LONDON BUS SERVICES LIMITED

Specification for new buses

Version 1.0

Issued December 2018

Effective from Tranche 670

Preface

This specification will determine the technical characteristics required for all new London buses.

Where a Vehicle Manufacturer perceives that a particular feature of this document should be changed, this should be raised by the Vehicle Manufacturer with the Approval Authority (LBSL) assessor present at the assessment, or in writing to the Approval Authority (LBSL) Nominated Officer in the absence of an assessor. The competent authority (LBSL) will assess the proposal based on their judgment and provide instruction to the assessment facility.

Vehicle Manufacturers are directly or indirectly barred from interfering with any assessment undertaken as part of this specification and prohibited from altering any characteristics that may impact the assessment, including but not restricted to vehicle setting, laboratory environment etc.

Version	Published	Details
0_9	N/A	LBSL Bus Specification

Disclaimer

LBSL 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, LBSL retains the right to make amendments and decide on the assessment and future outcome of the affected requirement(s).

Version Control

Revision Date	Tranche Implementation Date	Revision No	Page No	Section	Summary of changes
Dec 18	**670**	**1.0**			**Issued**

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1 Introduction

This document defines LBSL's technical requirements for new buses entering into service in London.

1.1 Scope

This protocol applies to all new buses intended for service under contract to LBSL 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 M3; Class I, Class II.

1.2 Purpose

LBSL wishes to promote a world leading bus service in London. As such LBSL has a range of objectives and wishes for all new buses used in London to contribute to the achievement of those objectives:

- Regulatory Compliance
- Safety: TfL and LBSL are committed to Vision Zero and believe that no death or serious injury when travelling in London is either acceptable or inevitable. LBSL's aim is that by 2030 nobody will be killed in a collision involving a bus.
- Environmental Performance: LBSL support the target to reduce the Capital's CO2 emissions by 60% by 2025 and become carbon neutral by 2050. To have a zero emission at tailpipe fleet by 2037. All new diesel powered vehicels buses will incorporate the latest technical designs, and systems to ensure the environmental performance of the vehicle delivers the highest possible sustainable clean energy standards and bus propulsion systems
- Operational efficiency
- Accessibility: LBSL aim to continue to improve the accessibility of their bus services
- Passenger experience
- Aesthetics and image

This specification is structured to allow LBSL to ensure certain minimum standards are met in relation to its objectives and to easily assess to what extent individual models of bus might exceed those requirements and contribute more to their objectives.

1.3 Process

From time to time, LBSL may require additional control systems to be installed, and/or integrated into the base vehicle systems for the purposes of conducting demonstrations and/or trials to test and evaluate new or emerging technologies. The aim of these trials is to achieve the continuous improvement and enhancement of driver and passenger safety/comfort systems, and to ensure road space is shared as safely as possible with other road users. These trials will also develop and promote innovations in London bus operations, bus design, accessibility features, and the continued reduction in harmful tailpipe emissions.

LBSL prior approval must be agreed for any exemptions/dispensations to allow for controlled deviation from the specified standards and/or performance requirements in this document. Request for exemptions/dispensation must be made in writing to the LBSL Nominated Officer.. The reason(s), benefits, and any associated risks from such exemption/dispensation must be identified and assessed with the appropriate mitigations.

1.4 Terminology

The language used in this specification is typical of standards documents and shall be interpreted as follows:

- Mandatory requirements are indicated by phrases such as ‘Must’, ‘Shall’ or ‘Required’.
- Where requirements are indicated by the word ‘should’ they are strongly recommended and applicants shall present strong evidence to justify why their vehicle remains acceptable if these recommendations are not followed.
- Where requirements are indicated by the word ‘may’ they are optional and manufacturers may deviate from the requirement without presenting additional justification.

In addition to the above, some whole sets of requirements are indicated as being ‘preferred’. These requirements are optional at the discretion of the manufacturer and operator but LBSL reserve the right to employ whatever commercial levers are at its disposal to encourage suppliers to choose to include these requirements and are more likely to select bids that include vehicles meeting the preferred requirements.

London Bus Services Ltd (LBSL) is the subsidiary of Transport for London (TfL) that is responsible for the contracting and operation of London’s bus network. LBSL and TfL are used interchangably throughout the document.

Section 4 of this document specifies TfL’s safety requirements for all new vehicles. Those requirments entering the fleet in future years as per the Bus Safety Roadmap for new build buses are highlighted with *italics*.

[ ] indicates TfL’s current assumptions for future requirements and will be updated once further development work has taken place.

1.5 LBSL Approval

Approvals, changes and dispensations to this specification can only be given by LBSL’s Nominated Officer in writing, or through a formal contract award letter issued by the Head of Bus Tendering and Evaluation (Richard Rampton). .

The Nominated Officer is Tom Cunnington, Head of Buses Business Development. ([redacted]@tfl.gov.uk)

2 Status of Application of Requirements

Many aspects of this specification are mandatory. However, some items will not become mandatory until a future date. Before that time, some of those may not be applicable at all, some may be requirements that must be followed if the system is fitted voluntarily, some may be permitted only as part of a controlled trial and some may be 'preferred' such that although not mandatory LBSL may employ commercial levers or incentives for buses that do comply with the requirements.

Table 2-1. Status of actual and planned application of each set of requirements

Main section	Subsection	2018	End of 2019	2020	2021	2022	2024
Regulatory Requirements	All	Required	Required	Required	Required	Required	Required
Safety	4.1 Fire	Required	Required	Required	Required	Required	Required
	4.2 Security	Required	Required	Required	Required	Required	Required
	4.3.1 Driver Assist: Acceleration	Required	Required	Required	Required	Required	Required
	4.3.2 Driver Assist AEB	Not Required	Trial Only	Preferred	Preferred	Preferred	Required
	4.3.3 Driver Assist: ISA	Required	Required	Required	Required	Required	Required
	4.3.7 Driver Assist: Vision – Direct vision	Not Required	Preferred	Preferred	Required	Required	Required
	4.3.7 Driver Assist: Vision – Enhanced indirect vision	Not Required	Not Required	Preferred	Preferred	Preferred	Required
	4.3.8 Driver Assist: Vision – Mirror Replacement CMS	Not Required	Not Required	Preferred	Required	Required	Required
	4.3.5 Driver Assist: Vision – Blind spot mirrors	Not Required	Required	Required	Not Required	Not Required	Not Required
	4.3.6 Driver Assist: Vision – Reversing	Not	Required	Required	Required	Required	Required

Main section	Subsection	2018	End of 2019	2020	2021	2022	2024
	CMS	Required					
	4.3.9 Front & Nearside Alert Systems	Not Required	Not Required	Preferred	Preferred	Preferred	Required
	4.3.10.3 Driver Assist: Pedal Application Error – Brake Toggling	Not Required	Preferred	Preferred	Required	Required	Required
	Driver Assist: Pedal Application Error – Pedal standardisation	Not Required	Not Required	Preferred	Required	Required	Required
	4.3.10.2 Driver Assist: Pedal Application Error – Accelerator light system	Not Required	Required	Required	Required	Required	Required
	4.3.10.4 Driver Assist: Pedal Application Error – pedal acoustic feedback	Not Required	Preferred	Preferred	Required	Required	Required
	Driver Assist: Pedal Application Error – AEB logic	Not Required	Not Required	Preferred	Preferred	Preferred	Required
	4.3.11 Driver Assist: Runaway Bus	Not Required	Preferred	Preferred	Required	Required	Required
	4.4.1 Partner Assist: Acoustic Conspicuity AVAS	Not Required	Required	Required	Required	Required	Required
	4.4.2 Partner Assist: Visual Conspicuity	Required	Required	Required	Required	Required	Required
	4.5.2 – 4.5.3 Occupant protection: Stairs, Seats, & Handrails	Required	Required	Required	Required	Required	Required
	4.5.4 Occupant protection: Guards	Not Required	Required	Required	Required	Required	Required
	4.5.5 Occupant Protection: Occupant	Not	Preferred	Preferred	Required	Required	Required

Main section	Subsection	2018	End of 2019	2020	2021	2022	2024
	friendly interiors – Level 1 requirements	Required					
	4.5.5 Occupant Protection: Occupant friendly interiors – Level 2 requirements	Not Required	Not Required	Preferred	Preferred	Preferred	Required
	4.5.6 Occupant protection: Slip prevention	Not Required	Required	Required	Required	Required	Required
	4.6.1 Partner Protection: VRU frontal crashworthiness – Minimum geometry	Not Required	Preferred	Preferred	Required	Required	Required
	4.6.2 Partner Protection: VRU frontal crashworthiness – Optimised geometry	Not Required	Not Required	Not Required	Not Required	Preferred 2022	Required
	4.6.3 Partner Protection: VRU frontal crashworthiness – Energy absorption	Not Required	Not Required	Not Required	Preferred	Preferred	Required
	4.6.4 Partner Protection: VRU frontal crashworthiness – Wiper protection	Not Required	Preferred	Preferred	Required	Required	Required
	4.6.5 Partner Protection: VRU frontal crashworthiness – Mirror Replacement CMS	Not Required	Not Required	Preferred	Required	Required	Required
	Bus Safety Standard Overall Score	Not Required	Required	Required	Required	Required	Required
	4.5.7 Door Safety	Required	Required	Required	Required	Required	Required
	Miscellaneous Safety Features	Required	Required	Required	Required	Required	Required
Environment	All	Required	Required	Required	Required	Required	Required
Operational Efficiency	All	Required	Required	Required	Required	Required	Required

Main section	Subsection	2018	End of 2019	2020	2021	2022	2024
Accessibility	All	Required	Required	Required	Required	Required	Required
Occupant Experience	All	Required	Required	Required	Required	Required	Required
Aesthetics	All	Required	Required	Required	Required	Required	Required
Signs	All	Required	Required	Required	Required	Required	Required
Maintenance	All	Required	Required	Required	Required	Required	Required

3 Regulatory Compliance

All vehicles must comply with all legislation applicable for buses driving in London. If there is any conflict between any requirement in this specification and any legislative requirement then the legislative requirement shall take precedence.

All London buses must be registered for road use in the UK. Registration requires that the vehicle must be approved via one of the following approval routes:

- EC Whole Vehicle Type Approval (ECWVTA)
- Small Series Approval (ECSSTA or NSSTA)
- Individual Vehicle Approval (IVA)

LBSL must be notified of any changes to the certificate of conformity issued by the approval authority (i.e. VCA if approved in the UK).

Vehicles approved to EC WVTA do not need to be fully certified to any additional regulations.

Vehicles approved to National Small Series Type Approval or IVA shall in addition demonstrate that they, or the relevant components they are fitted with, also comply with the following regulations:

- UNECE Regulation 118, as amended, on the burning behaviour of materials used in the construction of motor vehicles.
- UNECE Regulation 107, as amended, with respect to the fitment and technical standards of fire suppression systems in engine compartments of buses.
- All windows and glazing shall comply with ECE Regulation 43
- All status and indicator lamps, even those for systems not required by type approval (e.g. pedal confusion indicator lights) comply with the relevant requirements of UNECE Regulation 121.
- The brake system, including all required interlocks and control systems that interact with the brakes, complies with the requirements of UNECE regulation 13
- Engine emissions shall comply with the latest legal Euro requirements for ECWVTA at time of bus certification.

Compliance with any given regulation, or specific sections of such regulations, shall be demonstrated to LBSL either by providing copies of all relevant certificates of conformity or by providing a formal written declaration that the vehicle is in compliance with the Regulation or the required parts of the Regulation.

Buses should not be modified between registration and entry into service. If any modifications are made that affect the ability of the vehicle to carry the plated load, or the brake or steering systems or their mode of operation, then the manufacturer shall submit a Notifiable Alteration to DVSA and obtain approval for the modification.

All buses must comply with all relevant current legislation and take account of any intended legislative discussions that are considered imminent within the first 6 months of the bus's operational life. For clarity, this means within 6 months of the first delivery made as part of each specific order for new buses. It does not relate to when that model of bus first entered service.

4 Safety

4.1 Fire Safety

All materials used in the construction of the passenger saloon and structure separating the saloon from the engine compartment must meet the fire retardant standards defined in Attachment 6.

Engine and combustion heater compartments shall be equipped with a fully automatic fire suppression system compliant with UNECE R107 (As Amended). It shall capable of rapid deployment to extinguish a fire before passenger safety is compromised or serious bus damage is sustained.

On bus startup, the system shall provide the driver with audible notification that it is operative and free from defect.

Manufacturers shall complete a full fire risk assessment for each type of bus covering as a minimum the engine bay and combustion heater compartment. This should be undertaken in conjunction with the Fire Suppression System (FSS) manufacturer, where this is not the bus OEM, and Bus operators who have the necessary expertise. The outputs from the risk assessment should identify all potential sources of fire and identify the type and location of fire detection devices and fire suppressant dispensing outlets. It should also define the FSS maintenance requirements.

