of restraint above floor in mm (Hfeet) > 700 mm and < 800 mm) = (800 - Hfeet)/100
Final score = CLat + Height factor   Note final score capped at 1, i.e. if > 1 = 1

General/other	Score (0.3, 0.6 or 1)	Number of additional identical seats			Total	0.00
Hazard 1	0.00	0			0.00	4
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 (For more add rows)					0.00	

Injury potential: Head impact high; Other body regions low
Risk of impact:
- Hazard located in head impact inner zone categorise as high
- Hazard located in head impact outer zone categorise as low
- Hazard located in body impact zone categorise as low

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, Attachment 34. These guidance notes are aimed at bus operators and OEMs as a practical guide for implementation of the Bus Safety Standard.

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

Any modifications to the bus interior which have been either stipulated or conducted by the bus operator must be included in any assessment following the procedure defined in Attachment 35: Occupant Friendly Interiors Assessment Protocol, such that the assessment is completed on a bus in an “in service” condition.

2 Approach

2.1 Overall

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 . 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 OEMs 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.

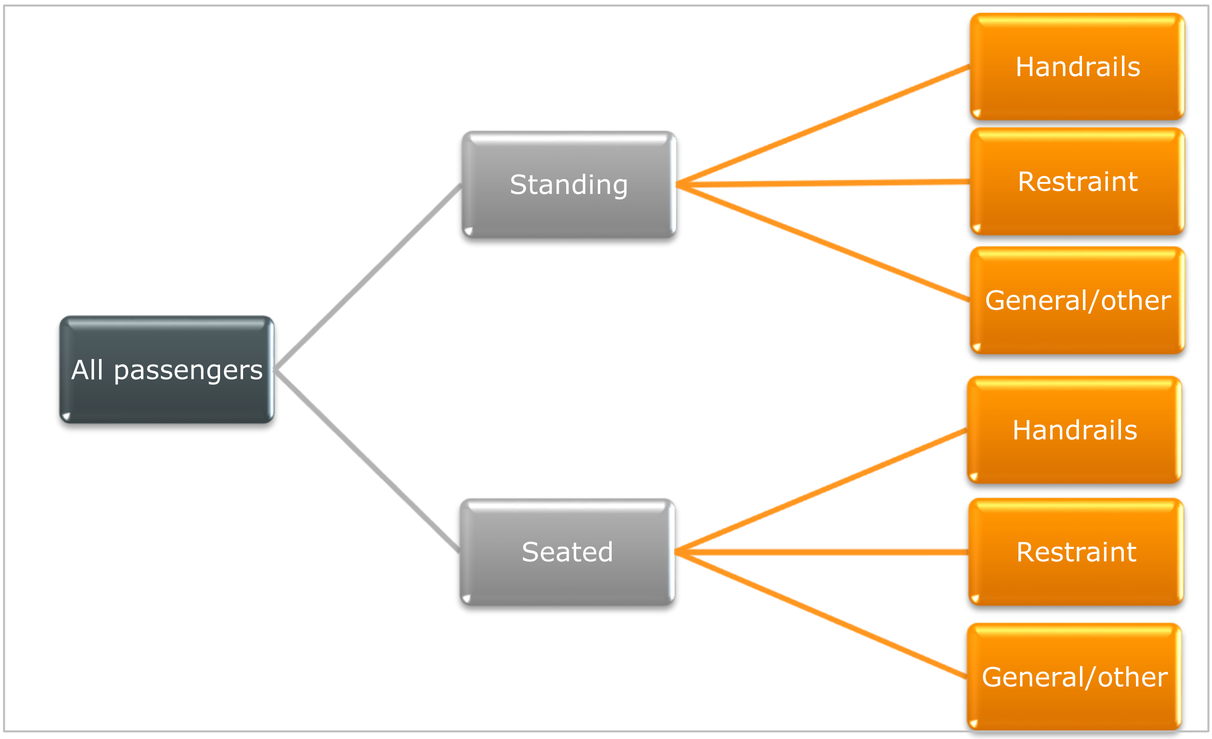


Figure 35_1: Visual inspection hazard categories

The purpose of each of the inspection categories is described below:

Standing: handrails

- To encourage vertical handrails to be positioned where they are less likely to be hit by a falling passengers
- To discourage the placement of horizontal handrails at a height, level with a passenger's head, where they are likely to be impacted

Standing: restraint:

- To encourage partitions that a passenger may stand behind to be of sufficient height to restrain the motion of a passenger in the event of harsh braking and / or a collision, i.e. they are not thrown over it

Standing general:

- To encourage the removal of features, such as sharp edges / corners and protrusions, that a standing passenger may hit when they fall, with focus on head impact.

Seated: handrails

- To encourage vertical handrails (mainly seat back to ceiling) to be positioned more inboard to reduce the risk of head impact for seated passenger

Seated restraint:

- To encourage structures in front of seated passengers (partitions or seatbacks) to have sufficient height and width to constrain passenger motion during harsh braking or a collision type event, i.e. they are not thrown over or around side of structure.

Seated general:

To encourage the removal of features, such as sharp edges / corners and protrusions, that a seated passenger may hit mainly when they are thrown forward during harsh braking or a collision type event.

2.2 Procedure

The procedure 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 below in Section 2.3.
- Weight the score for each potential hazard identified in each of the six categories and sum them to give overall point scores for the lower deck and, if applicable, the upper deck.
  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.

2.3 Example: Standing occupants - Horizontal handrails

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 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 below.

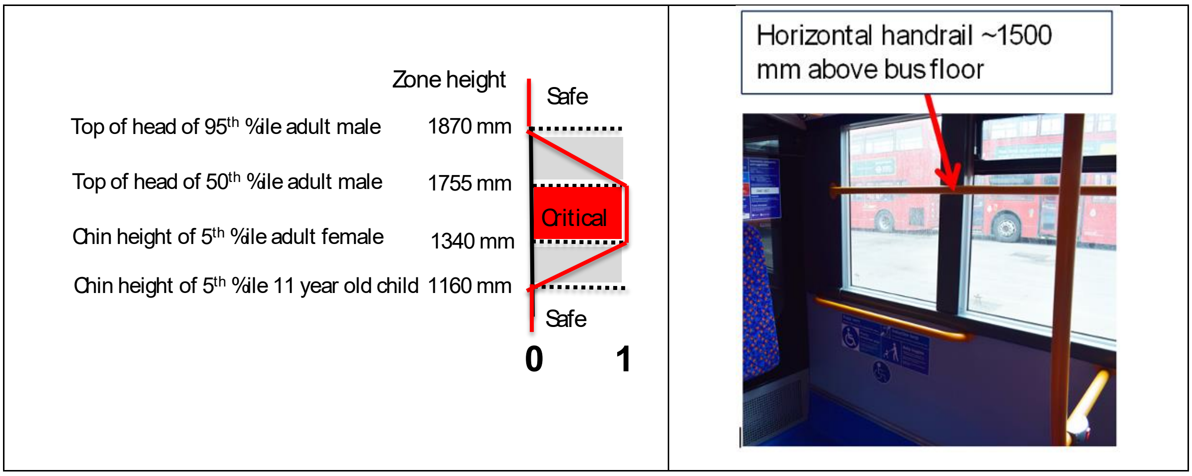


Figure 35_2: Illustration of Handrail safe zones

The red zone is positioned between 1340 mm (height of chin of 5th percentile female) and 1755 mm (height of top of head of 50th percentile male). 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 grey zones are positioned above and below the red zone using a sliding scale as the proportion of the population reduces. Hence, a score linearly reducing from 1 to 0 per unit of 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 1340 mm (height of chin of 5th percentile female) and 1160 mm (height of chin of 5th 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 1160 mm (bottom 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.

The unit length chosen was 500 mm on the basis that this is approximately the space taken up by one passenger standing, or leaning against the side of the bus.

> *Note: It can be seen that if an OEM 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 OEMs 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.

For full understanding of this Attachment it should be read in conjunction with the Attachment 37: Bus Impact Test Standard Guidance Notes and New Bus Specification, Section 4.6.3.

2 Scope

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

3 Purpose

The purpose of 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.

5 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 Service Limited New Bus Specification Section 4.6.3
- London Bus Service Limited New Bus Specification – Attachment 37: Bus Impact Test Standard Guidance Notes

- Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- 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.

6 Definitions

For the purpose of this protocol:

- **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.
- **Adult headform test area -** is an area on the outer surfaces of the front structure. The area is bounded:
    a) 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);
    b) 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
    c) 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.
- **A-pillar -** means the foremost and outermost roof support extending from the chassis to the roof of the vehicle.
- **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.
- **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.

- **Child headform test area -** is an area on the outer surfaces of the front structure. The area is bounded:
  a) 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);
  b) 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
  c) 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.
- **Driver mass -** means the nominal mass of a driver that shall be [68] kg.
- **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.
- **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:

$$HIC_{15} = \left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\,dt\right]^{2.5} (t_2 - t_1)$$

  Where:

  “a” is the resultant acceleration measured in units of gravity “g” (1 g = 9.81 m/s²);

  “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).
- **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.
- **Measuring point -** The measuring point may also be referred to as "test point" or "impact point".

  In all cases, the result of the test shall be attributed to this point, independent of where first contact occurs.

  "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 36_1). It will not be coincident with the centre of the headform for contacts with an inclined surface.

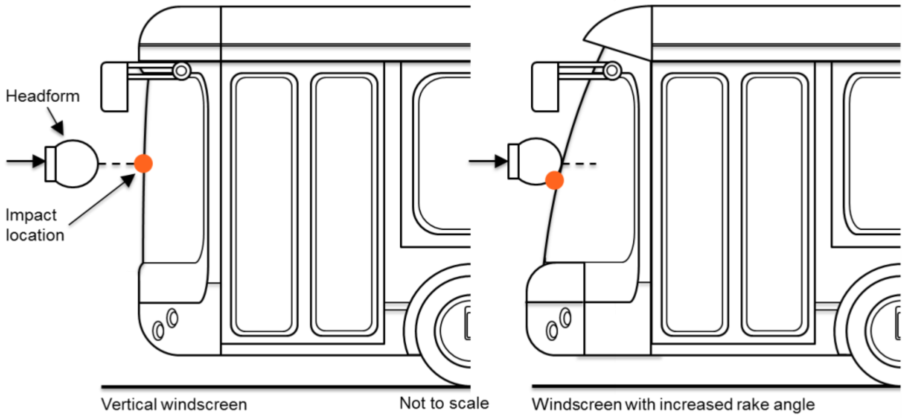


Figure 36_1: Measuring point in the vertical longitudinal plane through the centre of the headform impactor

- **Maximum ride attitude -** means the vehicle positioned on a flat horizontal surface with its mass in running order, with the tyres inflated to OEM recommended pressures, the front wheels in the straight-ahead position. The suspension shall be set in normal running condition as specified by the OEM for a speed of 40 km/h.
- **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 OEM. 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 OEM for a speed of 40 km/h.
- **Nominal ride attitude -** means the vehicle positioned at the mid-point of the maximum and minimum ride attitudes.
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **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 OEM 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.
- **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 36_2).