All identified potential sources of fire in the engine bay shall be protected by an effective FSS. This includes any at risk areas behind the engine such as starter motors or filter assemblies. This may increase the length of the trace tube or require additional nozzles. It may also require larger capacity fire suppression cylinders.

The fire suppressant material used should be ABC powder delivered at high pressure. However, water mist systems will be an acceptable alternative if strong justification is presented to LBSL.

The system shall provide accurate and early detection of fires, and multi point dispensing of fire suppressant material targeted at high-risk sections of the engine bay. Manual activation or override by the driver shall not be permitted.

On detection of a fire, the systems shall:

- Provide the driver with immediate audible notification of fire detection .
- shut off fuel supply to the engine bay and effectively isolate the fuel tank.
- Remove power to the cooling fan.

Double-deck buses shall be equipped with a concealed smoke detector in the upper deck rear seated area. A warning device shall inform the driver of activation of this detector as part of the audible information provided by the FSS.

The legally required manual engine emergency shut down device must be accessible without the need to open the main engine bay cover. It must also be of a type that allows the engine to be restarted from the driver's cab, provided the main rear engine bay cover is closed. The main engine bay cover must be kept locked when the bus is in service.

The manufacturer shall demonstrate compliance with these requirements by providing copies of the risk assessments to LBSL.

4.2 Security

4.2.1 Protecting the driver from assault

All buses shall be fitted with a partition screen separating passengers and the driver

The driver partition screen design must incorporate adequate provision for driver/passenger communication that is accessible to all customer groups. The means of providing such communication is at the discretion of the manufacturer and, for the avoidance of doubt, may include independent systems such as an electronic two-way communication system.

The driver's partition screen, including its mountings, the structures supporting it and the hinges and catches forming part of any section designed to open to allow driver access and egress, shall be designed to:

- fully protect the driver from sustained physical attack from any person
- minimise the likelihood of a pressurised spray and/or fluids directed at the screen from passing through at any point.
- Be tamper proof with all critical components designed to be difficult to forcibly remove

The screen shall be free from rattles during normal driving, free of any significant reflections and shall not not restrict or distort driver view to passenger entrance, wing mirrors or forward exterior view.

The driver must be further protected by an independent "siren / common network fleet sound" assault alarm also activating the bus hazard lights.

The driver's cab signalling window shall be resistant to assault, or protected by a device resistant to assault.

4.2.2 Discouraging pickpockets

Passenger seats shall be suitably designed to restrict the potential of pickpockets to operate whilst utilising the seating immediately rearward.

4.3 Driver Assist

4.3.1 Acceleration performance

The combined engine and transmission acceleration controls shall limit the bus to a rate that provides the driver with adequate driving acceleration in the fully laden condition, whilst not subjecting the passengers to excessive forces that potentially cause the passengers to become unstable. The maximum rate of acceleration shall be between 1.0 and 1.2m/s^2 under all load conditions.

4.3.2 Advanced Emergency Braking (AEB)

This requirement only applies to new vehicles entering the fleet from 2024 as per the Bus Safety Roadmap for new build buses

It should be noted that AEB is intended to operate only in the last second or two before an imminent collision. The driver remains responsible for all aspects of driving, including collision avoidance, at all times.

Buses shall be fitted with AEB systems complying with the following requirements:

- It shall be tested in accordance with LBSL's Test & Assessment protocol for AEB (Attachment 15) and it must attain a performance score greater than zero.
- The bus manufacturer must produce documentary evidence for LBSL approval to demonstrate that on average they would expect false positive activations in mixed London traffic less frequently than once every 600,000 km per vehicle.
- The bus to which AEB is fitted must have been assessed in accordance with the interior safety part of this protocol and have achieved the level 1 requirements, with a score of ≤80 for the lower saloon, and where applied to double deck vehicles, a score of ≤8 for the upper saloon.
- The system shall provide the driver with a status indicator that will inform the driver if the system is unavailable for any reason or if performance is degraded because of imperfect conditions such as sensor misalignment. Where this occurs, the system shall fail to a standard equivalent to an identical vehicle not fitted with AEB. The warning light illuminated in such cases shall be amber.
- The bus manufacturer must make signals regarding AEB function available for recording by the CCTV system (specified separately) and/or any other appropriate data recording device specified by the vehicle operators. These signals shall at all times indicate the status of the AEB system as follows:
    - Enabled, manually deactivated (if any deactivated mode, for example for service, is provided) or unavailable (for example due to self diagnosed defect or adverse weather).
    - Warning active.
    - Brake demand active.
    - Level of braking demanded.

4.3.3 Intelligent Speed Assistance (ISA)

An Intelligent Speed Assistance (ISA) system is an aid to the driver and does not absolve the driver of responsibility for complying with speed limits or selecting the most appropriate speed for the prevailing road conditions, which may be lower than the posted speed limit.

TfL will regularly provide updates of speed limits of all roads through the TfL Digital Speed Map (see map management section of this document). The TfL Digital Speed Map incorporates all public highways in every London borough

Where new buses are equipped with an Intelligent Speed Assistance system, it shall:

- operate at all times when travelling on any public highway defined by the TfL Digital Speed Map of London.
- limit the vehicle speed to the prevailing speed limits as indicated in the TfL Digital Speed Map.
- be tested in accordance with the procedures defined in Attachment 17 and achieve a 'Pass'.
- have no adverse effects on the fuel consumption or emissions.

4.3.3.1 Bus Integration

The system must be fully integrated by the bus OEM. Post vehicle homologation fitment of aftermarket equipment is not permitted.

For buses equipped with iBus 1, ISA can utilise the existing iBus GPS antenna (which provides reception on the L1 band) or any other existing bus architecture . The existing IBus antenna can be utilised through using a Radio Frequency (RF) splitter. The RF splitter is required to be approved for use by LBSL. LBSL accept the locational variance in geographic accuracy this entails will be within a 20 metre tolerance.

For buses equipped with iBus 2, the IBus 2 GPS antenna must also be used to provide the GPS signal for ISA by using an RF splitter. The RF splitter must be approved for use by LBSL.

The system shall obtain the speed of the vehicle from the appropriate Fleet Management System (FMS) data field via the FMS Gateway or directly from the CAN (which is reflected on the speedometer).

FMS & CAN vehicle speed must be sufficiently accurate to comply with the accuracy requirements of UNECE Regulation 39 on speedometers.

4.3.3.2 Operational

When entering a speed restricted zone or transitioning to a zone with a lower limit, the vehicle must comply with one of the following two performance specification options;

- Option 1
  - There shall be no intervention by any vehicle system to enforce a speed reduction.
  - The system will impose the speed restriction of the previous zone until the driver brings the vehicle below the prevailing speed limit.
  - When the vehicle drops below the prevailing speed limit, the vehicle shall then be actively limited. This shall be termed the Restricted Operating Mode (ROM). This is to prevent unpredictable behaviour by the vehicle.

- Any vehicle speed in excess of the prevailing limit, at any time, should be notified to the driver.

- Option 2
  - There shall be no intervention by any vehicle system to enforce a speed reduction. Energy recovery and engine retardation are permitted
  - The system will impose a speed restriction as soon as all conditions of ROM are met.
  - The driver should be notified of any enforced retardation of the vehicle.

When in a speed restricted zone and the vehicle is below the prevailing limit there shall be no change in the vehicle performance characteristics.

When a vehicle is in ROM and either:

- exits a speed restricted zone,
- enters a zone with a higher limit,
- or deactivates itself for any reason, for example as a consequence of loss of GPS position or speed signal (however sourced), then

the system should guard/mitigate against the vehicle accelerating unexpectedly if the accelerator pedal is depressed during the transition.

When the vehicle exits a speed restricted zone the vehicle shall be returned to normal operating mode.

It shall be possible to disable the speed limiting system when the ignition is on and the vehicle is stationary. This shall be possible for qualified personell only and not for the driver. As a minimum, the action of disabling the system shall be possible by connecting a suitably equipped laptop to the vehicle. Manufactures may also provide an additional means of disabling the system using the fleet management telematics.

4.3.3.3 GPS Accuracy and Driver Warnings

In the event of loss of GPS, FMS or CAN speed signal the system will fail safe whereby no digital speed map limit is implemented.

The system shall guard/mitigate against spurious signals/GPS inaccuracy for instances when a vehicle is travelling along parallel roads with varying limits or travelling through complex road junctions. The vehicle must travel a distance of at least 30 metres continuously inside a speed restricted zone and be within that zone for at least 5 seconds before the conditions for imposing ROM are applied.

Once the requirements above are met, the conditions for imposing ROM must be applied within 3 seconds.

Under the following conditions the ISA system must display a green continuous dash lamp:

- System installed, functioning correctly and inside speed restricted zone.
- Transitioning between speed restricted zones
- Enforcing a speed limit (Restricted Operation Mode).

Under the following conditions the ISA system must extinguish the green lamp and display continuous white dash lamp:

- Vehicle in fail safe mode (signal loss)
- Vehicle not within a speed restricted zone
- System disabled

Under the following conditions the ISA system must extinguish the green lamp and display continuous white & amber dash lamps:

- System fault present affecting the operation of ISA
- Any other condition resulting in the condition of ROM not not being implemented

4.3.3.4 Map Management

TfL shall provide a Digital Speed Map which identifies all speed restricted zones to be applied by the ISA system.

The file will be made available in one of the follow formats on request to TfL.

- Shapefile (ESRI)
- MITAB (MapInfo)
- KMZ (Google KML)
- GeoJSON (Geographical Java Script Object Notation)
- Geodatabase (gdb)
- GPKG (Open GeoPackage)

The Bus Operator shall ensure that any updates to the map are uploaded to the vehicle within 5 weeks of being released.

It is envisaged that TfL will carry out an annual map update to capture changing speed limits. Note: any reduction in carriageway speed limit prior to ISA map update being available, does not absolve the drivers of responsibility for adherence to speed limits or appropriate speed.

Whilst this is envisaged to be the norm, TfL would require operators to maintain the capacity to update maps immediately on an ‘extraordinary measures/emergency’ basis.

The digital speed map updates may be uploaded using portable data storage or existing local wi-fi network systems. To be agreed by Original Equipment Manufacturer (OEM) and bus operator.

An additional antenna for updating the digital map is prohibited.

4.3.3.5 System Failure

In the event of a system failure the system shall notify the driver via displaying an amber light, that the system has a fault. The fault shall be logged in the bus memory until inactive and memory is cleared.

ISA is a driver aid to improve driver performance. Drivers remain capable of driving the vehicle at safe speeds even when the system is unavailable. Thus, system failures or other that lead to a activation of the white & amber light combination does not mean the vehicle is unroadworthy (subject to any change in regulation).

4.3.4 Vision from vehicles: General

All buses shall allow the driver to have sufficient vision of his or her 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 performing low speed manoeuvres.

4.3.5 Blind Spot Mirrors

All buses shall, in addition to the mandatory fields of vision described in UN ECE Regulation 46, be able to see two rectangular areas on the ground plane with boundaries defined as described below.

- Nearside (Left Side) Blind Spot Zone:
  - Forward boundary: parallel to the frontal plane of the bus and 0.5m rearward of the driver's ocular reference point
  - Rearward boundary: parallel to the frontal plane of the bus and 4m rearward of the driver's ocular reference point
  - Inner boundary: parallel to the longitudinal plane of the bus and passing through the outermost point of the nearside (left side) structure of the bus within the forward/rearward boundaries
  - Outer boundary: parallel to the longitudinal plane of the bus and 2m outboard from the inner boundary defined in (c) above.
- Offside (Driver Side) Blind Spot Zone:
  - Forward boundary: parallel to the frontal plane of the bus and 0.5m rearward of the driver's ocular reference point
  - Rearward boundary: parallel to the frontal plane of the bus and 4m rearward of the driver's ocular reference point
  - Inner boundary: parallel to the longitudinal plane of the bus and passing through the outermost point of the offside (driver side) structure of the bus within the forward/rearward boundaries
  - Outer boundary: parallel to the longitudinal plane of the bus and 2m outboard from the inner boundary defined in (c) above.

These ground plane areas should be measured in accordance with the methods prescribed in UN ECE Regulation 46.

The reflecting surface and coefficient of reflection of the mirror achieving visibility of the above zone shall comply with the requirements for a class V mirror in UN ECE Regulation 46.

The bus manufacturer or, where installed as a component on an existing vehicle, the mirror supplier, shall provide documentary evidence of compliance with these requirements.

4.3.6 Camera Monitor System (CMS): Reversing

All buses shall be equipped with a rear-view (Class I) Camera-Monitor Systems (CMS) compliant with UNECE Regulation 46.