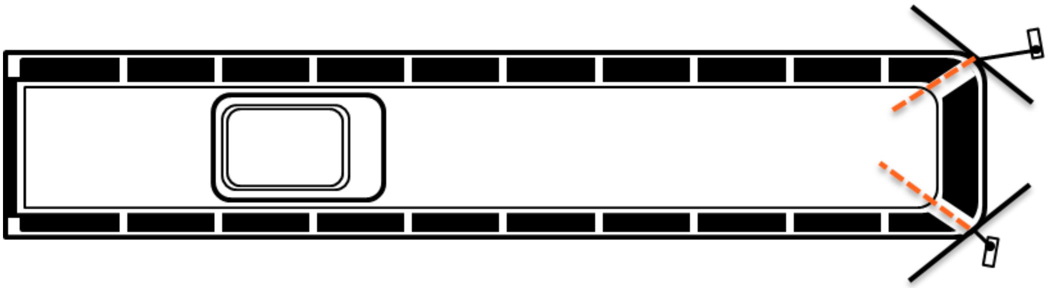


Figure 36_2a: Side reference line – plan view

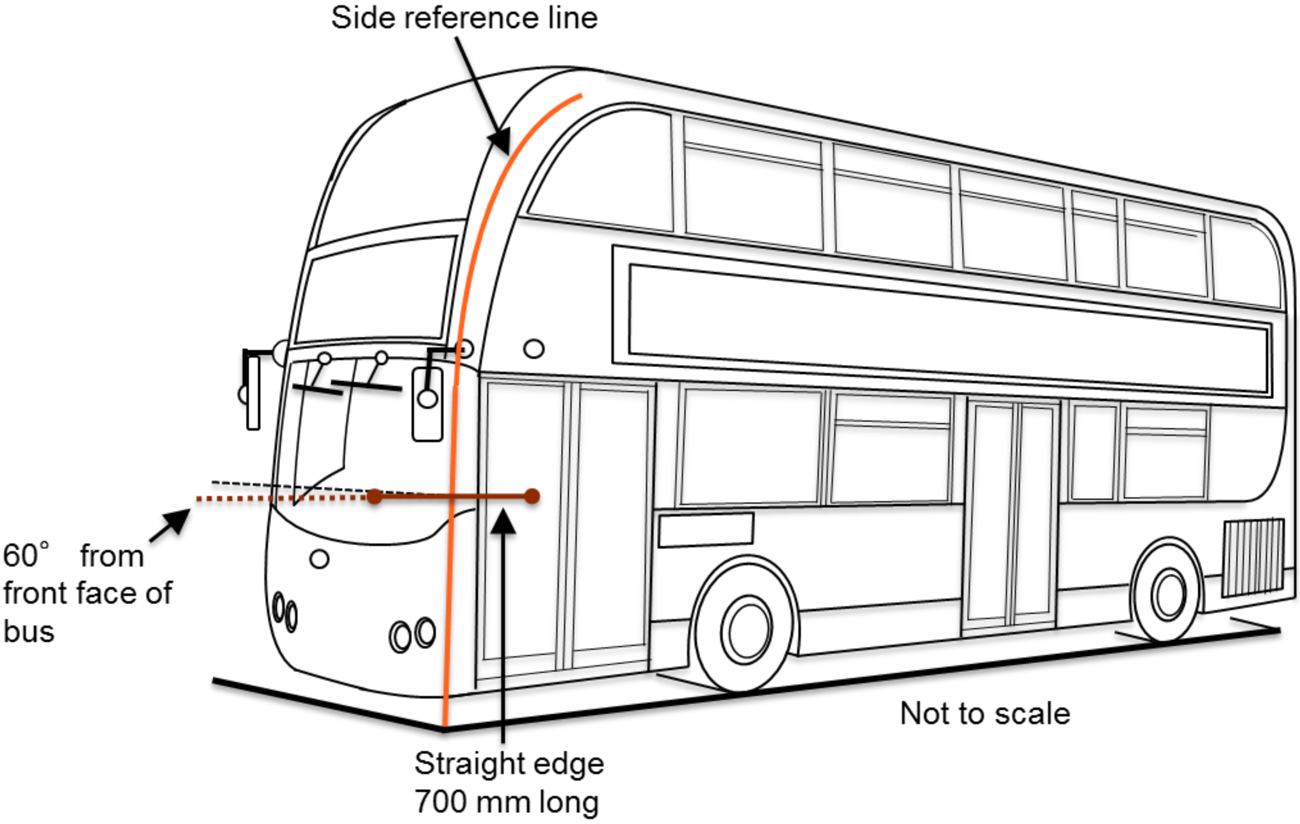


Figure 36_2b: Side reference line – front/side view

- **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 36_3).

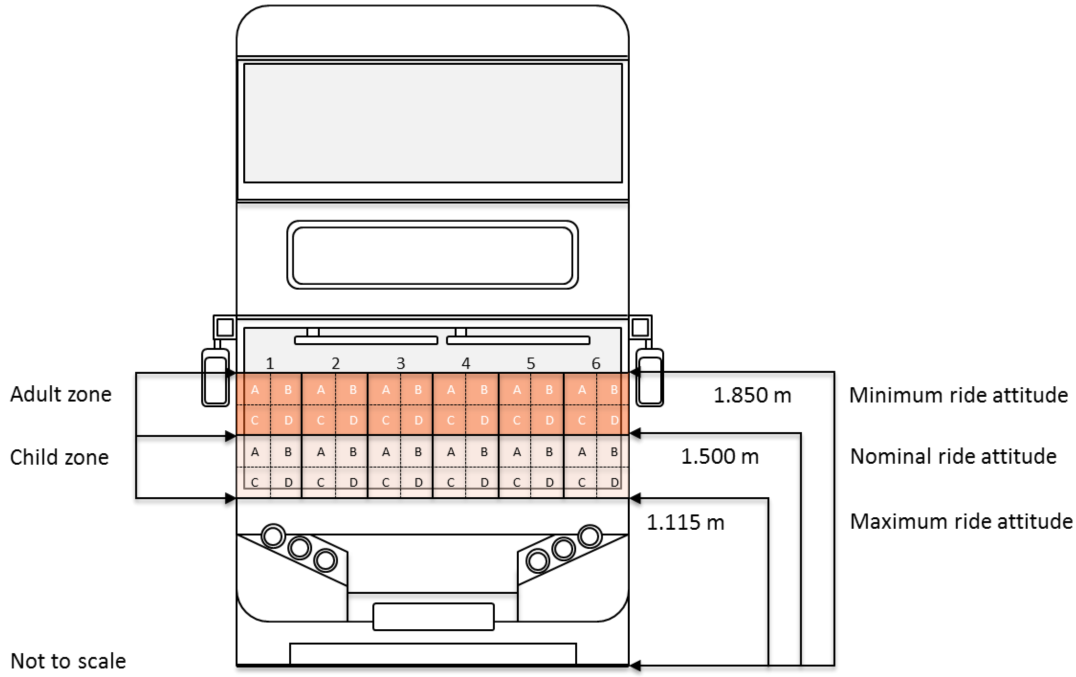


Figure 36_3: Labelling of test zones

- **Unladen vehicle mass -** means the nominal mass of a complete vehicle as determined by the following criteria:

  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.

  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 OEM.

- **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),

  in so far as they may be considered to have a negative effect on the results of the impact tests prescribed in this Regulation.

- **Windscreen -** means the frontal glazing of the vehicle.

- **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 36_4. 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).

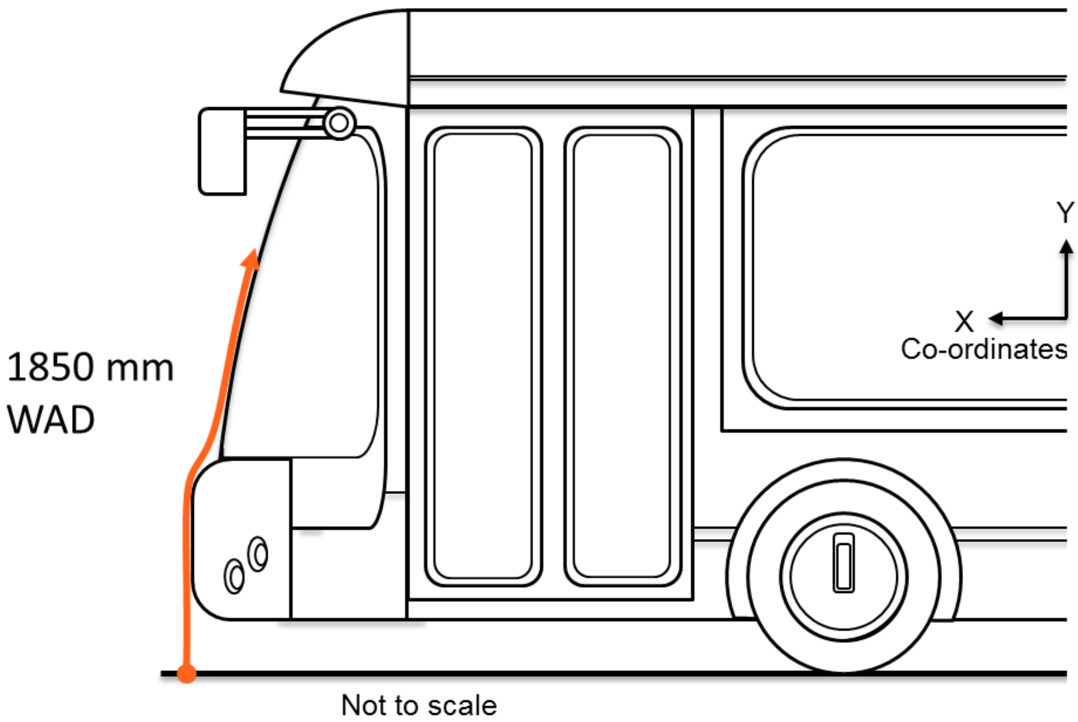


Figure 36_4: Wrap around distance measurement

7 Specifications

7.1 Minimum requirements

When tested in accordance with the test procedures in Section 8, all recorded HIC_{15} values shall not exceed [1,350].

In addition, the Bus VRU Impact Test Performance Score (BITS) (as defined in London Bus Services limited New Bus Specification, Section 4.6.3) must be, at least [25%].

7.2 OEM selected points

The OEM 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 OEM 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.

Example:

a) First test results in HIC = 1250

b) OEM elected retest results in HIC = 700

c) Mean HIC = 975

7.2.1 Bus VRU impact test performance scores (BITS)

The bus VRU impact performance score (BITS) shall be calculated for the bus front end using the following approach:

HIC_{15} 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

The total points score shall be divided by 24 to give a value between 0% and 100%.

8 Test procedure

8.1 When performing measurements:

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.

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.

8.2 Impact tests

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.

Tests shall be made to the bus front end within the boundaries, as defined in Section 6 of this protocol.

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 6 of this protocol), at positions judged to be the most likely to cause injury.

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 6 of this protocol), at positions judged to be the most likely to cause injury.

Tests shall be to different types of structure, where these vary throughout the area to be assessed.

Any parts damaged by an impact must be replaced before carrying out the next test.

The selected measuring points for the child and adult headform impactors shall be a minimum of 165mm apart.

These minimum distances are to be set with a flexible tape held tautly along the outer surface of the vehicle.

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.

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.

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.

The direction of impact shall be perpendicular to the lateral vertical plane of the vehicle to be tested.

9 Test Report

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

9.1 Reference information

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

b) Make (trade name of OEM);

c) Model/Type;

d) Commercial name(s) (if available);

e) Means of identification of type, if marked on the vehicle;

f) Location of that marking;

g) Variant (if applicable);

h) Category of vehicle;

i) Name and address of OEM;

j) Name(s) and address(es) of assembly plant(s);

k) Name and address of the OEM’s representative (if any);

l) General construction characteristics of the vehicle;

m) Photographs and/or drawings of a representative vehicle;

n) Bodywork;

o) Type of bodywork;

p) Materials used and methods of construction;

q) Running order information;

r) Pedestrian protection;

s) 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.

9.2 Confirmation of protocol compliance

Predominantly this item will relate to providing a description of testing completed.

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.

Photographs should identify the test site before and after each test.

Records should be kept of the components changed between tests due to damage.

9.3 Performance data

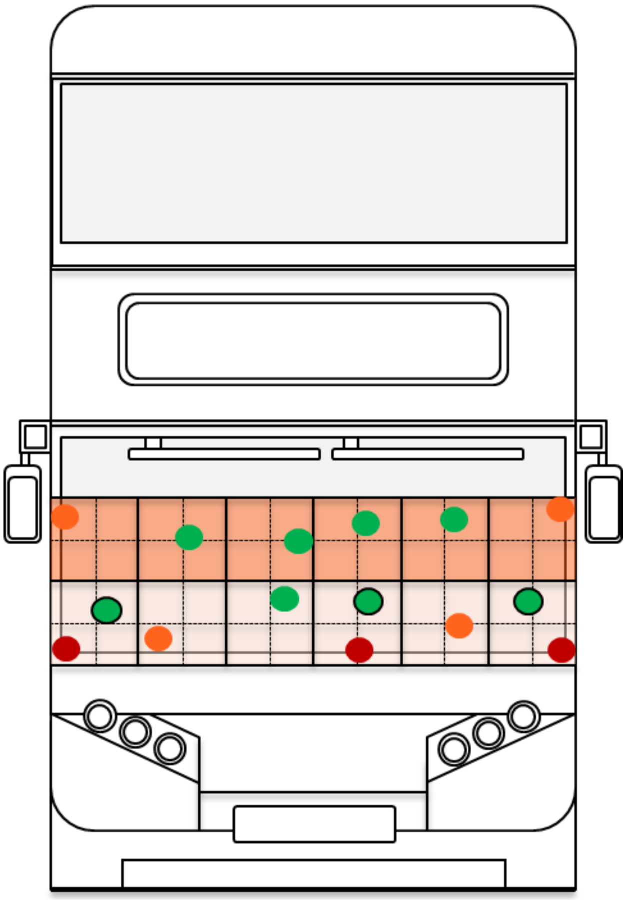
Every test shall be reported along with the corresponding HIC_{15} value.

Furthermore, the BITS score associated with each result shall be recorded as well as the overall BITS score for the bus (Table 36_1 provides a blank example of a results table).

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 36_5.

Table 36_1: 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 (OEM elected retest)			
A4			
A5			
A6			
C1			
C2			
C3			
C4			
C5			
C6			
Total			



Not to scale

Figure 36_5 Example image showing test results from Bus VRU Impact Test Standard (BITS)

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.

Child and adult headform impactors

The child headform impactor (Figure 36_6) 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.

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 36_6) 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.

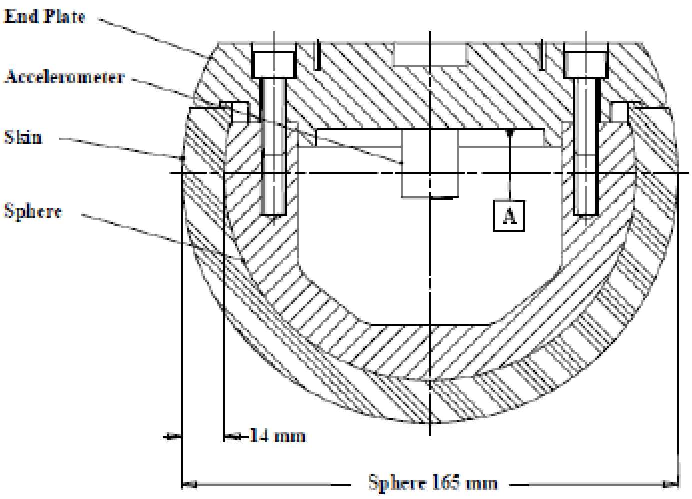


Figure 36_6: Child headform impactor

Adult headform impactor

The adult headform impactor (Figure 36_7) 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 36_7. 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.

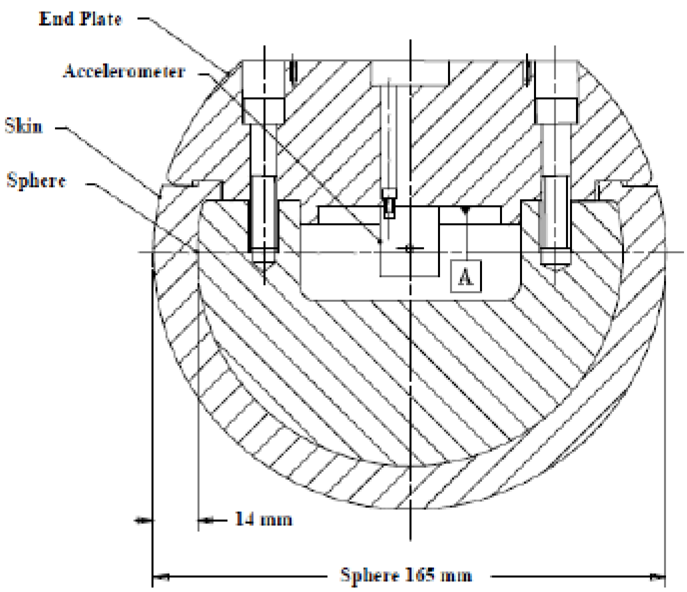


Figure 36_7: Adult headform impactor

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 36_7) 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.

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.

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.

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.

Test procedure

The headform impactor shall be suspended from a drop rig as shown in Figure 36_8.

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.

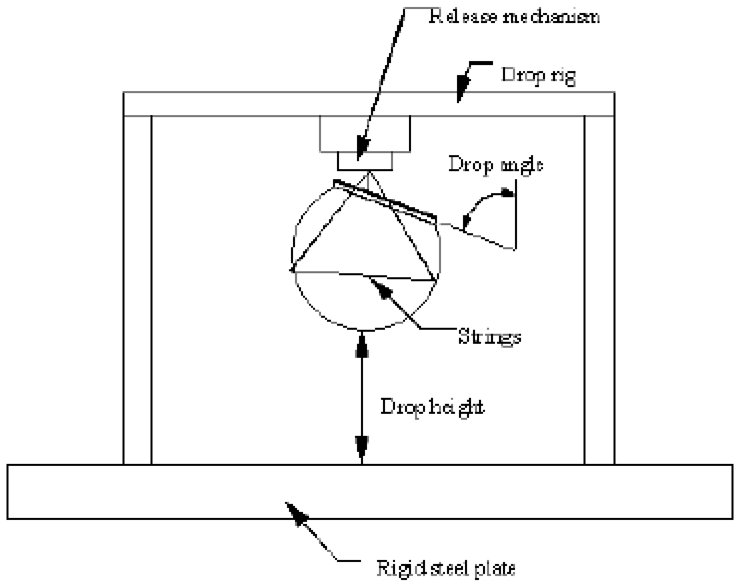


Figure 36_8: Test set-up for dynamic headform impactor certification test

Annex 3 General test conditions

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.

Impact test site

The test site shall consist of a flat, smooth and hard surface with a slope not exceeding 1 per cent.

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 OEM 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.

Annex 4 Common test specifications

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.

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.

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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

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 minimum boundary height of 1115 mm relating to the height of a 5th percentile 6 year old. Figure 37_1 shows the marking of the two test zones.