In order to ensure optimum interaction with the driver, the CMS shall in addition meet the following criteria:

- Rear-view CMS monitor images shall only be visible to the driver when the reverse gear is engaged

The bus manufacturer or, where installed as a component on an existing vehicle, the CMS supplier, shall provide documentary evidence of compliance with these requirements.

4.3.7 Enhanced Indirect and Direct Vision

This total requirement only applies to new vehicles entering the fleet from 2024 as per the Bus Safety Roadmap for new build buses

All buses shall be assessed in accordance with the bus vision standard testing and assessment protocols (Attachment 19), reporting the direct vision performance score (DVS) and overall bus vision standard performance score (BVS) for each bus model or bus model variant (as appropriate).

All buses shall meet the minimum direct vision performance score (DVS) requirement of [85]%.

All buses shall meet the minimum overall bus vision standard performance score (BVS) requirement of [85]%.

The bus manufacturer shall provide documentary evidence of compliance with these requirements.

4.3.8 Camera Monitor System (CMS): Mirror Replacement

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

All buses shall use Camera-Monitor Systems (CMS) compliant with UNECE Regulation 46 to replace physical mirrors, at least for the class II field of vision defined by the same Regulation and the blind spot fields of vision defined by the bus vehicle specifications for blind spot mirrors (section 4.3.5).

In order to ensure optimum interaction with the driver, the CMS shall in addition meet the following criteria:

- [Human-machine interface requirements to be determined based on additional studies/trial results]

The bus manufacturer or, where installed as a component on an existing vehicle, the CMS supplier, shall provide documentary evidence of compliance with these requirements.

4.3.9 Front & Nearside Blind Spot Warnings

This requirement only applies to new vehicles entering the fleet from 2024 as per the Bus Safety Roadmap for new build buses

All buses shall provide additional information to drivers to inform them about the potential hazards presented by vulnerable road users in close proximity to [the front and nearside of] the bus, or intervene if necessary, to support the safe execution of the low speed, close proximity, driving tasks required in service in London.

All buses shall have a system installed that informs the driver of the presence of vulnerable road users in close proximity [to the front and nearside of] the bus, provides a warning signal to the driver if the bus is on a collision trajectory with a vulnerable road user [during nearside-turn and moving-off manoeuvres] and/or intervenes if a collision is unavoidable [during moving-off manoeuvres]. The installed system shall have one or more of these functions:

- VRU proximity information signal and/or;
- VRU collision warning signal and/or;
- Motion inhibit

All buses shall be assessed in accordance with the Blind Spot information, Warning and intervention (BSW) systems standard testing and assessment protocol (Attachment 24), reporting the BSW performance score for each bus model or bus model variant (as appropriate). Each bus shall achieve a score of [60]% or more

The bus manufacturer or, where installed as a component on an existing vehicle, the Blind Spot information, Warning and intervention system supplier, shall provide documentary evidence of compliance with these requirements.

4.3.10 Pedal Application Error

4.3.10.1 Footwell camera

A camera shall be installed in the driver footwell area to provide full and uninterrupted coverage of brake and acceleration pedal operation.

The foot well camera shall:-

- Maintain good image quality under all lighting conditions, including the capability of operating in "zero lux" conditions (e.g. using infrared if necessary)
- have a minimum IP65 rating
- be integrated into the main CCTV recording system to maintain security water marks, consistent time code, date stamp, and bus information (speed, location, and fleet number)
- A separate standalone camera with internal memory card is not permitted

4.3.10.2 Pedal use indicator lights system

This is a driver aid intended to help prevent pedal misapplication and may help recovery from a pedal confusion event. The system has no control over vehicle trajectory or velocity. It does not absolve the driver of responsibility for following safe driving procedures and pressing the correct pedal at all times.

A light-based visual indicator shall illuminate when the accelerator pedal is positioned at >80% of maximum demand.

The light shall be located in a suitable location such as the dashboard or an LCD information screen.

The light shall be large enough so it is clearly visible from the driver's seat.

The light shall not negatively affect the driver's direct or indirect vision of the road, the cabin or the interior of the bus.

The accelerator light shall be designed and installed such that:

- maintenance and repair is as convenient as possible.
- it complies with to the requirements set out in 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 system must be fully integrated by the bus OEM. Post vehicle homologation fitment of aftermarket equipment is also permitted as long as the work is undertaken by the bus OEM.

Information on the position of the brake and accelerator pedals shall be taken from existing on-board sensors via the CAN bus, or some other suitable signal input with an accuracy of ±1%.

Any delay between first movement of the pedal and the lamp achieving most of its steady state output, as a consequence of either delays in electrical transmission of the signal or in terms of the lamps ability to respond quickly to that signal, shall be sufficiently small as to appear instantaneous to the driver.

The CAN bus data supplied to the system must be accurate enough to determine when the driver is pressing the accelerator pedal.

The Pedal use indicator lights shall

- operate automatically without the need for the driver to activate or deactivate the system.
- operating in all driving scenarios.
- be tested according to the protocol defined in Attachment 26 and be certified as a "Pass".
- have no adverse effects on other vehicle operations and systems.
- not distract the driver from completing their driving tasks.
- illuminate one uniform colour whenever accelerator pedal position >80% of maximum
- not illuminate at a position of ≤80% of maximum accelerator pedal position

Only a qualified and authorised engineer shall be able to disable the system following the procedure set out by the vehicle manufacturer. It should be possible to shut down the system through a laptop connected to the vehicle.

It shall only be possible to disable the system when the bus is stationary, with the engine switched off and the ignition on.

In the event of a system failure the following requirements are applicable

- The driver shall be warned of a system failure through the activation of an amber warning light on the dashboard.
- The system is a driving safety aid. It will be perfectly feasible for a careful and competent driver to drive the vehicle safely without this assistance. As such, a system failure shall not be deemed to render the vehicle unroadworthy (subject to any change in regulation).

4.3.10.3 Brake toggle system

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

The brake toggle system is intended to provide a regular refresh of the driver's memory of the use of the brake pedal. The system aims to help prevent pedal misapplication and may help recovery from a pedal confusion event. The system has no control over vehicle trajectory or velocity. The driver is ultimately responsible for pressing the correct pedal at all times.

The system is intended to ensure that the brake pedal must be fully depressed and then fully released before the bus can pull away from stationary for the first time since the doors were last opened or the ramp last deployed.

The system must be fully integrated by the bus OEM.

The system shall be integrated with the vehicle's CAN bus, or other suitable information transmission system, so that it can receive the required real-time information on the position of the brake pedal. The signal shall be accurate to ±1%.

The Brake Toggle System shall

- operate automatically without the need for the driver to activate or deactivate the system.
- be capable of operating in all driving scenarios.
- be tested in accordance with the protocol defined in Attachment 26 and achieve a score of 7.
- have no adverse effects on other vehicle operations and systems.
- ensure that the halt brake will only release after the brake pedal is fully depressed and then released. As such, the vehicle will be incapable of movement until the brake has been applied and released, even if the throttle pedal is depressed.
- release the halt brake no more than 500ms after the driver releases the brake pedal.

Only a qualified and authorised engineer shall be able to disable the system following the procedure set out by the vehicle manufacturer. It should be possible to shut down the system through a laptop connected to the vehicle.

It shall only be possible to disable the system when the bus is stationary, with the engine switched off and the ignition on.

The driver shall be warned of a system failure through the activation of an amber warning light on the dashboard. This warning light shall be separate to the one allocated to the pedal application indicator lights

If a fault occurs with the halt brake system, rendering it inoperable, then a red warning light shall activate along with a text message asking the driver to stop the bus when it is safe to do so.

Any fault with the system shall log a diagnostic trouble code in a suitable memory system at least while the fault is active and preferably for a significant period of time after the fault is active unless manually cleared.

4.3.10.4 Halt Brake

The halt brake shall be engaged whenever the centre bus doors are opened or the passenger ramp is lowered. It shall not activate in any other circumstances.

4.3.10.5 Pedal acoustic feedback system

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

An audible accelerator pedal feedback system should be fitted to quiet running vehicles to provide an audible cue to avoid pedal confusion. The following requirements apply:

- The feedback system shall have a master volume control that can only be set by the bus manufacturer to prevent increasing the noise levels inside the saloon of the bus.

- The level set by the manufacturer shall be audible by the driver and not cause undue annoyance. (Levels to be defined by testing using ISO 5128 -1980 (E); Acoustics - Measurement of Noise inside Motor Vehicle).
- A local Driver volume control shall also be incorporated that will allow the driver to reduce the volume of the system to a pre set minimum level (not to switch off) and also not increase the volume beyond the manufacturers pre-set point.
- The feedback speaker(s) should be mounted behind the drivers head area at ear height.
- 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.

Note : Consideration should be given to the utilisation of existing equipment, such as speakers already fitted to the bus, which could be beneficial in reducing the amount of equipment around the drivers head.

4.3.11 Runaway bus prevention

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

The runaway bus prevention system will not replace the halt brake but instead will work in concert with it 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.

The system shall:

- Act on the park brake and not the service brake such that it is not possible for air leakage over time to result in bus movement
- As a minimum automatically detect driver seat pressure, driver cabin door status, passenger door status and park brake activation status.
- Be tested in accordance with the protocol defined in Attachment 28 and achieve a score of 12 in each checklist to result in a 'Pass' certification.
- not activate in a situation where the bus is already intentionally in motion (moving >5 mile/h and driver in seat). The system shall not act as an emergency brake if the driver loses control of the vehicle while driving.

The seat sensor is specified as a measure of whether the driver is present in the cab, and relying only on the cab door being shut is insufficient. If some other means to identify the driver presence in the cab is technically preferrable by manufacturers then this may be submitted with evidence and schematics for consideration by LBSL.

Should a failure be detected in any element of the system while the runaway bus prevention system has already (correctly) activated the parkbrake, it shall continue to apply the park brake until such time that a qualified person activates or permits activation of the auxiliary release mechanism in order to safely release the bus.

In the event of a sensor failure that would cause the runaway prevention system to render the vehicle immobile (despite the fact that a runaway bus event is not in progress) the auxiliary release system should be engaged to disable the system and allow the bus to return to the depot to have the sensor repaired/replaced. In the event of a sensor failure that does not cause the runaway prevention system to render the bus immobile then there shall be a warning light to indicate to the driver and the system shall be disabled to prevent unintended activation.

4.4 Partner Assist

4.4.1 Acoustic Conspicuity

Buses shall be fitted with a reversing alarm that issues an audible warning of “white sound” whenever reverse gear is selected and the vehicle is in motion. The system shall incorporate a driver’s cab time delayed isolation override.

All quiet running buses of categories M2 and M3 are fitted with a front emitting Acoustic Vehicle Alerting System (AVAS) which is fully compliant with UN ECE Regulation 138[1]. This include electric, hybrid and other alternative powertrains that are quiet running.

A two channel directional AVAS should be selected.

Note: Early discussions with an AVAS manufacturer revealed that two options were available. These were an ECU with integrated speaker and an ECU with separate speaker (2ch). This gives options when maximum dimensions, size and weight constraints are considered.

A 2 channel system is preferred because it allows for the two main accident scenarios to be catered for, that being stepping off the kerb and already crossing in front of the bus. The output speakers shall be concealed at the front of the bus:

- Horizontal plane - up to a maximum 0.6 m either side of the centre line of the bus
- Vertical plane - between 0.5 m to 1.0 m (Normally 0.8 m)

The speaker(s) must be installed such that they have an unobstructed sound path in the direction they are intended to be effective.

The speakers shall be positioned one on each side of the bus front. Each speaker shall have a horizontal beamwidth/directivity pattern in the range 120^{o} to 140^{o} and a vertical beamwidth/directivity pattern in the range 70° to 110°.

The centre line of the speakers shall be aligned towards the nearside kerb at an angle of 20^{o} to 30^{o} from the front surface of the bus.

If the two speakers are playing the same sound, the sounds shall be incoherent to avoid interference patterns affecting conspicuity.

The AVAS should be capable of receiving an updated sound file in the future, via telematics or a USB type device.

The system shall have the capability to have at least 3 sounds stored on the system (one sound at installation / entry into service, then a further two additional sounds)

[1] UN ECE Regulation 138; Uniform provisions concerning the approval of Quiet Road Transport Vehicles with regard to their reduced audibility.

The sound to be used with the AVAS for London buses is LBSL Urban bus sound, version 1.0.

The AVAS shall be assessed according to Attachment 30 and be shown compliant.

4.4.2 Visual Conspicuity

The housings for driver's near side and off side mirrors shall be coloured yellow in their entirety.

No additional warnings or markings shall be present on the all-yellow mirror head.

4.5 Occupant Protection

4.5.1 Staircase

Double-deck buses must have a forward ascending 9-step straight staircase with a step tread depth not less than 230mm, and a step riser of not more than 245mm located as on the agreed bus layout drawings in Attachment 8.

Hand rails must be provided to both sides of staircase, continuous throughout its profile, with no potential hand traps.

An additional off side (body panel side) horizontal handrail on the staircase is required, to improve passengers' handhold options when using the staircase. Attachment 8 shows a typical arrangement as an example.

Exposed butt ends to handrails are not permitted anywhere on the staircase or its access.

Headroom throughout the staircase should be sufficient to minimise risk without the need to provide impact protection.

Finishing edges shall be high quality moulded covers that cope with high passenger volume operation

If transparent materials are used to provide the aisle side staircase panel in the lower salon, it should be of obscured material to achieve a decency screen for staircase users.

If interior panel / corner finishing is utilised, it should be of suitable quality / standard to cope with high wear operation, and if damaged, should not present an immediate increased safety risk.

4.5.2 Seats

Tip up seats are not generally permitted anywhere on the bus However these will be considered by LBSL where they can demonstrate an improvement in safety and/or customer experience.

Seats should be forward facing, except where the chassis design function over wheel boxes necessitates inward or rearward facing.

4.5.3 Handrail/stanchion construction and installation

All handrails and stanchions shall be constructed such that they form a smooth tube of between 30mm and 35mm in diameter and finished in powder coating or nylon dipped (both with a matt crackle finish). Handrails and Stanchions should be coloured, yellow (RAL 1028), green (RAL 6018) or orange (RAL 2028). Any alternative colours will require the prior approval of the Nominated Officer.

Staircase handrails shall be of identical cross section to the main saloon handrails

A longitudinal waist height handrail shall be provided, forming a continuous passenger waist height hand grip support from the front passenger door entrance / driver cab area to the beginning of the passenger seated area or staircase steps.

Door partition handrails, positioned to assist boarding and alighting, must be fitted at all entrance and exit points, excluding emergency exits.

Seat back to ceiling handrails (with bell push) are required at all forward facing seats in the lower saloon and at alternate seats in the upper saloon.

All bell push buttons shall be coloured red with surrounds coloured such that they contract with both the red bell push and the hand poles, whatever their colour.

Where horizontal hand rails are fitted in standing areas, bell pushes, as described above, must be placed in a position so as to limit the risk of accidental activation by passengers leaning on them.

Horizontal rails above the wheel chair and/or standing areas to be fitted with hanging grab hand holds of the flexible type. These grab hand holds shall only be used in the low floor area and must not be placed in entrance / exit doorway areas.

4.5.4 Guards for exposed seats

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, as specified in the 06 series of amendments for UNECE Regulation No. 107[2].

Note: The UK DfT proposed this amendment which was adopted as part of the 06 series of amendments, supplement 5. For vehicles approved following EC whole vehicle type approval (ECWVTA), it is expected that these amendments will be mandatory circa 2020. Previously, Regulation 107 specified that guards must be fitted for exposed seats behind step wells, only.

Guards for exposed seats shall:

- have a minimum height from the floor on which the passenger's feet rest of 800 mm and shall extend inwards from the wall of the vehicle at least as far as 100 mm beyond the longitudinal centre line of any seating position where the passenger is at risk.
- be enclosed (i.e. the size of any aperture shall not exceed 50 mm) and the lower edge of the guard shall not be more than 100 mm from the floor on which the passengers feet rest.

[2] https://www.unece.org/fileadmin/DAM/trans/doc/2015/wp29grsg/ECE-TRANS-WP29-GRSG-2015-34e.pdf

4.5.5 Bus Interior Safety Assessment

Level 1 requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

Level 2 requirement only applies to new vehicles entering the fleet from 2024 as per the Bus Safety Roadmap for new build buses

Bus interior safety shall be assessed according to the protocol defined in Attachment 34. Assessments shall be undertaken for each bus model / variant in a service ready condition.

The bus interior safety assessment score counts potential hazards. Thus a bus with a lower score, with less potential hazards, is better. Two levels of safety are considered. To be certified as meeting level 1, then the bus must achieve a score of:

- Lower deck ≤ [80]
- AND Upper deck (if applicable) ≤ [8].

Note: Main changes anticipated are in the middle door area including incorporation of guard in front of seats behind wheelchair area and modifications to guard for seats behind middle doors.

To be certified as meeting requirements level 2, then the bus must achieve a score of:

- Lower deck ≤ [30].
- AND Upper deck (if applicable) ≤ [4].

Note: Main changes anticipated are throughout the whole bus to achieve an improved rating for handrails, restraint and general hazards. Improved restraint is also likely to require fitment of some seats with higher backs.

4.5.6 Flooring and Slip prevention

The following requirements apply:

- Floor coverings shall have joints minimised.
- Colour contrasting step nosing shall be used on all step edges in accordance with the PSVAR 2000.
- There should be no cross hatching (or any other marking) of the floor area rear of the “Do not stand forward of this point” sign.
- There shall be no cross hatching (or any other marking) of the floor area forward of the “Do not stand forward of this point” sign.
- Slip resistant flooring shall be fitted throughout passenger saloon area.
- The slip resistance of all flooring material types shall be characterised under wet conditions and in all directions as per the test and assessment protocol.
- All flooring material types shall, at the point of entering service, provide a slip resistance of at least 36 (Pendulum Test Value) PTV.

- All flooring material types shall, after 100,000 passengers have accessed the vehicle, or after an in-service period of 6 months, whichever is sooner, provide a slip resistance of at least 40 PTV.
- Thereafter, all flooring material types shall, for a period of 7 years from the point of entering service, provide a slip resistance of at least 40 PTV (based on an annual assessment).

Floors shall be tested according to the protocol defined in Attachment 32 and achieve a 'Pass'

Compliance with these requirements shall be demonstrated by providing LBSL with documentary evidence of the performance of flooring material types in the form of United Kingdon Accreditation Service (UKAS) certificates.

4.5.7 Door Safety

Front, entrance to be inward glider type, flush fitting to the body side when closed and one piece full depth glass in each door leaf for maximum driver view of kerb side.

Centre or rear, entrance or exit doors to be outward slider type, flush fitting to the body side when closed and one piece full depth glass in each door leaf for maximum view of kerb side.

All door header panels must provide adequate prevention against finger ingress to the door operation mechanism

Door or door partition handrails positioned to assist boarding and alighting must be fitted at all entrance and exit points and must be shown on the approved arrangement drawings as Attachment 5

Overhead illumination, of door opening area must be provided at minimum levels as stated in section 8.2.

Door closing audible warning device on all exit doors, to be of beeping sound and not to exceed 75dba, when measured at 1m height from the body floor on centre line of the bus and exit door. It should be noted that:

- White sound noise type will also be considered
- Voice or other tones are not acceptable.
- Warning on exit door opening is not permitted

See also Section 4.3.10.4..

4.6 Partner Protection

Bus front ends have been identified as one of the key contact points of the vehicle in collisions with vulnerable road users (VRU). Several different safety features are required to minimise the injury potential in those collisions.

In all assessments of these features, the physical or virtual test vehicle to be assessed shall be configured at its maximum ride attitude from the ground plane, with its mass in running order (the nominal unladen vehicle and driver mass), tyres inflated to manufacturer recommended pressures and vehicle suspension set to normal running conditions (as specified by the manufacturer for a speed of 40 km/h).

4.6.1 VRU Frontal Crashworthiness: Minimum Geometry

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

All bus front ends are required to have a geometric design that both improves protection for VRUs during the primary impact of a collision and reduces the risks of VRUs being subsequently run-over.

All buses shall have a front end geometry that complies with the minimum bus front end geometry requirements for both vertical rake angle and horizontal curvature.

Vertical rake angle is specified as an angle in the longitudinal plane formed at the intersection of the vertical transverse plane of the vehicle and a plane located at a tangent to the test point surface. The minimum requirements shall be:

- Minimum vertical rake angle of [1]° ±0.5° tested at the worst-case location between vertical heights of [0.8]-[1.2] m from the ground plane and across the test vehicle width at the bus front end; and
- Minimum vertical rake angle of [4]° ±0.5° tested at the worst-case location between vertical heights of [1.2]-2.0 m from the ground plane and across the test vehicle width at the bus front end.

Horizontal angle is specified as an angle in the horizontal plane formed at the intersection of the vertical transverse plane of the vehicle and a plane located at a tangent to the test point surface. Minimum requirements shall be:

- Minimum horizontal angle of [15]° ±0.5° tested at the worst case location between lateral positions of 0-0.3 m from the most lateral aspect of the test vehicle width at the bus front end and between vertical heights between [0.8]-2 m from the ground plane; or
- Wrap around windscreen and bumper bus front end design with a radius of curvature of >0.3 m tested at the worst case location between lateral positions of 0-0.3 m from the most lateral aspect of the test vehicle width at the bus front end and between vertical heights between [0.8]-2 m from the ground plane.

Bus front end features and components with a cross section of less than 236 mm x 236 mm shall be exempt from these requirements.

Test vehicle width shall be defined as the distance between two points located at the most lateral aspects of the vehicle structure (see ISO 612-1978 for component exemptions) and coincident to the first axle.

Compliance may be established through either a CAD based approach or physical testing. The bus manufacturer shall provide documentary evidence of compliance with these requirements.

4.6.2 VRU Frontal Crashworthiness: Enhanced Geometry

This requirement only applies to new vehicles entering the fleet from 2024 as per the Bus Safety Roadmap for new build buses

The Enhanced Geometry is defined as for the minimum geometry above except that the following requirements shall supercede their equivalents defined by the minimum geometry:

- Minimum vertical rake angle of [8]° ±0.5° tested at the worst-case location between vertical heights of [0.8]-2.0 m from the ground plane and across the test vehicle width at the bus front end.
- Minimum horizontal angle of [15]° ±0.5° tested at the worst case location at lateral positions >0.5 m outboard from the longitudinal centreline of the bus front end and between vertical heights of [0.8]-2 m from the ground plane; and
- Minimum horizontal angle of [30]° ±0.5° tested at the worst case location between lateral positions of 0-0.3 m from the most lateral aspect of the test vehicle width at the bus front end and between vertical heights between [0.8]-2 m from the ground plane.

4.6.3 VRU Frontal Crashworthiness: Energy Absorption

This requirement only applies to new vehicles entering the fleet from 2024 as per the Bus Safety Roadmap for new build buses

All bus front ends, in the region of potential head contacts, are required to have a construction that absorbs energy to improve protection for VRUs during a collision and in the event of a contact at that location on the vehicle.

All buses shall have their VRU impact safety performance tested and assessed in accordance with the bus VRU impact test standard, as defined in Attachment 36.

All buses shall have front ends which are energy absorbing or sufficiently compliant and/or frangible to meet the performance requirements of the bus VRU impact test standard.

No bus shall have a headform impact test result leading to a head injury criterion (HIC15) value in excess of [1,300].

All buses shall meet the minimum bus VRU impact test performance score (BITS) requirement of [25%].

4.6.4 VRU Frontal Crashworthiness: Wiper Protection

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

Windscreen wipers, and in particular the windscreen wiper bosses and spindles, that are mounted in the region of a potential VRU impact provide rigid structures that may cause greater injuries if struck. Windscreen wipers are therefore required to be positioned above the windscreen or have a construction that absorbs energy to improve protection for VRUs during an impact.

All buses shall have the impact safety performance of their windscreen wipers tested and assessed at their worst case location in accordance with the bus VRU impact test standard as defined in attachment 36.

Windscreen wipers mounted at a height of greater than 2.0 m from the ground plane shall be exempt from this requirement.

No [new] bus shall have a windscreen wiper spigot:

- Lower than 2.0 m from the ground plane, and
- With a headform impact test result leading to a head injury criterion (HIC15) value in excess of [1,300].

4.6.5 VRU Frontal Crashworthiness: Class II CMS

This requirement only applies to new vehicles entering the fleet from 2021 as per the Bus Safety Roadmap for new build buses

In order to avoid situations where mirrors and mirror arms collide with vulnerable road users, all buses shall be fitted with a class II CMS to replace the main mirror. These devices shall be as specified by section 4.3.8.

4.7 Miscellaneous Safety features

All wheel arches shall be fitted with tyre blow out protection liners

Headroom should be sufficient at all positions throughout the bus without the need to provide impact protection or warning notices.

In addition to emergency controls on main entrance and exit doors, exits may be provided via main saloon windows or a suitably positioned exit door. These window positions or door must be shown on the general arrangement drawing as approved in Attachment 5.

Double-deck buses shall be fitted with a substantial near side front tree guard, located into the structure of the bus, giving additional forward protection to the front seated passengers, exterior dome and near side corner window-pillar.

5 Environmental Performance

5.1 General

The combined engine and transmission acceleration controls should limit the bus to a rate that delivers an acceptable LBSL emissions performance whilst still providing the driver with adequate acceleration performance in the fully laden condition.

Full bodywork insulation shall be fitted to sides, roof, front and rear and internal bulkheads where appropriate to minimise heat loss from the heated passenger saloon to the environment in cold weather and to minimise heat intrusion from the engine into the passenger saloon, particularly in warmer conditions.