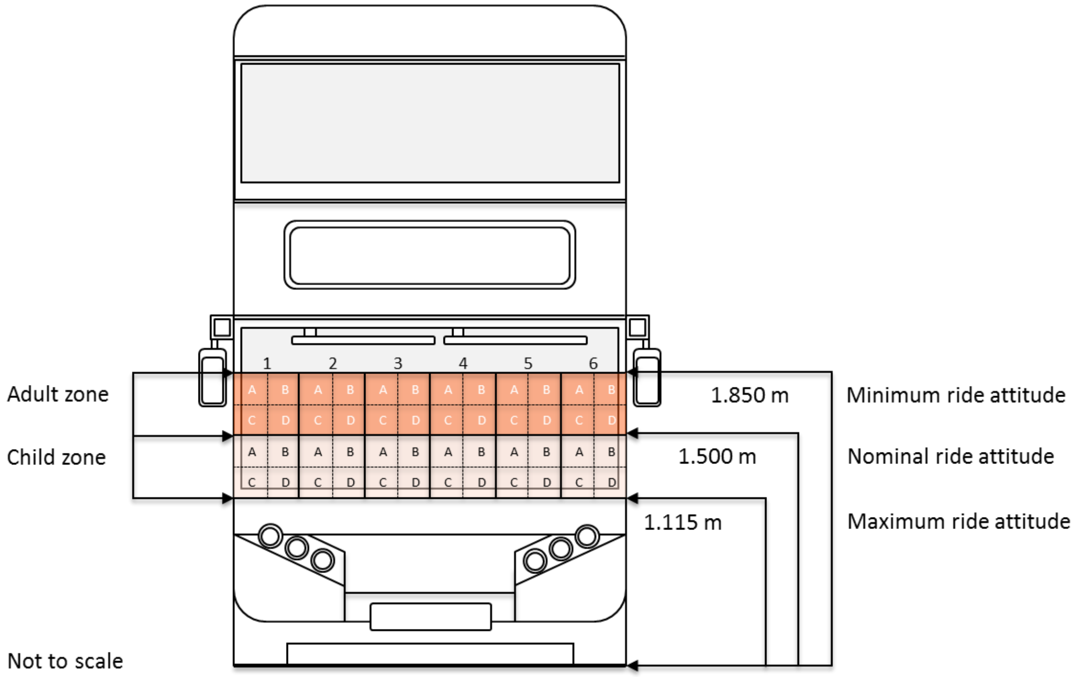


Figure 37_1: Marking out of test zones

Both the child and adult test zones are divided horizontally into six areas and labelled A1,

A2……C5, C6 as shown in Figure 37_2. Each area is then sub-divided into quarters.

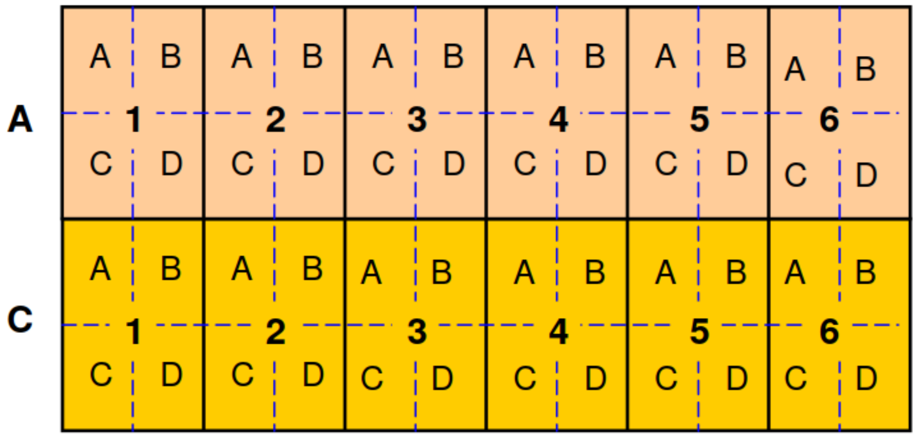


Figure 37_2: Labelling of test zones

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 OEM 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 [6.94 ± 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 1350.

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 OEM 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:

- **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.
- **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.

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 OEMs. 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)

1 Introduction

Bus fronts have been identified as one of the key injury-causing contact areas of the vehicle in collisions between buses and Vulnerable Road Users (VRU). Therefore, all bus front ends are required to have a global geometric design that both improves protection for VRUs during the primary impact of a collision and reduce the risks of VRUs being run over subsequently.

As such, all [new] buses shall have a front end design that complies with the Vulnerable Road User (VRU) crashworthiness minimum bus front end geometry requirements for both vertical rake and wraparound windscreen curvature.

This document sets out the guidance notes related to the assessment of the global bus front end geometry and specifically, with respect to the minimum requirements contained in Section 4.6.1 of the Bus Vehicle Specification. These guidance notes are aimed at bus operators and OEMs as a practical guide for implementation of the requirements specified by the Bus Vehicle Specification.

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

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.6.1

2 Selection of buses/systems

From 2021 until 2024, 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 wraparound windscreen curvature. Therefore, selection can be any bus model or variant that is compliant with these specifications.

2.1 Intention of the requirements

The minimum bus front end geometry requirements intend to encourage bus front end designs that implement a wraparound windscreen design (as opposed to a box-fronted front end, where the A-pillars are located at the very front edges of the windscreen), as well as a positive vertical rake angle (i.e. the vertical angle).

It was found in research conducted on behalf of TfL that impacts against the more compliant wraparound windscreen material resulted in a considerable reduction in VRU injury risk, relative to impacts against the much stiffer A-pillar structures. This was coupled with a significant proportion of VRUs impacting the A-pillar region during collisions, particularly on the passenger side. Furthermore, run over risks were found to increase during collisions with bus front end designs that included a section with a negative vertical rake, due to the VRU essentially being pushed under the bus by these sections.

Of the bus model variants investigated, the wraparound windscreens with a radius of curvature of ~150 mm at the edge of the windscreen were found to be safer than traditional windscreen designs (where A-pillars are located at the front of the bus). As the structural stiffness of these wraparound sections are determined by the radius of curvature, a radius of curvature of less than 150 mm at the edges of the wraparound windscreen is considered undesirable, as this stiffens the structure and causes greater harm to the VRU if impacted. Similarly, negative vertical rake angles are considered undesirable, due to the increased run over risks that they present to VRUs.

These requirements therefore seek to promote the deployment of [new] buses into the TfL network with wraparound windscreen designs and positive vertical rakes, as these are intrinsically safer than traditional windscreen designs. To control for the stiffness of wraparound windscreens, these requirements ensure a minimum permissible radius of curvature of 150 mm between 0.75-2.0 m. To ensure that no bus results in a design that pushed VRUs under the bus, these requirements ensure minimum vertical rake angles of at least 1° between 0.75-1.2 m and 4° between 1.2-2.0 m.

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 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 protrusions 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 size of the areas presenting that angle then the more effective the measure will be.

2.3 Compliance checks

It is expected that compliant vehicles may be selected from the current available TfL bus fleet. On consultation with OEMs, it was agreed that all current bus model variants with a wraparound windscreen design should have a radius of curvature and vertical rake that comply with these requirements.

Bus operators should ask to see documentary evidence of compliance with these 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.

3 Training

3.1 For Test Services

The nature of verifying compliance with the requirements will depend on whether it is demonstrated through CAD or physical testing.

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 or radii to the surface where the appropriate angles of rake or radius of curvature can be viewed. It should be possible for the inspection to identify the worst-case angle throughout the section.

For physical inspections, the vertical rake can be measured with an inclinometer. Here it should be noted that the footprint for these measurements should be 236 ± 5 mm x 236 ± 5 mm. This is to ensure that only the global geometric features of the bus are considered by these requirements and that smaller features are considered to not have a significant effect on the outcomes of VRU collisions. 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 radius of curvature of the wraparound windscreen may be physically tested using a radius gauge. This gauge may be used as a go/no-go gauge, by setting it to 150 mm and observing whether any aspect of the tested wraparound windscreen edge has a radius of curvature smaller than the gauge.

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 VRU 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.

As these minimum requirements do not take bus front end geometries beyond that of existing designs, it is considered that these potential issues are not perceived to be critical factors above that already accepted as common practice within the current fleet. However, operators should be mindful of the potential and will be expected to log and feedback any potential issues, if substantiated reports become available.

Attachment 39: Bus Front End Geometry Test and Assessment Protocol

1 Introduction

This document presents a procedure, hereon referred to as the Front End Geometry Test (FEGT), for objectively measuring the global geometry of a bus front end for the purposes of requiring a design that optimises the kinematics of collisions between bus front ends and vulnerable road users to mitigate the risks of injury and run-over events.

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.6.2 and Attachment 40 - Bus Front End Design – Enhanced Geometric Requirements Guidance Notes

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 by the Consolidated Resolution on the Construction of Vehicles (R.E.3) as M_3[1]; Class I.

3 Purpose

The purpose of this test and assessment protocol is to bring about an improvement in the global geometry of the front end of buses which have been identified as a principle cause of injuries when involved in collisions with vulnerable road users (pedestrians, cyclists and motorcyclists).

The vehicles tested under the Front End Geometry Test (FEGT) 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.

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

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

edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- London Bus Service Limited New Bus Specification Section 4.6.2
- London Bus Service Limited New Bus Specification – Attachment 40: Bus Front End Design – Enhanced Geometric Requirements Guidance Notes
- Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- Regulation (EU) 2018/858 of the European Parliament and of the Council of 30th May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC.

5 Definitions

For the purposes of this protocol:

- **A-pillar** - means the foremost and outermost roof support extending from the chassis to the roof of the vehicle.
- **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.
- **Bus front end geometry envelope** - means the range of horizontal angles and vertical rake angles for each test position, outside of which the bus front end would be considered to be non-compliant.
- **Driver mass** - means the nominal mass of a driver that shall be [68] kg.
- **Front End Geometry Performance Evaluation Tool** - means the spreadsheet tool used to assess the safety performance of the global geometric characteristics of the bus front end
- **Frontal plane** - means a plane perpendicular to the median longitudinal plane of the vehicle and touching its foremost point, disregarding the projection of devices for indirect vision and any part of the vehicle greater than 2.0 m above the ground.
- **Ground reference plane** - means a horizontal plane that passes through the lowest points of contact for all tyres of a vehicle with its mass in running order. 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.

- **Global coordinate system** - means the coordinate system located with its origin at the intersect of the longitudinal median plane of the vehicle, the frontal plane and the ground reference plane and its axes orientated such that the positive X-axis is directed forward, the positive Y-axis is directed towards the offside of the vehicle and the positive Z-axis is directed upward.
- **Horizontal angle** - means the angle measured at each test point between the frontal plane of the bus and the tangent to the bus front end structures in a plane parallel to the horizontal plane of the vehicle.
- **Inboard** - means in a direction toward the median longitudinal plane.
- **Lower test reference line** - means the geometric trace on the bus front end of a horizontal plane located at a wrap around distance of 750±10 mm above the ground reference plane.
- **Mass in running order** - means the nominal mass of a vehicle as determined by the sum of the unladen mass and driver's mass.
- **Measuring point** - means the location on the bus front end at which the horizontal angle and vertical rake angle values are measured.
- **Median longitudinal plane** - means the centreline of the subject vehicle parallel to the forward direction of travel.
- **Nearside** - means the left-hand side (i.e. passenger side) of the subject vehicle.
- **Offside** - means the right-hand side (i.e. driver side) of the subject vehicle.
- **Outboard** - means in a direction away from the median longitudinal plane.
- **Side reference line** - means the geometric trace of the most outboard 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 75°, is traversed rearwards to contact the sides of the bus front end (Figure 39_1).

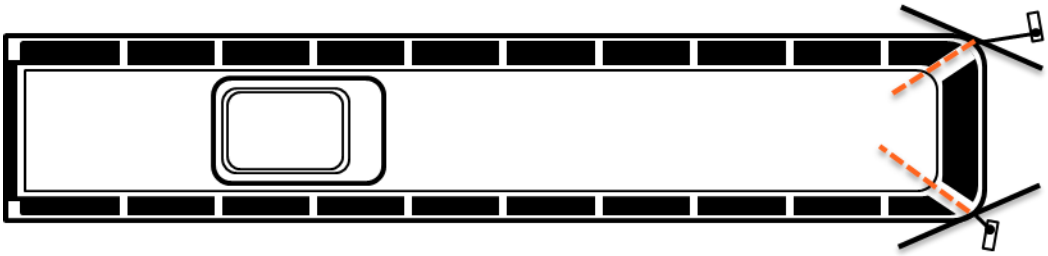


Figure 39_1a: Side reference line – plan view

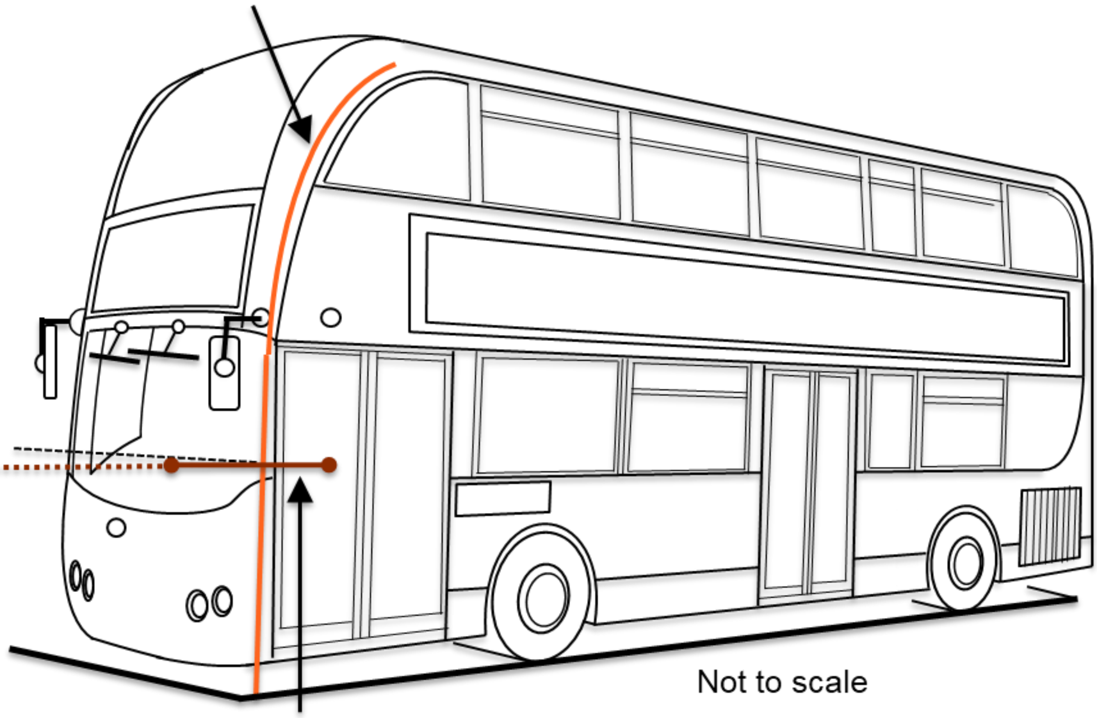


Figure 39_1b: Side reference line – front/side view

- **Subject vehicle** - means the vehicle being tested.
- **Test position** - means the position used to locate the measuring point in the Y-axis on the bus front end. Each test position shall extend between the lower and upper test reference lines. Five test positions are specified:
  - Outboard nearside test position (P1), with test points located at a horizontal wrap around distance of 150 mm inboard from the nearside side reference line.
  - Inboard nearside test position (P2), with test points located at a horizontal wrap around distance of 725 mm outboard from the median longitudinal plane and toward the nearside.
  - Central test position (P3), with test points located on the median longitudinal plane.
  - Inboard offside test position (P4), with test points located at a horizontal wrap around distance of 725 mm outboard from the median longitudinal plane and toward the offside.
  - Outboard offside test position (P5), with test points located at a horizontal wrap around distance of 150 mm inboard from the offside side reference line.
- **Test zone** - area on the bus front end structures bounded by the upper and lower test reference lines and the nearside and offside reference lines.

- **Unladen mass** - means the nominal mass of a complete vehicle as determined by the following criteria:
  - 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.
  - 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 OEMs.
- **Upper test reference line** - means the geometric trace on the bus front end of a horizontal plane located at a wrap around distance of 2000±10 mm above the ground reference plane.
- **Vertical rake angle** - means the angle measured at each test point between the frontal plane of the bus and the tangent to the bus front end structures in a plane parallel to the median longitudinal plane of the vehicle.
- **Vehicle type with regard to enhanced geometry requirements** - means a category of vehicles with front end designs which, within the test zone, do not differ in such essential respects as:
  - The global geometric dimensions,
  - The external component arrangement,

  in so far as they may be considered to have a negative effect on the results of the impact tests prescribed in this Regulation.
- **Vulnerable road user (VRU)** - means an adult or child pedestrian or an adult or child cyclist
- **Wrap around distance** - means the geometric trace described on the outer surface of the bus front end structures by a flexible tape, when it is held in the vertical or horizontal 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 origin of the measurement (see Figure 39_2).

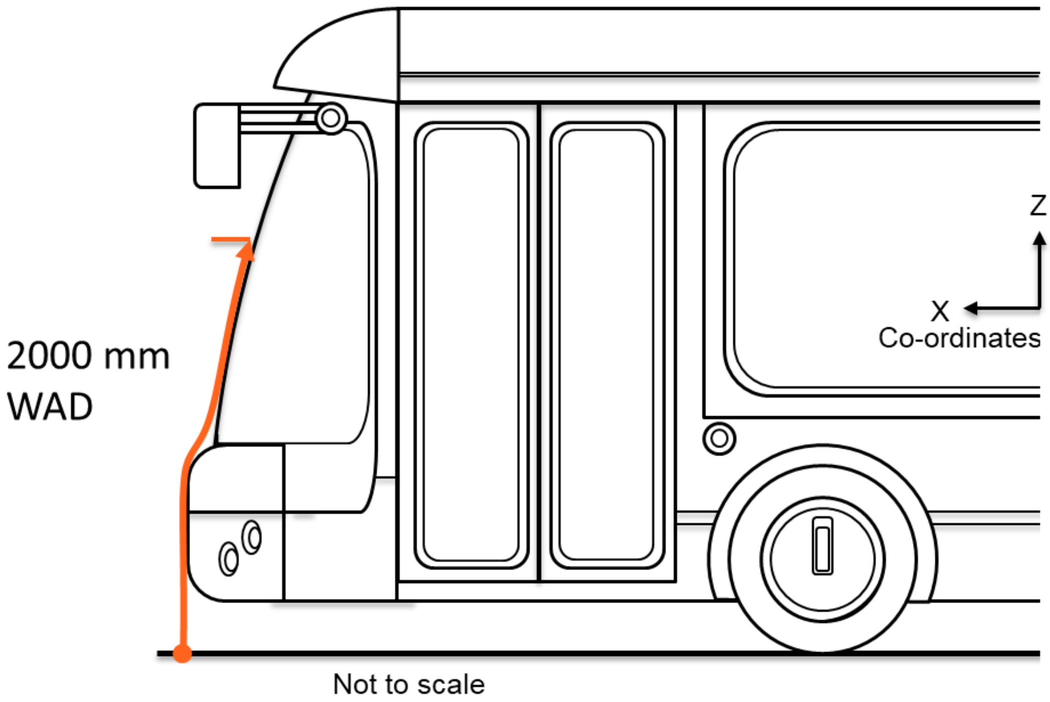


Figure 39_2: Wrap around distance measurement

6 Specifications

When tested in accordance with the test procedures in Section 7, the following minimum requirements shall be met:

a) All horizontal and vertical rake angles shall be compliant with the bus front end geometry envelope boundaries defined in Section 0.

b) A weighted bus front end geometry score (FEGS) of 0% (as defined in Section e)) shall be exceeded.

c) There shall be no more than eight safety performance criteria scores with a value of 0.