5.2 Air quality and emissions

The tailpipe emissions from the bus shall be measured according to the process defined in Attachment 1 and shall fall within the limit values specified in that Attachment.

Bus production lead times to certification shall be minimised at times of Euro legislation updates, providing the earliest introduction of latest emissions legislation. No advanced registration of earlier Euro status engines will be accepted.

The use of BS EN 590:2000 (50 ppm sulphur) compliant diesel fuel is a minimum requirement. Fuel utilised may also be subject to verification by a LBSL testing procedure.

Any alternative fuels, additives, after treatments, power sources or technology that may potentially change the agreed emissions standards will require the prior consent of LBSL before their use in LBLS's contracted bus fleet. Manufacturer / Supplier funded testing over the LBC cycle under LBSL supervision is required to establish that the technology proposed delivers emissions standards that are better than the equivalent currently used standard bus.

Exhaust fumes should be delivered on or below the bus skirt to the rear of the bus, either at the offside portion of the rear of the bus, or on the offside of the bus, behind the rear axle. Exhaust fumes shall not be emitted at the near side of the bus. If any exhaust fumes are not delivered on or below bus skirt level, they should be delivered at roof level with the final position agreed with LBSL prior to bus manufacture / design.

To prevent engines running long periods at idle, an automatic engine shutdown system shall be incorporated. The engine shall be automatically shut down when the bus is stationary for 2.5 minutes, with the park brake applied. The driver shall be provided with an audible 1 minute warning of the shut down and have the facility to override back to the 2.5 minutes of stationary operation.

5.3 Carbon dioxide emissions

The bus manufacturer shall, for all hybrid buses and zero tail-pipe emission buses, provide a statement of the embedded carbon footprint of the bus covering initial manufacturing to disposal at the end of a 14 year life cycle. This calculation shall exclude fuel, oil and tyres used during operations.

Engine cooling fans shall be environmentally efficient. Hydraulically driven engine cooling fans shall not be permitted.

5.4 Noise emissions

The braking system should use disc brakes at each wheel station in order to minimise brake squeal.

The exterior and interior noise level of the bus shall be tested and assessed using the method defined in Attachment 2. The completed vehicle supplied for testing either by the manufacturer or an operator shall be fully compliant with all other aspects of this specification and be fitted with all equipment necessary for operation in London.

The results of the test shall demonstrate that the drive-by noise test emissions are at least 1 dB less than the legal limit (diesel buses) or 2 dB less than the legal limit (hybrid buses) defined in type approval regulation. Zero Emission Buses shall be at least 3 dB less than the legal limit

All noise test results may be subject to LBSL verification at any time.

The manufacturer shall demonstrate compliance with this requirement by providing a copy of both the type approval certificates relating to the noise tests and a LBSL type approved noise statement, as set out in Attachment 2.

5.5 Infrastructure protection

Buses shall be equipped with road friendly suspension, which is defined as a suspension system where at least 75% of the spring effect is caused by an air spring or where the suspension is recognised as equivalent to air suspension using the definitions of Annex II of Council Directive 96/53/EC on authorised weights and dimensions.

6 Operational Efficiency

Buses shall be capable of high frequency, stop-start, fully passenger laden PSV operational schedules, operating in adverse traffic conditions, during typical London weather conditions. The typical operational parameters are 18 hours per day, 7 days per week, 364 days per year, with an average operational speed of between 6 and 12 mile/h, and a minimum average daily range of 150 miles without the need to refuel the bus.

The bus proposed must be suitable to achieve a minimum efficient operational life within London of 14 years.

6.1 Vehicle capacity

Manufacturers must have general dimensions, seating and layout arrangement drawings agreed by LBSL as scheduled in Attachment 5. These individual manufacturers' drawings should comply with the detail below. They are deemed to be approved by LBSL if marked with a valid a LBSL reference number issued from the Nominated Officer. The respective manufacturer's LBSL reference number must be quoted on all proposals. If a manufacturer cannot provide the approved LBSL reference number, a fully dimensioned general arrangement drawing for the proposed bus must be provided by operators submitting a bid based on the use of that vehicle. LBSL reserves the right to not consider bids unless this condition can be satisfied.

Any amendments to any of these layout drawings will require the approval of LBSL before a bus constructed with the revised layout can be used in service in London.

A laden and kerb / un-laden weight chart by axle and total against GVW shall be provided for the completed bus Body Layout Option. This must be approved by LBSL. Any significant changes to this standard must be notified to LBSL.

Unladen weight has a relationship to fuel economy and buses should be designed to maximise their fuel economy.

The standing capacity of the bus will be determined by the lower of the calculation be weight (using 68kg per person) and no more than 6 standees per square meter in the areas of the bus where standing is permitted.

All buses should comply with the general dimensions and capacities defined in Table 6-1 and a layout drawing identifying the actual dimensions and capacities for the bus shall be provided to LBSL.

Table 6-1: General Dimensions and Capacities

Passenger capacity (minimum)		Single deck Single door 36		Single deck Single door 45		Single deck Dual door 50		Single deck Dual door 55		Single deck Dual door 60		Single deck Dual door 70		Double deck Dual door 87	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Overall Length*	metres	7.8	7.9*	8.9	9.0*	9.3	9.9*	10.1	10.4*	10.4	10.9*	11.5	12.0*	10.1	10.9*
Overall Width*	metres	2.30	2.55*	2.45	2.55*	2.45	2.55*	2.45	2.55*	2.45	2.55*	2.45	2.55*	2.45	2.55*
Overall Height (non- Zero Emission)*	metres	2.85	3.10*	2.85	3.10*	2.85	3.10*	2.85	3.10*	2.85	3.10*	2.85	3.10*	4.20	4.42*
Overall Height (Zero Emission only)*	metres	2.85	3.40*	2.85	3.40*	2.85	3.40*	2.85	3.40*	2.85	3.40*	2.85	3.40*	4.20	4.42*
Aisle headroom at centre line	metres	1.83		1.83		1.83		1.83		1.83		1.83		1.83	
Seat Width	mm	440		440		440		440		440		440		440	
Aisle Width (between seats) - top of seat back	mm	590		590		590		590		590		590		590	
Aisle Width (between seats) - bottom of seat back	mm	535		535		535		535		535		535		535	
Objective Wheelchair space **	metres	2.0		2.0		2.0		2.0		2.0		2.0		2.0	
Entrance & Exit step Height (Un-knelt)	mm		320		320		320		320		320		320		320
Entrance & Exit step Height (knelt)	mm	265	240	265	240	265	240	265	240	265	240	265	240	265	240
Entrance & Exit Door Headroom	mm	1840		1840		1840		1840		1840		1840			
Entrance Door Clear Width	mm	1200		1200		1035		1035		1035		1035		1035	
Exit door Clear Width	mm	n/a		n/a		1200		1200		1200		1200		1200	
Passenger capacity:-															
Total		36		45		50		55		60		70		87	
Low Floor Seated: Priority		4		4		4		4		4		4		4	
Low Floor Seated: Preferential (in addition to Priority)		2	4	2	4	2	4	2	4	2	4	4		4	
Total Seated Lower Deck		18		24		24		26		30		35		21	
Total Seated Upper Deck		n/a		n/a		n/a		n/a		n/a		n/a		41	
Total Standing (assuming <6 people/sqm of standee floor space)		15		20		24		26		28		32		22	
Wheelchair		1		1		1		1		1		1		1	
Standing with wheelchair		11		18		20		22		24		28		18	

*= Subject to being able to traverse the specified route and serve all stops safely

**= target - subject to a agreement on total capacity and seating a minor reduction may be permitted

6.2 Energy efficiency – Electric Vehicles

Manufacturers and Operators need to be satisfied that the battery capacity, charging regime and battery life of vehicles are suitable and appropriate for the route(s) on which they are proposed, including the heating and cooling requiremens set out in this specification.

To maximise interoperability between electric buses and charging systems, the charging interface should meet industry-recognised, open protocols – whether de-facto or published international standards. The charging interface 'standard' which defines the physical connection or electromagnetic coupling between vehicle and its charging system can include:

- Orientation/ alignment of the vehicle with respect to the charging connection

Location of charging connection/ interface on the vehicle

- Communication protocols between vehicle and charging system
- Dimensional parameters/ boundaries (whether conductive via plug-and-socket or pantograph, or wireless/ induction)

6.3 Minimising dwell time

The choice of the number of doors fitted to a bus shall be informed by an analysis of the effect of dwell time at typical bus stops on the route intended for.

London Bus generally operate a two door system with the entrance door forward of the front axle and the exit door between front and rear axle. When single or three door buses are requested, the front door remains unchanged, the centre door is deleted or duplicated at a specified area of the bus.

Requirement for all doorways are as follows:

- Entrance and front door exit only shall provide an individual clear width of 1035mm minimum (1100mm for single door vehicles excluding door mounted handrails) and utilise an equal width two door leaf closure
- Exit doors to provide an individual clear width of 1200mm minimum (excluding door mounted handrails) and utilise an equal width two door leaf closure

6.4 Fleet management

6.4.1 CCTV/Audio recording

Colour Digital CCTV shall be fitted to all buses and shall provide the specific functionality defined in Attachment 11.

Evidence shall be supplied to demonstrate that

- recording systems fully comply, at all times, with the relevant principles of the General Data Protection Regulations (GDPR)

- operators have registered for this type of application with the Information Commissioner's Office
- Privacy Impact Assessment (PIA) has been completed and signed
- PIAs will be reviewed periodically to ensure measures continue to remain proportionate and/or necessary.
- A full detailed privacy notice has been placed on your company website, with the website information included in the space on the sign.

Recording equipment will be subject to periodic auditing for installation compliance and serviceability.

Where audio recording (which is optional) is installed, these requirements apply to both continuous and driver activated recording devices, (eg Incident Data Recorders). Close proximity (directional) microphones must be used to ensure only conversations in the immediate area around the driver cab can be heard. Signage informing passengers that audio recording is operating in the driver's cab area shall be installed. This will be issued by LBSL.

6.4.2 Fleet Management System

All buses shall be fitted with Fleet Management System version 3, unless specifically exempt as agreed with LBSL.

The Fleet Management System should be compliant with the requirements set out in Attachment 3.

All buses shall be provided with ducting and cable runs to ease the installation of additional equipment. These shall meet the requirements defined in Attachment 4.

6.4.3 Communications

LBSL will issue, free of charge, iBus equipment to operator or manufacturer against each set of new vehicles confirmed by LBSL

All buses must make provision for the installation and suitable protection of this equipment. The approved package of installation must consider the free issue iBus equipment as an integral part of the design of the vehicle.

For full details of the installation principles recommended, refer to the generic 'iBus Installation Manual' [Document Ref: LBSL Equipment for new buses Installation manual BHN01 170970V15] which has been issued to all bus manufacturers. A copy of the 'iBus Installation Manual' is available on the Hyperion server to all bus operators.

For any new bus types or modifications to the roof area of existing designs, the position of the antenna must be approved by LBSL Drawings showing the roof layout and positions/ dimensions of all roof mounted equipment must be submitted as part of the general arrangement drawing.

The bus communications antenna should always be positioned on the highest point of the roof and spaced well away from any other objects or obstructions.

In order to maintain the omnidirectional radiation pattern of the antenna and to avoid the shielding of radio signals in certain directions, a minimum spacing between the antenna and any other object that protrudes above its mounting point must be observed:

- Objects up to 300mm in height above the antenna mounting point must be spaced at least 1000mm away from the antenna.
- For objects that are between 300 and 500mm in height, the minimum spacing must be increased to 2000mm.
- If the item height exceeds 500mm, please contact LBSL's Radio Infrastructure Engineer.

No electronic equipment may be located in the roof space directly underneath or within 500mm of any part of the bus antenna. Any cables routed within this zone must be fully screened and bonded to the vehicle earth at both ends.

6.4.4 Ticketing

LBSL will issue, free of charge, a ticketing machine, base plate and smart card readers to operator or manufacturer against each tender award.

All buses must make provision for the installation and suitable protection of this equipment. The approved package of installation must consider the free issue ticketing equipment as an integral part of the design of the vehicle.

For full details, refer to the installation and provision of electrical supply to the Ticket Machine as described in the document "Guidelines for Bus Builders for the installation of Ticket Machines with Smart Card Readers", published by the ticketing system supplier and available from LBSL

Note: The ticket machine and equipment will be installed after a bus arrives in London.

The ticket machine base position must be provided with a clean power supply that is maintained for 30 minutes after shutdown.

7 Accessibility

The completed bus must be designed as a low floor.

A minimum of 4 priority seats shall be provided. and must be clearly identified by the standard (LBSL Issue) notice.