Bus front end geometry envelope boundaries

a) The bus front end geometry shall be compliant with the following boundary conditions:

b) Vertical rake angles for all measuring points at all test positions (P1-P5) shall be no less than 4° and no greater than 23°.

c) Horizontal angles for all measuring points at the outboard test positions (P1 and P5) shall be no less than 20° and no greater than 33°.

d) Horizontal angles for all measuring points at the inboard test positions (P2 and P4) shall be no less than 11° and no greater than 18°.

e) Weighted bus front end geometry score (FEGS)

The weighted FEGS shall be calculated for each subject vehicle using the following approach:

a) Safety performance scores shall be calculated for all safety performance measures (head injury risk, thoracic injury risk and run-over risk) at each impact position and each impact velocity using the Front End Geometry Performance Evaluation Tool provided.

b) The Front End Geometry Performance Evaluation Tool shall then be used to extract the FEGS for the bus front end of the subject vehicle.

c) The FEGS shall then be ranked according to the following star rating approach:

1) 0 star: FEGS ≤ 0%
2) 1 star: 0% < FEGS ≤ 10%
3) star: 10% < FEGS ≤ 20%
4) star: 20% < FEGS ≤ 30%
5) star: 30% < FEGS ≤ 40%
6) star: FEGS >40%

Vehicle types may be exempt from these requirements, should documentary evidence be provided to demonstrate to the Test Service how the geometric design of the subject vehicle bus front end reduces the risks of VRU injuries and run-overs relative to current bus designs.

A simulation based test and assessment approach shall be provided as evidence.

Although the OEMs has the responsibility to ensure such evidence provides sufficient assurance of real-world improvements in VRU injury and run-over risks, guidelines on a simulation based testing approach are provided in 0.

7 Test procedure

When performing measurements:

a) 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.

b) 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.

Vehicle set up:

a) The vehicle shall be tested with the mass in running order.

b) The side, upper and lower reference lines and the test positions shall be marked on the subject vehicle.

c) Three measuring points, with at least 500 mm wrap around distance between them, shall be marked on the vehicle for each test position.

Bus front end geometry measurements:

a) At each measuring point, the vertical rake angle and horizontal angle shall be assessed.

b) To ensure only the global geometric features of the bus front end are tested, these angles shall be assessed using a 236±5 mm x 236±5 mm rectangular plane, with its centre placed against the surface of the bus at the measuring point.

c) Assessment of weighted front end geometry scores (FEGS):

d) Input the vertical rake angle, to the nearest degree, for all measuring points at all test positions (P1-P5) to the Front End Geometry Performance Evaluation Tool.

e) Input the horizontal angle, to the nearest degree, for all measuring points at the inboard and outboard test positions (P1, P2, P4 and P5) to the Front End Geometry Performance Evaluation Tool.

Extract and report the following criteria:

a) The weighted FEGS.

b) The number of safety performance criteria scores with a value of 0.

c) The bus front end geometry envelope compliance status.

d) The star rating score.

Approaches other than the above procedure, such as CAD based methods, may be considered as equivalent by the Test Service, should documentary evidence be provided to verify that the requirements of the test procedures described in this Section have been met.

8 Test Report

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

8.1 Reference information

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

a) Make (trade name of OEMs)
b) Model/Type
c) Commercial name(s) (if available)
d) Means of identification of type, if marked on the vehicle
e) Location of that marking
f) Variant (if applicable)
g) Category of vehicle
h) Name and address of OEMs
i) Name(s) and address(es) of assembly plant(s)
j) Name and address of the OEMs's representative (if any)
k) General construction characteristics of the vehicle
l) Photographs and/or drawings of a representative vehicle
m) Bodywork
n) Type of bodywork
o) Materials used and methods of construction
p) Running order information
q) A detailed description, including photographs and/or drawings, of the vehicle with respect to the structure, the dimensions, the relevant reference lines and the exterior bodywork of the frontal part of the vehicle shall be provided

8.2 Confirmation of protocol compliance

a) Predominantly this item will relate to providing a description of testing completed.

b) The measuring points tested by the laboratories shall be indicated in the test report. The test position and height from the ground plane of each measuring point shall be noted, as well as specific descriptions of the structures at the test point.

c) Photographs should identify the measuring points before testing.

8.3 Performance data

All vertical rake and horizontal angles for each measurement point shall be reported, alongside their positions relative to the global coordinate system (Table 39_ provides a blank example template of this table).

The safety performance criteria scores for each test position, vehicle speed and injury criteria shall be reported, taking the values reported by the Front End Geometry Performance Evaluation Tool (Figure 39_3).

The weighted FEGS, the number of safety performance criteria scores with as value of 0, the bus front end geometry envelope compliance status and the star rating shall be reported, taking these values reported by the Front End Geometry Performance Evaluation Tool (Figure 39_3).

Table 39_1: Example table for reporting of measurement point results

Test Position	Measurement Point Y Position	Measurement Point Z Position	Vertical Rake Angle	Horizontal Angle
P1-1	WWW mm	XXX mm	YY°	ZZ°
P1-2				
P1-3				
P2-1				
P2-2				
P2-3				
P3-1				
P3-2				
P3-3				
P4-1				

P4-2				
P4-3				
P5-1				
P5-2				
P5-3				

Safety Performance Criteria Scores		
HIC	**Rib Deflection (mm)**	**Run-Over Proximity (m)**
1	0	1
0	1	2
1	1	2
1	1	1
1	2	0
1	2	1
0	2	0
1	2	2
0	1	1
2	2	2
2	2	1
2	2	2
2	2	0
0	1	1
1	2	2

Weighted Front End Geometry Score	26.7%
Safety Performance Criteria Scores with a Value of 0	8
Front End Geometry Envelope Compliance	PASS
Bus Front End Geometry Star Rating	3

Figure 39_3: Example image showing results from front end geometry performance evaluation tool

Annex 1 - Simulation based testing guidelines

1 Introduction

The Vulnerable Road User (VRU) crashworthiness enhanced bus front end geometry requirements are intended to improve protection for VRUs during the primary impact of a collision and reduce the risks of VRUs being run over subsequently.

The clause on simulation evidence in the requirements permit an alternative pathway for compliance, whereby the intentions of these enhanced geometry requirements may be satisfied via a simulation based approach.

While ultimately the responsibility for ensuring sufficient real-world improvements in VRU injury and run-over risks remains with the OEMs, this Annex sets out a series of guidelines for simulation based approaches to be considered as equivalent evidence when compared to the requirements of the previously defined bus front end geometry test and assessment protocols.

2 Simulation Set Up Guidelines

2.1 Bus model validation

The geometry of the bus front end and structures is expected to come from CAD files of the bus and formed of suitably accurate representations of at least the bus front end components.

The material properties and the simulated structures should be tuned in a correlation exercise in order to develop a representative material model. This should be correlated against test data; for instance, comparing headform kinematics between physical and simulated tests against the flat, curved and/or wraparound areas of the windscreen. This model validation should occur before the simulations are performed to satisfy the requirements of the simulation approach.

It is recognised that there is a balance to be struck between quality of the simulation output and computational efficiency. However, it is expected that the simulation output is validated against physical (test) evidence and that this validation forms part of the simulation evidence package. It is anticipated that the testing is based on designs produced by the OEMs, rather than third party data, so that the correlation in bus front end response and VRU protection can be understood in terms of the detailed design approach adopted by the OEMs.

Pilot simulations should be used to assess whether the model produces a range of responses that are reasonable and reliable. Things to consider are:

- All VRU body parts are capable of contacting, where appropriate, with the bus front end components with a representative response during the simulations
- There are no simulation artefacts that significantly govern the response of the model (i.e. penetration through surfaces).

This approach may accept developmental models to support the validation as long as they are representative of the final design of the subject vehicle; it doesn’t have to be the final production (pre-production) design.

2.2 VRU surrogate models

As there is a need to avoid protection that is highly optimised for any single VRU size or type (e.g. a 50th percentile male pedestrian). Instead, the design approach to safety should intend to provide equivalent protection across all vulnerable road users.

In the evidence package it is recommended that the simulations generally concentrate on a single size/type of VRU model, such as the 50th percentile male pedestrian. This VRU model should be used to look for and demonstrate any improvements in safety over the baseline case.

Supplementing this there should then be an initiative to explore potential degradation in safety performance for other sizes or types of VRU.

The choice of other VRUs to be considered in the modelling should follow a sensible review of structural changes in the front end design of the bus. For instance, if there is a discontinuity in the surface profile around 1.5 m from the road, then testing with a large child or small adult would be important to explore and understand the implication of that profile for frontal crashworthiness and VRU protection. Cyclist models shall also be investigated.

The most representative approximation of a VRU should be sought in developing the simulation evidence. This may be taken to infer the use of detailed human body models (for example the Toyota Total Human Model for Safety (THUMS[2]), or the Global Human Body Modelling Consortium model (GHBMC[3])). However, it is appreciated that not all suppliers of simulation capabilities have access to these detailed human body models (and the associated compute time) at reasonable costs. Therefore alternatives may be sought.

In prior work TfL’s technical partner has gained experience with frontal VRU crashworthiness simulations with a standing or cycling variant of a Hybrid III crash test dummy model. Simulation validity (biofidelity) was observed to improve with the addition of a more compliant shoulder and chest. Therefore, when using alternative VRU surrogates, such as crash test dummy models, it is recommended that the at least the thorax and shoulder of the surrogate have been developed for use in VRU or side impact specific simulations.

2.3 VRU manoeuvres

There is also a need to avoid protection that is highly optimised for any one type of VRU motion (walking, running or cycling behaviour). It is important to consider that in a potential collision with a VRU, their behaviour could be from a relatively wide variety of walking, running or cycling speeds and with any horizontal travel direction vector. It is important to have confidence that these variations do not lead to poor interactions with the bus front end which would give a concern for VRU frontal crashworthiness.

Several impact positions should be evaluated across the width of the bus front end. Whether or not the bus is symmetrical about the central vertical and longitudinal plane, it is likely to require testing the bus front on the right and left for a VRU

[2] https://global.toyota/en/newsroom/corporate/26497281.html
[3] https://www.elemance.com/

travelling from one side to the other. This is because the VRU will have its own velocity which may influence the interaction with the bus front end and the rebound speed and direction. As such, a minimum of five test positions is recommended, as specified in the previous requirements, to account for horizontal curvature changes across the bus front end.

The position of the legs (for instance, where they are in the 'gait' cycle) of the VRU has also been shown to influence the interaction of the VRU with the bus front end. This potential variation in interaction should also be built into the simulation matrix so that confidence is given to the range of outputs and their ability to account for this effect. This will help in understanding the sensitivity of the design to likely collision scenarios and should be used to capture the worst case for protection.

2.4 Simulation boundary conditions

There is a need to avoid protection that is highly optimised for a single set of boundary conditions (e.g. collision speeds). The boundary conditions for the simulations should cover the range of realistic inputs. This will mean evaluating simulation outcomes with deliberately selected:

- Closing speeds
  - With representative bus speeds
    - For example, a range of 10 to 30 mph is reasonable based on travel speeds and collision case data
    - A single evaluation point could be used (e.g. 20 mph) for the major part of a simulation matrix assuming that the variation with speed was shown to be predictable in a subset of the tests
  - With representative travel speed for the VRUs
    - A range of 2 to 8 m/s could be used to represent reasonable walking and running behaviours of a pedestrian
    - Again, a smaller set of speeds could be used in the simulation matrix if it could be demonstrated that worst case interactions were understood in the derivation of that matrix
- Contact friction
  - Some friction with the ground is necessary
  - 0.6 has been used as the coefficient of friction in prior research work
- Braking vehicle dynamics
  - A representative braking rate shall be selected for use in determining the risk of a run-over, with -3.5 m/s^2 previously used. To simplify the braking response, this may be assumed as a constant braking rate (i.e. no need to model driver reaction and brake build up times).
  - It is suggested that some diving (forward pitching) of the bus front can be expected in many collision scenarios due to the pre-impact braking response
  - A representative forward pitch for the subject vehicle should be chosen for simulaitons to reflect potential collision scenarios and possible worst case interactions for the VRU
- Start and finish times for simulation runs
  - The start time should be prior to the first contact between bus and VRU
  - The finish time should allow adequate prediction of VRU throw characteristics to assess the risk for the bus running over the VRU after the primary interaction

3 Assessment of safety performance

The objective of the VRU crashworthiness safety measure is to assess injury causing consequences and demonstrate that a design for a bus front improves protection for VRUs during the primary impact, whilst reducing the risks of VRUs being subsequently run over. The requirements of this alternative compliance path are that the simulations provide an assessment of both direct contact injury risk and the subsequent 'run-over' risk.

To demonstrate safety performance improvements any new subject vehicle shall be compared against a database of responses built around a bus front end design that is representative of current/past geometries and structures. This shall be used to assess head and chest injury risk and the subsequent risk of being run-over for the VRU, due to these injury mechanisms being associated with the greatest risks of fatal and severe VRU collision injuries.

Although many injury risk metrics for each body region exist, and may be accepted if appropriately justified, a recommended dataset of metrics for the simulation outcomes is provided below:

- Head injury risk
  - 15 ms Head Injury Criteria (HIC_{15})
- Chest injury risk
  - Rib deflection distance
- Run-over risk
  - Proportion of collisions with a minimum clearance of <0.5 m, at any point in time during the collision, between the trajectory of the bus front end structures and VRU centre of gravity

Further detail on the average injury risk metrics across all five test positions and three different impact speeds for current best-in-class bus designs, as determined through simulations performed on behalf of TfL, may be found below in Table 39_2. These values may be used as comparators to assess the relative VRU safety performance of the subject vehicle, but should always be placed in the context of the range of VRU surrogate models and boundary conditions investigated by the specific evidence pack provided by the OEMs.

Table 39_2: Average injury risk metrics for HIC_{15} and lateral rib deflection injury metrics and proportion of run-over events across all five test positions for collisions at three representative impact speeds

Vehicle Speed	HIC_{15}	Lateral Rib Deflection (mm)	Run Over Risk (m)
10mph	21.5	13.5	0%
20mph	254.6	25.6	20%
30mph	739.7	37.3	60%

Alternatively, the subject vehicle may be directly compared to an earlier vehicle design from the OEMs (ensuring that this earlier design was the latest variant that was type approved before 2019). For this analysis an overall improvement in outcome must be shown with the subject vehicle when directly compared to the earlier vehicle design, with outcomes and criteria for both buses following the approaches defined in these sections. Both buses would be expected to be appropriately modelled and validated.

4 Example Simulation Matrix

As specified in the previous sections, the responsibility lies with the OEMs for deriving a simulation matrix to assure the Test Service that the changes in bus front end design results in an overall improvement in VRU safety and that any unintended consequences for a particular collision scenario have been mitigated.

Such a simulation matrix should include consideration of the following elements:

- VRU type
- VRU size
- VRU impact position
- VRU speed
- VRU gait
- Bus speeds

An example of such a matrix is shown below in Table 39_3, however, it is expected that OEMs propose their own matrices to prove overall improvements in injury and no unintended consequences to the Test Service.

Table 39_3: Indicative simulation matrix

#	Size	Impact Position	VRU activity	Struck-side leg position	Bus speed
1	Adult male (50th percentile)	P1	Walking	Forward	20 mph
2	Adult male (50th percentile)	P2	Walking	Forward	20 mph
3	Adult male (50th percentile)	P3	Walking	Forward	20 mph
4	Adult male (50th percentile)	P4	Walking	Forward	20 mph
5	Adult male (50th percentile)	P5	Walking	Forward	20 mph
6	Adult male (50th percentile)	P1	Running	Forward	20 mph
7	Adult male (50th percentile)	P4	Running	Forward	20 mph
8	Adult male (50th percentile)	P1	Cycling	Forward	20 mph
9	Adult male (50th percentile)	P3	Cycling	Forward	20 mph
10	Adult male (50th percentile)	P4	Cycling	Forward	20 mph
11	Adult male (50th percentile)	P3	Walking	Together	20 mph
12	Adult male (50th percentile)	P3	Walking	Behind	20 mph
13	Adult male (50th percentile)	P1	Walking	Together	20 mph
14	Adult male (50th percentile)	P1	Walking	Behind	20 mph
15	Adult male (50th percentile)	P3	Walking	Forward	10 mph
16	Adult male (50th percentile)	P3	Walking	Forward	30 mph
17	Adult male (50th percentile)	P2	Walking	Forward	10 mph
18	Adult male (50th percentile)	P2	Walking	Forward	30 mph
19	Child (10 years')	P1	Walking	Forward	20 mph
20	Child (10 years')	P3	Walking	Forward	20 mph
21	Child (10 years')	P4	Walking	Forward	20 mph

Attachment 40: Bus Front End Design – Enhanced Geometric Requirements Guidance Notes

(Vulnerable Road User (VRU) Frontal Crashworthiness)

1 Introduction

Bus fronts have been identified as one of the key injury-causing contact areas of the vehicle in collisions between buses and Vulnerable Road Users (VRU). Therefore, all bus front ends are required to have a global geometric design that both improves protection for VRUs during the primary impact of a collision and reduce the risks of VRUs being run over subsequently.

As such, all new buses shall have a front end design that complies with the Vulnerable Road User (VRU) crashworthiness enhanced bus front end geometry requirements for both vertical rake and horizontal curvature.

This document sets out the guidance notes related to the assessment of the global bus front end geometry and specifically, with respect to the enhanced requirements contained in Section 4.6.2 and Attachment 39 of the Bus Vehicle Specification. These guidance notes are aimed at bus operators and OEMs as a practical guide for implementation of the requirements as specified by the Bus Vehicle Specification.

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

2 Selection of buses/systems

From 2024, 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 can be any bus that is compliant with these specifications.

2.1 Intention of the requirements

The enhanced bus front end geometry requirements intend to mandate bus front end designs that implement a progressively curved (in the horizontal plane) and raked (i.e. vertically angled) design.

It was observed, in research performed that impacts against curved and raked bus front ends improved VRU injury and run over risks relative to traditional flat-fronted designs. This benefit was, however, limited to a particular optimised design envelope, with this enhanced bus front end geometry envelope found to considerably improve risks relative to current bus front end designs (i.e. larger/smaller vertical rake angles and shallower/deeper horizontal curvatures therefore did not improve VRU injury and run over risks).

It was also found within this research that the geometric design of bus front ends could be further optimised within the enhanced bus front end geometry envelope. This would provide additional casualty saving benefits, beyond that of bus front end geometries at the boundaries of the design envelope. This relationship is, however, highly complex and non-linear due to the many interactions between the various variables involved in such collisions. To this end, these requirements also specify the use of a bus front end geometry performance evaluation tool to provide guidance to users on the relative safety performance level of their designs.

Due to the complex nature of the interactions between variables for these collisions, these requirements also provide OEMs with an alternate compliance pathway. This permits OEMs to evidence improvements in the safety performance of the bus front end through a simulation-based approach, rather than by demonstrating compliance with the enhanced bus front end geometry envelope. OEMs are required to prepare a dossier of evidence that ensures that their simulations are of an appropriate quality and that they demonstrate improvements in safety across a range of expected VRU collision scenarios.

These requirements therefore seek to mandate the design of bus front end geometries for new buses into the TfL network to improve VRU injury and run-over risks relative to current designs. These requirements also seek to promote the design of new bus front ends that optimise the interaction of the VRU with the bus to further reduce the overall risks of injury and run-over.

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

To achieve compliance with these enhanced bus front end geometry requirements, changes in bus lengths or capacity, driven by the raking and curvature of the bus front end, may be expected. Extended bus front end lengths or an increase in the rearward sweep of the bus front end may either be adopted to meet these design requirements, with both approaches needing to consider the impact they would have on operations. The extension of the front end may be expected to impact the turning circle, approach angle, ramp angle and stabling capacity of the bus, whilst an increase in the rearward sweep could impact door positioning, available passenger capacity and accessibility.

Information should therefore be sought by operators to understand the impact that the design approach adopted by the OEMs would have on operational constraints. This said, the enhanced bus front end geometry envelope requirements permit a range of vertical rake and horizontal curvature for selection. The minimum impact this design envelope should have on bus front end lengths is an extension of circa 300 mm at the longitudinal centreline of the bus, with similar distances rearward at the edges of the bus should there be no length extension.

It is advised that no extension should exceed 300 mm at the centreline (relative to current models) if a bus is likely to operate in space-constrained environments (depots or bus routes). Furthermore, a greater horizontal curvature of the bus front end may be employed by bus manufacturers/designers to control the outer turning radius of the bus and aid the manoeuvrability of the vehicle.

The enhanced requirements are intended to dictate a progressive surface geometry for the bus front end 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 protrusions 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 size of the areas presenting that angle then the more effective the measure will be.

2.3 Compliance and warranty

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.

Bus operators should ask to see documentary evidence of compliance with these 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.