A minimum of a further 2 additonal "preferential" passenger seats shall be provided in the low floor area (see table 6-1), for passengers who are less able to stand or who are travelling with small children. These will be of similar space requirement to the priority seats. Preferential seats must be clearly identified by the standard (LBSL Issue) notice.

Priority or preferential seating on the low floor area shall maximise under-seat space as much as possible, for use by guide or assistance dogs. The height from the floor to the top of the seat cushion should be approx 490mm to achieve this

All of these seats will be fully defined on the approved seating layout as scheduled in Attachment 5.

All buses must make provision to carry a wheelchair and its occupant. Buses shall be designed such that wheelchair access is via the door positioned mid wheelbase on two or more door buses or via the front door on single door buses.

An access ramp shall be provided to enable wheelchairs to ride across the gap between kerb and vehicle. Access ramps shall:

- Be power operated by driver controls;
- Telescopic single or two stage ramp platform type with minimal deviations in surface plane;
- have a total platform length of no less than 1000mm when fully deployed. This length must not include any section of the floor;
- not incorporate a hinged lowering floor section or any similar design arrangement intersecting with the top of the ramp platform;
- Incorporate exterior ramp request buttons adjacent to the wheelchair entrance / exit door. These must be positioned clear of the open door position;
- Be installed in a way that maximises protection of the ramp from damage and operational reliability;
- incorporate an audible warning of ramp deployment. The warning shall be of beeping sound and shall not exceed 75dB(A), when measured at 1.25m height from the exterior ground, on the centre line of the exit door at a distance of 1.5m.
- automatically undertake a partial operation extending cycle of approximately 50mm deployment on every start-up of the bus. This is to test the ramp and remove any loose dirt or debris from ramp mechanisms. The ramp deployment audible warning device must not sound during this test operation.
- display a constant warning light in the driver's cab if operation of the ramp fails in service. This shall remain illuminated whenever the bus is in use, until a successful ramp operation occurs.

- Be positioned such that he ramp forward edge is recessed at the centre door from the main bodywork exterior by not less than 25mm and ideally by 35mm. The area between the lower edge of the closed door leaf and the floor should be protected against water or any other form of material ingress.
- function on all kerb surfaces likely to be encountered on London streets.

Objective wheelchair area length shall be ≥2000mm unless agreed otherwise by the Nominated Officer. The wheelchair area shall be located on the off side:

- opposite the wheelchair entrance / exit door (two or more door buses.)
- immediately rearward of the driver's cab and wheel box (where appropriate) (Single door buses).

The wheelchair interior manoeuvring area and the ramp deployment area must be monitored by CCTV and displayed on the driver's cab monitor when doors are open.

The wheelchair area shall provide alternative buggy space and standing area when not in use by a wheelchair user. Suitable hand rails and leaning rails must be provided for this purpose.

A wheelchair logo shall be incorporated into the floor covering, readable by a person facing the off side of the vehicle. The logo shall display the rearward facing position of the wheelchair. The full wheelchair area shall be coloured blue (as close as possible to the blue used on the wheelchair notice, PMS 300) and the wheelchair logo shall be coloured white. The wheelchair logo must comply in size and appearance to that shown in Attachment 7. The designated wheelchair area must be shown on the respective manufacturer's bus layout drawings as defined in Attachment 5.

The main floor covering surrounding the wheelchair area may be coloured at the discretion of the operator but must offer substantial colour contrast compared with the full wheelchair area.

The wheelchair floor to ceiling security handrail must have two bell pushes. The lower (blue button, facing forwards) to activate ramp request (as required by PSVAR2000) and a higher (red button, facing rearwards) as a standard bell push.

The wheelchair stanchion hand pole should not attach to the floor to allow for unhindered manoeuvres into and out of the wheelchair area.

The ramp request blue button push operation must activate an alternative sound from that of the standard bell push. The alternative sound must be:

- audible each time the button is pressed
- clearly audible from the wheelchair position
- easily accessible by the wheelchair occupant while in the recommended travelling position.

The blue ramp request button when pressed must

- illuminate a ramp request light in the driver's cab
- be clearly visible
- remain illuminated until the wheelchair exit door is opened

A manual or automatic security arm shall not be used to replace the floor to ceiling handrail.

Note: Special attention to the design and positioning of the vertical stanchion pole around the wheelchair area is required to ensure the wheelchair manoeuvrability space is optimised for access and egress. A fixed anti-slew wheelchair restraint design arrangement to the aisle side of the wheelchair area that avoids the stanchion being fixed to the floor would be a preferred option. In addition, special attention must also be given to ensuring the blue access ramp request button is easily reached by the wheelchair occupant travelling in the recommended rear facing position.

Stanchion pole design/arrangements must be such that standing passengers are not able to support themselves in the seating position.

All bell pushes are required to be marked in brail with the brail symbol for the letter S, as shown in Figure 7-1, and the word 'STOP' in white. This is to provide additional assistance to the iBus audible information announcements.

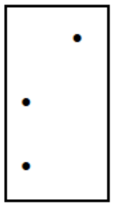


Figure 7-1: Brail symbol for S

Bell pushes at priority seating areas must be positioned such that they are within easy reach, and passengers can remain seated while operating them.

Buses shall be fitted with an induction loop system linked to iBus announcements, and for driver-passenger communication with T band electronic hearing device(s). The following areas must be covered by induction loop(s):

- Passenger entrance platform / cab interface
- Priority seating positions
- Wheelchair area

The induction loop zones must provide sufficient audio frequency levels to ensure passengers using T band electronic devices can comfortably hear the driver and iBus announcements when positioned in each of the above areas.

Each bus type will have unique differences depending on seating layout, single/double deck, loop pad size, panel design, and available space behind panelling. The induction loop installation standards should take all of the design features into account to ensure the system functions are at the optimised operating range, providing the best possible service to customers.

A driver's cab microphone, for communicating with passengers using T band equipment must be:

- active at all times when the bus is in service.
- positioned to the side or above the driver partition screen.

Nationally accepted signage/notices shall be attached at each location identifying induction loop zones.

The induction loop supplier and OEM must provide to LBSL a specification document for each bus type showing:-

- exact pad location using visible datum points and measurements for loop positioning
- audio frequency field strength using diagrams showing coverage along swept area, horizontal and vertical axis
- background noise, interference does not exceed the recommended limits as defined in standards BS7594, BS6083, BS6840, BS EN 60118

To ensure consistency in testing methods and standards; the height measurements within the swept area must be specified to ensure all passenger groups including seated, wheelchair users and standing passengers have a clean audio signal free from interference.

Only testing and measuring equipment approved by the induction loop supplier must be used

8 Occupant Experience

8.1 Driver cab ergonomics

The general layout shall be suitable as a working environment and be ergonomically designed to assist and protect the driver.

The windscreen in front of the driver shall have a tinted section at the top or a suitable sunblind

A driver operated PA system (for driver to passenger communications) will be provided as part of the iBus system.

The cab area must be designed to accommodate the iBus system as described in section 4.3.2, 4.9 and 4.10 of the generic iBus installation manual (BHN01 1709 70V15) with details of the optimal and acceptable zones recommended for placement in the cab of the driver's iBus MDT terminal, microphone and speakers.

The cab area must be designed to accommodate the ticketing equipment as described in electrical section and in the specification document "Guidelines for Bus Builders for the installation of Ticket Machines with Smart Card Readers", published by the ticketing system supplier and available from LBSL

8.2 Passenger saloon ergonomics

All side glass windows (excluding doors and driver's signal window) of identical tinted glass, where legally permitted.

- Solar energy transmittance of not more than 65%
- Light transmittance of not more than 80%

As part of the iBus system, illuminated display signs providing passengers with information on the next stop will provided (on both decks where applicable). These shall be suitably positioned for maximum visibility to passengers. Suitable mouldings and fixings for the LBSL provided iBus signs must be provided. Duplication of this iBus signage is not permitted with LBSL's consent.

Interior saloon lighting shall provide the minimum levels of illumination at the locations defined below:

- Seats, 150mm above cushion level: 150 Lux
- Aisles, at floor level on bus centreline adjacent to each and every seat:100 lux.
- Steps, at floor level at the centre of entrance and exit steps: 100 lux
- Double deck stairs, at floor level on the centre of every tread: 100 lux

The interior saloon lighting shall be automatically switched off when exterior ambient illumination levels are sufficiently high.

Turning on of the interior lighting shall remain under the driver's control.

8.3 Heating, Ventilation & Air Conditioning (HVAC)

Passenger saloon general ventilation should be provided by opening (hopper vent) side windows.

On single deck buses such windows shall be provided at all full size bays.

On Double Deck Buses such windows shall be provided:

- Lower deck
  - At all full size bays
- Upper deck
  - At foremost full size bay, nearside and offside
  - At rearmost full size bay, nearside and offside
  - At one other full size bay, nearside and offside

At least 11% of the total surface side glass area (excluding door glass and destination glass) should be of the open hopper type, providing an open area air gap of not less than 3.5% of total glass area.

An air conditioning system for the driver's cab shall be provided and shall be fully controlled by the driver

A cab screen demisting system shall be provided and shall be fully controlled by the driver. It shall be capable of operating independently from the saloon heating, upper deck cooling or cab air conditioning.

All buses shall be equipped with:-

- A fully automatic heating and ventilation system with saloon operational temperatures set as defined in Attachment 9.
- Blown air heating and ventilation system to both lower and upper deck where appropriate. The system should provide a good circulation of air throughout the length of the bus interior. Convection only systems are not acceptable.
- Fully automatic thermostatic control of the system. The thermostatic sensors should be positioned to reflect the interior, upper and/or lower deck temperature of the bus and be in a tamper proof location. Heated or unheated air should be circulated throughout the bus dependant on interior bus temperature. It should not be necessary for the driver, maintenance teams or any other parties to adjust or set the heating or ventilation system during variations of temperature, such as during summer and winter periods. If engine bay "maintenance only" shut off valves are required, they must utilise an independent hand tool and not be capable of being adjusted by lever or hand operation. The system should be designed to enable a full operational check of component functions and settings in the regular service routine.

Double-deck buses shall also be equipped with an air cooling system for the upper saloon with operational temperature set as shown in Attachment 9. This system must be capable of reducing the internal saloon temperature by 5ºc when subject to an interior saloon temperature of 28ºc by inputting at variable fan speeds suitable quantities of conditioned and cooled air via saloon length ducting. Compliance with this requirement shall be demonstrated by means of a LBSL pull down test as defined in Attachment 9.

Each of these systems shall be integrated into a fully automatic heating and ventilation system that avoids operational conflicts in accordance with Attachment 9.

The driver shall not be able to override the automatic heating / cooling systems for the passenger section of the bus. Any maintenance or testing function must be automatically reset to its full operational condition after every engine restart.

In addition zero emission bus types must have a zero emission heating solution (ie diesel heaters are not permitted).

A pre heat capability to soak upper and lower deck interior areas with forced heated air to warm up the side panels, hand poles and seating surfaces may be used. Such a interior pre heat process must have a separate power supply to that of the main battery charging. Any pre heating process must not impact on bus battery charging

8.4 Seating

Operators should provide generous seat pitches throughout the bus to permit ease of movement and local stowage of hand luggage. Particular attention to generous spacing should be given to the seats in the upper saloon on double-deck buses. General arrangement drawings and capacities shall be agreed with LBSL by manufacturer as part of Attachment 5 and should not be adjusted without prior approval from LBSL.

Individual passenger seats shall be installed at all seating positions and shall be no less than 440mm wide, including moulded panel areas, except when identified and accepted on drawings in Attachment 5

Seats shall be equipped with securely fixed, replaceable seat and back pads. These seat and back pads shall be of sufficient thickness and quality to provide a good quality of comfort and support for passengers.

Any seat backs and pads that are moulded into body panels must provide equivalent levels of comfort to that provided by the main saloon seating.

8.5 Mobile phone and tablet charging points

For all new buses, USB power supply and charging points should be provided at all seating areas and the designated wheelchair area and shall be capable of charging typical mobile phones and tablet computers. They should where possible be mounted in seat backs.

Installation of USB power supplies must be such that:-

- Each individual plug-in port must incorporate an inline fuse
- Each plug-in port maintains the seat back profile, and does not protrude from the panel surface panel by more than 4mm
- The plug-in port is finished in a colour that would not be mistaken for a bell push

- they are tamper proof
- they have a minimum IP54 rating
- they are E marked
- Plug- in ports must not be located within any head impact zones (such as the top of the seat in front; this would be classed as a hazard in the Occupant Friendly Interior Assessment in Attachment 34)
- The plug-in port for the designated wheelchair area must be accessible for the wheelchair occupant when in the recommended travelling position

9 Aesthetics & Image

Closed circuit television (CCTV) security cameras, monitors, digital recording devices, safety enhancments, iBus and ticketing systems are considered an integral part of the bus design and the necessary visual attention to their design and installation detail must be taken. Wiring looms should be integrated by the OEM`s where possible.

10 Route and destination board, signs and notices, livery, advertising etc

10.1 Destination and Route Number displays

Buses shall be equipped with power operated front, side and rear destination displays simultaneously controlled by one route / destination selection unit in the driver's cab. It is essential that all displays are correctly positioned and coordinated whilst a bus is in service, regardless of the equipment type used, and this is the Operator's responsibility. It shall be possible for the driver to easily identify from the cab seat that the front display is correctly positioned. Dimensions for all display units shall comply with the requirements of Attachment 10.

All destination displays shall use Transport for London's New Johnston condensed font in white on a black background including out of service or any other passenger information.

All destination displays shall be fully back illuminated by LED type lighting systems and automatically illuminated at all times. Light sources shall be positioned at the horizontal centreline of each blind, providing an even distribution of illumination across the full blind area.

No light illumination gaps shall be visible around any point on the displays from the exterior view of the bus.

No logos, signs or abbreviations are permitted on the destination display. The approved ultimate and intermediate display wording will be provided by LBSL by the formal Route Record.

Where double letters or numbers occur on any display, additional separation space shall be provided to improve identification.

Blind jockey rollers or other devices must be utilised when necessary to keep blinds taught and as close as possible to the glazing line

All displays shall be equipped with an exterior anti-vandal impact and anti reflection overlay.

The front route display shall show the ultimate destination with a single track number in a side by side arrangement.

- The front visual display shall be no smaller than that defined in Attachment 10.
- The ultimate destination shall be displayed at the maximum height/size available. A proportional reduction in font size is permitted only where necessary to accommodate long destination points.
- The ultimate destination sight size (visible area) shall not be less than 1160mm in width and 330mm in height.
- The route number shall utilise the full depth available from the display height and shall have a sight size of not less than 450mm in width and 330mm in height.

- The destination shall display the wording defined in the Route Record issued by LBSL only, no intermediates, logos, qualifiers, curtailment points or any other information that is not part of the approved wording shall be shown

The nearside route display must have the ultimate destinations and single track number in a side by side arrangement. The route number must be shown to the forward most point of display.

- Equipment may be a combined single track or split number but in either case must achieve the dimensions defined in Attachment 10
- The ultimate destination and route number shall utilise the full first window bay width
- The side visual display shall be no smaller than that defined in Attachment 10
- The ultimate destination sight size shall not be less than 687mm in width and 210mm in height
- The route number shall utilise the full depth available from display height and the sight size shall not be less than 270mm in width and 210mm in height.
- The height of the horizontal centreline of the characters in the display shall not be less than 1200mm or more than 2500mm from ground at the normal bus ride height.

The Rear route display shall display a number identical to the independent front route number display.

10.2 Running numbers

Running number boards (if utilised) must be positioned and displayed in a manner that cannot be misinterpreted as a route number. They should to the sides of the vehicels on the bodywork, or if in the windscreen area in a position that does not in any way obstruct the drivers' view.

- The character font must be yellow on black
- Font size shall not be greater than 200mm in height
- The display shall be of a professional appearance.
- Soft print copy taped or positioned adjacent to windows is not permitted

10.3 Other internal and external signs and notices

Exterior and interior notices are provided by LBSL as listed in the notices guidance booklet, and must be fitted in the appropriate positions.

All such notices shall be as defined in the booklet Manufacturers' Application Procedure. These notices may be obtained by bus manufacturers or operators FOC from the current supplier Stewart Signs.

Specific operator notices shall not be permitted, for example

- Operator specific Welcome Aboard notices (on driver's cab door, panels, glass, or in floor covering)
- No notices, information, legal address, recruitment or any other advertising material is permitted on the interior or exterior of any window without prior permission of LBSL
- CCTV advisory notices
- Audio advisory notices

Notices provided by operator must be fitted in the appropriate positions:-

- Fleet numbers and operator identification code shall be marked on the roof. Operator codes shall be as defined in Attachment 13 with black cut out lettering of operator code over fleet number, character New Johnston Bold font 350mm in height, positioned on centre line of bus, transversely at rear of white roof section.
- Operator logo positions shall be as agreed in management document illustrations for each operator
- All external and internal legal notices, shall be in a single contrasting colour, cut out type if appropriate.
- All notices and signs to be in Transport for London's "New Johntson" bold or medium font unless legally required otherwise

10.4 External Advertising

Exterior advertising panels are permitted in the following areas when bus width permits:-

- Off Side
- Near Side
- Rear

All advert panels must be framed with the frame in London Bus Red, except where specific LBSL authority has been given to support a particular activity. Any non-standard, illuminated or special in any way advertising method or advertising display must be approved by LBSL prior to installation.

10.5 Paint colours and Livery

All buses shall be painted in a livery that is fully London Buses Red Reference ICI P498FPF3 or exact colour equivalent with the following exemptions

- White roof panels on both single and double decks to interior cove joint (i.e. not visible from pavement level) for heat rejection

- Road wheels are not to be repainted and should remain in the OEM's standard finish

The TfL Roundel is mandatory and should be fitted in accordance with guidance contained in the latest LBSL booklet.

Should the livery illustration(s) incorporated into your Framework Agreement not include a livery as described above, you should enclose a copy of the rear, front and side illustrations in colour of such a livery. This will be subject to prior approval by LBSL

11 Design for ease of maintenance

Closed circuit television (CCTV) security cameras, monitors, digital recording devices, iBus and ticketing systems are considered an integral part of the bus design and the necessary attention to their long term maintenance and repair must be taken into considering when they are installed. Wiring looms should be integrated by the OEM`s where possible. It is imperative that the necessary practical detail of assessing these components for maintenance purposes is taken into account.

Design and selection of materials utilised must facilitate ease of cleaning and be maintained to a satisfactory level of appearance throughout the in service bus contract period.

Attachment 1

LONDON BUS SERVICES LIMITED

London Bus Cycle (LBC)

1 Introduction

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

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

2 Normative References

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

3 Definitions

Test Authority: The test authority is an organisation designated by TfL to ensure comparative standards and quality of testing is achieved. Only an accredited testing authority can be used, a list of approved authorities is available on request to TfL

Test Bus: is the vehicle being assessed for its emissions performance

Kerb Weight:

ULW: Unladen weight of the bus when all fluid levels are filled to recommended levels but no driver, passengers or luggage are on board.

GVW: Gross Vehicle Weight is the maximum weight of the vehicle permitted by law or defined by the vehicle manufacturer, whichever is the lower.

Payload capacity: is the GVW minus the Kerbweight.

Test weight: Is the total mass of the vehicle at which testing shall be undertaken and is equal to the kerbweight plus the passenger load

Passenger load: The passenger load is a mass equal to the number of passengers multiplied by 68 kg plus 75kg to represent the driver.

ECU: Electronic Control Unit

4 Vehicle Preparation

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

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

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

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

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

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

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

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

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

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

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

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

5 Test Procedure & Limit Values

5.1 All Buses

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

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

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

5.1.4 Drivers cab demisters shall be turned on to full.

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

5.1.6 Interior heating shall be set at 17°C ± 2^0 C (if not automatically controlled) for diesel & diesel-electric hybrid vehicles, 15°C for battery & fuel cell electric vehicles with a ± 1^0 C variation during test permitted. Heating shall be switched on at the start of the warm up phase of the test procedure. Doors shall remain closed throughout the warm up phase.

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

5.1.7.1 Lower Saloon, 1m above the saloon floor

- centre front of bus (0.5m from windscreen).
- centre of middle aisle
- centre rear (0.5m from back of bus).
- next to front windscreen demister vent

5.1.7.2 Upper Saloon, 1m above saloon floor:

- centre front of bus (0.5m from windscreen).
- centre of middle aisle
- centre rear (0.5m from back of bus).

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

5.2 Conventional Diesel and Diesel Electric Hybrid Buses

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

- Outer Urban Phase
- Inner Urban Phase
- Rural Phase

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

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

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

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

5.2.6 To clarify;

- UKBC = Outer + Inner + rural phases
- LBC = Outer and Inner phases (Previously MLTB)
- 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
- Pre-test cycle warmup shall be an Outer Urban Phase, and shall be performed prior to each test run.

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

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

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

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

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

- Engine NOx, NO, NO2, HC, CO, CO2 at 1 Hz
- Tailpipe NOx, NO, NO2, HC, CO, CO2 at 1 Hz
- FTIR at tailpipe (NO, NO2, N2O, methane (CH4), NH3)
- Particle number to PMP method
- Three dilute 'bags' collected and analysed for NOx, CO, HC & CO2
- 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.
- Fuel Consumption is calculated using Carbon Balance Method, reported in Litres / 100km

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

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

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

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

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

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

5.3 Battery Electric Buses

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.4 Plug-in & Opportunity Charging Hybrid Buses

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

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

5.5 Fuel Cell Buses

5.5.1 The evaluation process is currently under development.

Attachment 2

LONDON BUS SERVICES LIMITED

Noise Test Procedure and Limit Values

1 Introduction

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

2 Normative References

ISO 10844:2014 – Acoustics: Specification of test tracks for measuring noise emitted by road vehicles and their tyres.

IEC 61672-1:2013 – Electroacoustics – Sound level meters – Part 1: Specifications

IEC 60942;2017 – Electroacoustics - Sound Calbrators

ISO 362:2007 – measurement of noise emitted by accelerating road vehicles – engineering method – part 1: M and N categories

United Nations Economic Commission for Europe (UNECE) Regulation 51: Uniform Provisions Concerning the Approval of Motor vehicles having at least 4 wheels with regard to their sound emissions - 03 Series of amendments.

ANSI S3.5-1969, “Methods for Calculation of the Spech Intelligibility Index”

3 Definitions

Sound Intensity is defined as the power carried by sound waves per unit area in a direction perpendicular to that area. Its standard unit is the watt per square metre. Clearly this is a complex measurement involving multiple units and the range of sound intensity can be very large. Thus, sound intensity is usually measured in Decibels (dB).

Decibels (dB) are effectively a logarithmic ratio of sound intensity relative to a threshold level of 0 dB. Zero dB is the quietest sound audible to a healthy human ear. From there, every increase of 3dB represents a doubling of the sound intensity.

Sound pressure level (SPL) is strongly related to sound intensity and is the difference between ambient air pressure and the peak pressure caused by the sound wave and is measured in units of Pascal. However, sound pressure levels are also often expressed in Decibels. Hearing is directly sensitive to sound pressure.

Maximum SPL is the peak value of SPL recorded during any given measurement peridod.

L_{EQ} is the Equivalent Sound Level and is defined as the constant sound level that would produce the same cumulative sound intensity as a sound whose level varies over a defined recording period

A-weighting: Sound intensity is spread out across a wide range of frequencies. However, the human ear is not as good at hearing very high or very low frequencies as it is those in the mid range. The standard decibel scale treats all frequencies equally and is referred to variously as flat, linear or Z weighted. An A-weighted decibel scale dB(A) has been developed that weights sound intensities at lower and higher frequencies differently so it more closely represents a human response to sound at relatively low levels.

Articulation Index (AI) is a quantitative measure of the intelligibility of speech; the percentage of speech items correctly perceived and recorded. An articulation index of 100% means that all speech can be understood, 0% means that no speech can be understood.

4 Test Site

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

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

5 Environmental Conditions

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

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

6 Instrumentation

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

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

7 Test Vehicle

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

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

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

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

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

8 Dynamic tests

8.1 General

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

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

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

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

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

8.2 Exterior

8.2.1 Vehicles with Internal Combustion Engines

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

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

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

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

8.2.1.5 The tests shall be completed with cooling fans disabled.

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

8.2.2 Vehicles with Hybrid (Parallel and Series) Powertrains

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

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

8.2.3 Stationary Vehicle Sound Emissions and Compressed Air Noise

8.2.3.1 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

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

8.3 Interior

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

- Driver, right-hand ear position.
- Forward most seated position, closest to centreline of test vehicle.
- Directly above rear axle, closest to centreline of test vehicle.
- Rear 5-way, centre seat.

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

- Forward-most, closest to centreline of test vehicle.
- Rear 5-way, centre seat.

8.3.3 Test conditions and measurements shall be:

- Constant speed, 16 kmh^{-1}, HVAC system off: LEQ SPL, 5 second measurements.
- Constant speed, 40 kmh^{-1}, HVAC system off: LEQ SPL, 5 second measurements.
- Acceleration speed, 16 - 40 kmh^{-1}, HVAC system off: Maximum SPL.

9 Static tests

9.1 General

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

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

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

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

9.1.5 Arithmetic average to be declared.

9.2 Exterior

9.2.1 Door Warning Device(s)

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

9.2.1.2 Maximum SPL shall be declared.

9.2.1.3 Requirements are applicable to each door.

9.2.2 Ramp Warning Device(s)

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

9.2.2.2 Maximum SPL shall be declared.

9.2.2.3 Applicable to each ramp fitted.

9.2.3 Interior

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

- Driver, right-hand ear position.
- Forward most seated position, closest to centreline of test vehicle.
- Directly above rear axle, closest to centreline of test vehicle.
- Rear 5-way, centre seat.