2.4 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 stiffer structural members within the broad VRU contact area. It is advised that protection in these other modes is considered at the same time as implementing design changes aimed at protecting VRUs. This is needed to deliver protection to both the bus drivers, other road users and VRUs.

One option is to use UN Regulation 29 (with regard to the protection of cab occupants of a commercial vehicle), and this has already been used by some OEMs. 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.

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 physical testing.

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 at the test point where the appropriate angles of vertical rake or horizontal curvature can be viewed.

For physical inspections, the vertical rake can be measured with an inclinometer, while the horizontal angle can be measured through a protractor arrangement that may be used to determine the horizontal angle relative to the frontal plane of the bus. Here it should be noted that the footprint for the measurements should be 236 ± 5 mm x 236 ± 5 mm. This is to ensure that only the global geometric features of the bus are considered by these requirements and that smaller features are considered to not have a significant effect on the outcomes of VRU collisions.

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.

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 VRUs 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.

As these enhanced requirements will take the design envelopes for bus front end geometries beyond that of existing designs, it is feasible that these new designs may be 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 41: Bus Front End Design – Wiper Protection Guidance Notes

(Vulnerable Road User (VRU) Frontal Crashworthiness)

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 OEMs as a practical guide for implementation of the Bus Safety Standard.

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

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.6.4 and Attachment 36: Bus Impact Test Standard Assessment Protocol

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 OEM.

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 – applicable to all ‘new entry buses’

b) If mounted at or below 2.0 m, documentation showing the vehicle is fitted with a protective covering and a VRU Impact Performance test report confirming that when impacted at the worst-case location, the head injury criterion (HIC_{15}) value was reduced by 50% when compared to the same location without a protective covering – applicable to all existing bus models.

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 an OEM, 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.

Attachment 42: Complex Electronic Control Systems

1 General

This attachment defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of Complex electronic vehicle control systems (Definitions 4. below) as far as this attachment is concerned.

This attachment may also be called, by special paragraphs in this Regulation, for safety related functions which are controlled by electronic system(s).

This attachment does not specify the performance criteria for "The System" but covers the methodology applied to the design process and the information which must be disclosed to the Technical Service, for type approval purposes.

This information shall show that "The System" respects, under normal and fault conditions, all the appropriate performance requirements specified elsewhere in this Regulation.

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 4.3.2, Attachment 15: Advanced Emergency Braking (AEB) Assessment Protocol and Attachment 16: Advanced Emergency Braking (AEB) Guidance Notes

2 Scope

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

3 Normative References

- London Bus Services Limited New Bus Specification Section 4.3.2
- London Bus Services Limited Attachment 15: Advanced Emergency Braking (AEB) Assessment Protocol
- London Bus Services Limited Attachment 16: Advanced Emergency Braking (AEB) Guidance Notes

4 Definitions

For the purposes of this attachment:

- **Boundary of functional operation** defines the boundaries of the external physical limits within which the system is able to maintain control.
- **Complex electronic vehicle control systems** are those electronic control systems which are subject to a hierarchy of control in which a controlled function may be over-ridden by a higher level electronic control system/function.
  A function which is over-ridden becomes part of the complex system
- **Electronic control system** means a combination of units, designed to co-operate in the production of the stated vehicle control function by electronic data processing.
  Such systems, often controlled by software, are built from discrete functional components such as sensors, electronic control units and actuators and connected by transmission links. They may include mechanical, electro-pneumatic or electro-hydraulic elements.
  The System, referred to herein, is the one for which type approval is being sought.
- **Higher-level control** systems/functions are those which employ additional processing and/or sensing provisions to modify vehicle behaviour by commanding variations in the normal function(s) of the vehicle control system.
  This allows complex systems to automatically change their objectives with a priority which depends on the sensed circumstances.
- **Range of control** refers to an output variable and defines the range over which the system is likely to exercise control.
- **Safety concept** is a description of the measures designed into the system, for example within the electronic units, so as to address system integrity and thereby ensure safe operation even in the event of an electrical failure.
  The possibility of a fall-back to partial operation or even to a back-up system for vital vehicle functions may be a part of the safety concept.
- **Transmission links** are the means used for inter-connecting distributed units for the purpose of conveying signals, operating data or an energy supply.
  This equipment is generally electrical but may, in some part, be mechanical, pneumatic, hydraulic or optical.
- **Units** are the smallest divisions of system components which will be considered in this annex, since these combinations of components will be treated as single entities for purposes of identification, analysis or replacement.

5 Documentation

5.1 Requirements

The manufacturer shall provide a documentation package which gives access to the basic design of "The System" and the means by which it is linked to other vehicle systems or by which it directly controls output variables.

The function(s) of "The System" and the safety concept, as laid down by the manufacturer, shall be explained.

Documentation shall be brief, yet provide evidence that the design and development has had the benefit of expertise from all the system fields which are involved.

For periodic technical inspections, the documentation shall describe how the current operational status of "The System" can be checked.

Documentation shall be made available in 2 parts:

(a) The formal documentation package for the approval, containing the material listed in Section 5. of this attachment (with the exception of that of Paragraph 8 of Section 5.4 below) which shall be supplied to the Technical Service at the time of submission of the type approval application. This will be taken as the basic reference for the verification process set out in section 4. of this attachment.

(b) Additional material and analysis data of Paragraph 8 of Section 5.4 below, which shall be retained by the manufacturer, but made open for inspection at the time of type approval.

5.2 Description of the functions of "The System"

A description shall be provided which gives a simple explanation of all the control functions of "The System" and the methods employed to achieve the objectives, including a statement of the mechanism(s) by which control is exercised.

A list of all input and sensed variables shall be provided and the working range of these defined.

A list of all output variables which are controlled by "The System" shall be provided and an indication given, in each case, of whether the control is direct or via another vehicle system. The range of control exercised on each such variable shall be defined.

Limits defining the boundaries of functional operation (see section 4 Definitions of this attachment) shall be stated where appropriate to system performance.

5.3 System layout and schematics

5.3.1. Inventory of components

A list shall be provided, collating all the units of "The System" and mentioning the other vehicle systems which are needed to achieve the control function in question.

An outline schematic showing these units in combination shall be provided with both the equipment distribution and the interconnections made clear.

5.3.2. Functions of the units

The function of each unit of "The System" shall be outlined and the signals linking it with other Units or with other vehicle systems shall be shown. This may be provided by a labelled block diagram or other schematic, or by a description aided by such a diagram.

5.3.3. Interconnections

Interconnections within "The System" shall be shown by a circuit diagram for the electric transmission links, by an optical-fiber diagram for optical links, by a piping diagram for pneumatic or hydraulic transmission equipment and by a simplified diagrammatic layout for mechanical linkages.

5.3.4. Signal flow and priorities

There shall be a clear correspondence between these transmission links and the signals carried between units.

Priorities of signals on multiplexed data paths shall be stated, wherever priority may be an issue affecting performance or safety as far as this Regulation is concerned.

5.3.5. Identification of units

Each unit shall be clearly and unambiguously identifiable (e.g. by marking for hardware and marking or software output for software content) to provide corresponding hardware and documentation association.

Where functions are combined within a single Unit or indeed within a single computer, but shown in multiple blocks in the block diagram for clarity and ease of explanation, only a single hardware identification marking shall be used.

The manufacturer shall, by the use of this identification, affirm that the equipment supplied conforms to the corresponding document.

The identification defines the hardware and software version and, where the latter changes such as to alter the function of the unit as far as this Regulation is concerned, this identification shall also be changed.

5.4 Safety concept of the manufacturer

The manufacturer shall provide a statement which affirms that the strategy chosen to achieve "The System" objectives will not, under non-fault conditions, prejudice the safe operation of systems which are subject to the prescriptions of this Regulation.

In respect of software employed in "The System", the outline architecture shall be explained and the design methods and tools used shall be identified. The manufacturer shall be prepared, if required, to show some evidence of the means by which they determined the realisation of the system logic, during the design and development process.

The manufacturer shall provide the technical authorities with an explanation of the design provisions built into "The System" so as to generate safe operation under fault conditions. Possible design provisions for failure in "The System" are for example:

(a) Fall-back to operation using a partial system.

(b) Change-over to a separate back-up system.

(c) Removal of the high level function.

In case of a failure, the driver shall be warned for example by warning signal or message display. When the system is not deactivated by the driver, e.g. by turning the Ignition (run) switch to "off", or by switching off that particular function if a special switch is provided for that purpose, the warning shall be present as long as the fault condition persists.

If the chosen provision selects a partial performance mode of operation under certain fault conditions, then these conditions shall be stated and the resulting limits of effectiveness defined.

If the chosen provision selects a second (back-up) means to realize the vehicle control system objective, the principles of the change-over mechanism, the logic and level of redundancy and any built in back-up checking features shall be explained and the resulting limits of back-up effectiveness defined.

If the chosen provision selects the removal of the higher level function, all the corresponding output control signals associated with this function shall be inhibited, and in such a manner as to limit the transition disturbance.

Paragraph 8

> The documentation shall be supported, by an analysis which shows, in overall terms, how the system will behave on the occurrence of any one of those specified faults which will have a bearing on vehicle control performance or safety.
>
> This may be based on a Failure Mode and Effect Analysis (FMEA), a Fault Tree Analysis (FTA) or any similar process appropriate to system safety considerations.
>
> The chosen analytical approach(es) shall be established and maintained by the manufacturer and shall be made open for inspection by the technical service at the time of the type approval.

This documentation shall itemize the parameters being monitored and shall set out, for each fault condition of the type defined in paragraph 8 above, the warning signal to be given to the driver and/or to service/technical inspection personnel.

6 Verification and test

The functional operation of "The System", as laid out in the documents required in Section 5. above, shall be tested as follows:

6.1 Verification of the function of "The System"

As the means of establishing the normal operational levels, verification of the performance of the vehicle system under non-fault conditions shall be conducted against the manufacturer's basic benchmark specification unless this is subject to a specified performance test as part of the approval procedure of this or another Regulation.

6.2 Verification of the safety concept

The reaction of "The System" shall, at the discretion of the Type Approval Authority, be checked under the influence of a failure in any individual unit by applying corresponding output signals to electrical units or mechanical elements in order to simulate the effects of internal faults within the unit.

The verification results shall correspond with the documented summary of the failure analysis, to a level of overall effect such that the safety concept and execution are confirmed as being adequate.

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