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

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

- Rear 5-way, centre seat.

9.2.4 Door Warning Device(s)

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

9.2.4.2 Maximum SPL shall be declared

9.2.4.3 Requirements are applicable to each door.

9.2.5 Ramp Warning Device(s)

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

9.2.5.2 Maximum SPL shall be declared.

9.2.5.3 Applicable to each ramp fitted.

9.2.6 Engine Idle, HVAC system off

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

9.2.7 Engine Idle, HVAC system on

Tests shall be undertaken at maximum fan speed.

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

10 Articulation Index (AI)

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

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

10.3 Average of AI values to be declared.

11 Sound Pressure Level Limits

Table 11-1. Limits for diesel buses.

Single/ Double	Test Element	Limit, dB(A)	AI, %
Both	8.2.1 ECE R51-03 “Motion”, Exterior	76/78/80[1]	N/A
Both	8.2.1 ECE R51-03 “Static” , Exterior	N/A	N/A
Both	8.2.3 ECE R51-03 “Compressed Air” , Exterior	72	N/A
Both	8.2.4 ECE R51-03 Improved, Exterior	75/77/79[2]	N/A
Single	8.3 Constant Speed, 16 kmh^{-1}, HVAC off, Interior	60	
Single	8.3 Constant Speed, 40 kmh^{-1}, HVAC off, Interior	67	
Single	8.3. Acceleration, 16 - 40 kmh^{-1}, HVAC off, Interior	68	
Double	8.3. Constant Speed, 16 kmh^{-1}, HVAC off, Interior	62/65[3] 52/54[4]	
Double	8.3 Constant Speed, 40 kmh^{-1}, HVAC off, Interior	69/70[5] 62/62[6]	
Double	8.3 Acceleration, 16 - 40 kmh^{-1}, HVAC off, Interior	70/72[7] 60/61[8]	
Both	9.2.1 Door Warning Device, Exterior		N/A
Both	9.2.2 Ramp Warning Device, Exterior	75	N/A
Both	9.2.4 Door Warning Device, Interior	75	N/A
Both	9.2.5 Ramp Warning Device, Interior		N/A
Both	9.2.9 Engine Idle, HVAC off, Interior		
Both	9.2.10 Engine Idle, HVAC on, Interior		

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

Table 11-2. Limits for hybrid buses

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	9.2.4 Door Warning Device, Interior	75	N/A
Both	9.2.5 Ramp Warning Device, Interior		N/A
Both	9.2.9 Engine Idle, HVAC off, Interior		
Both	9.2.10 Engine Idle, HVAC on, Interior		

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

Attachment 3

LONDON BUS SERVICES LIMITED

Fleet Management System (FMS)

(To Follow)

Attachment 4

LONDON BUS SERVICES LIMITED

Installation Specification for Fleet Management Systems

1 Introduction

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

2 Definitions

Cable: this is a generic term used for a wire or lom and an Ethernet cable.

Channel: a channel is an unrestricted free space through which a cable can be easily drawn. It can be specifically designed for the purpose or make use of the existing design.

Fixing, a point to which a cable can be secured.

Roof space, this is the entire void between the inner and outer roof and coving skins.

Void: an enclosed space.

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

3 General Principles for Cabling Access

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.14 All access panel fastenings shall be captive.

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

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

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

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

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

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

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

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

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

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

4 Enclosure Specification

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

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

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

Attachment 5

LONDON BUS SERVICES LIMITED

TfL Approved Bus Layouts

Attachment 6

LONDON BUS SERVICES LIMITED

Standard for the Fire Retardant Properties of Materials

1 Introduction

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

2 Normative References

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

BS476: Fire tests on building materials and structures

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

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

3 Requirements

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

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

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

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

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

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

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

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

3.3.6 Seat assemblies shall comply with BS5852 Crib 7

3.3.7 Body Insulation shall comply with BS 476 Class 2

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

3.3.9 Body and Floor insulation shall comply with BS476 Class 2

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

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

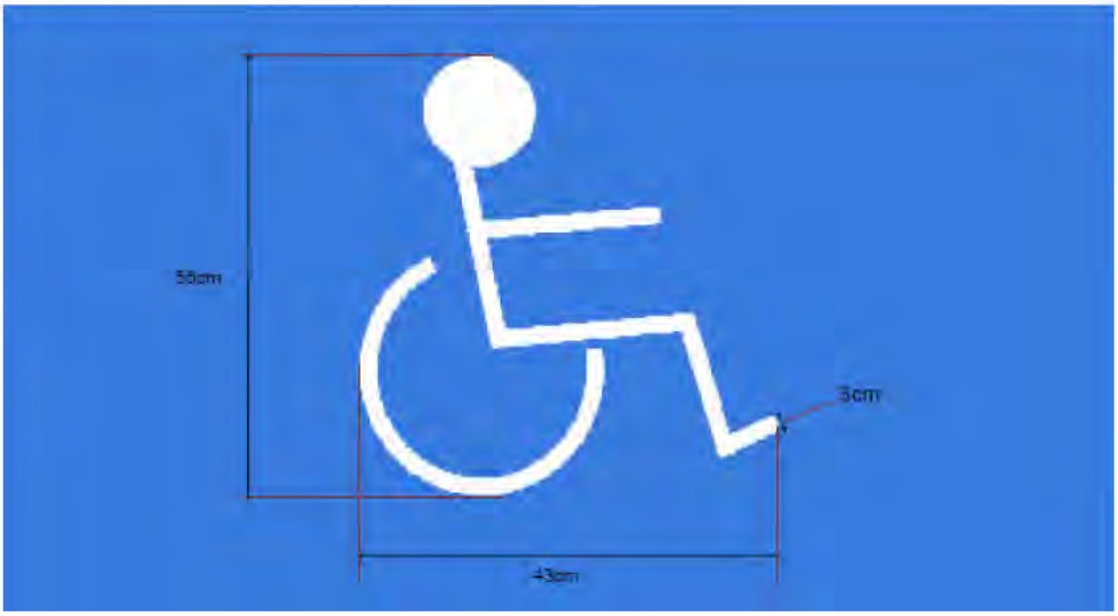
Attachment 7

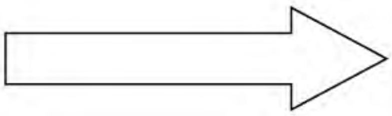
LONDON BUS SERVICES LIMITED

Wheelchair Floor Logo

1 Whelchair Floor Logo

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



To Rear of Bus 

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

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

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

Attachment 8

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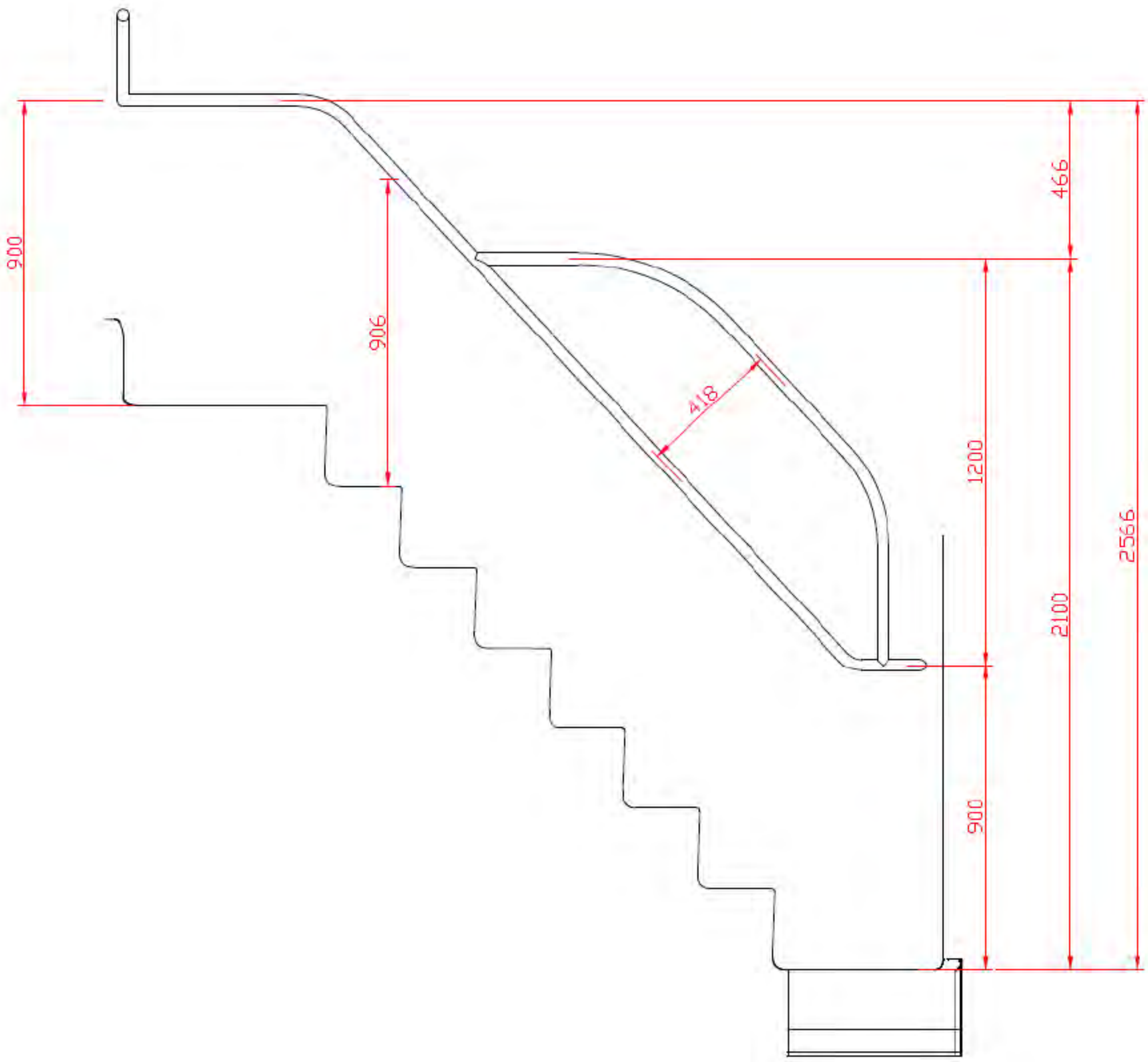
Staircase Handrail Layout

2 Body side staircase handrail

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



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

2.3 All handrails must be securely fixed to body structure

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

2.5 Continuous rails are the preferred arrangement

Attachment 9

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Heating Ventilation and Air Conditioning (HVAC)

(To Follow)

Attachment 10

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Destination Display Layout

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

LONDON BUS SERVICES LIMITED

CCTV

(To Follow)

Attachment 12

LONDON BUS SERVICES LIMITED

Exterior and Interior Notices

(To Follow)

Attachment 13

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Operator Codes and Fleet Number Identification

1 Operator Code Requirements

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

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

Typical Operator Code and Fleet Number Arrangement

Rear of Vehicle

All Characters shall be in New Johnston Bold font

Characters shall be in Matt Black cut out vinyl

Characters shall be 350mm in height

Attachment 14

LONDON BUS SERVICES LIMITED

Free Issued Equipment

(To Follow)

Attachment 15

LONDON BUS SERVICES LIMITED

Assessment Protocol:

Automated Emergency Braking (AEB)

Preface

This protocol covers the assessments to be carried out for Automated Emergency Braking (AEB).

Where a Vehicle Manufacturer perceives that a particular feature should be changed, this should be raised by the Vehicle Manufacturer with the Approval Authority (TfL) assessor present at the assessment, or in writing to the Approval Authority (TfL) Nominated Officer in the absence of an assessor. The Approval Authority (TfL) will assess the proposal based on their judgment and provide instruction to the Test Service.

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

Version	Published	Details
1.1	19/12/18	TfL AEB Assessment Protocol

Disclaimer

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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1 Introduction

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

1.1 Scope

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

1.2 Purpose

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

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

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

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

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

2 Normative references

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

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

3 Definitions

For the purpose of this Protocol:

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

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

(b) AEB Pedestrian – an AEB system that detects and responds to imminent collisions with pedestrians.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.8 **Test Target (TT)**: an item of test equipment accurately representing the characteristics of the relevant road user, as seen by the relevant sensing technologies used by AEB. A range of specific test targets are defined[1]:

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

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

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

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

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

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

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

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

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

4 Reference system

4.1 Local co-ordinates

A local co-ordinate system (x,y,z) for the VUT shall be defined such that the x-axis points toward the front of the bus, the y-axis towards the left and the z-axis upwards, as shown in Figure 1, below.

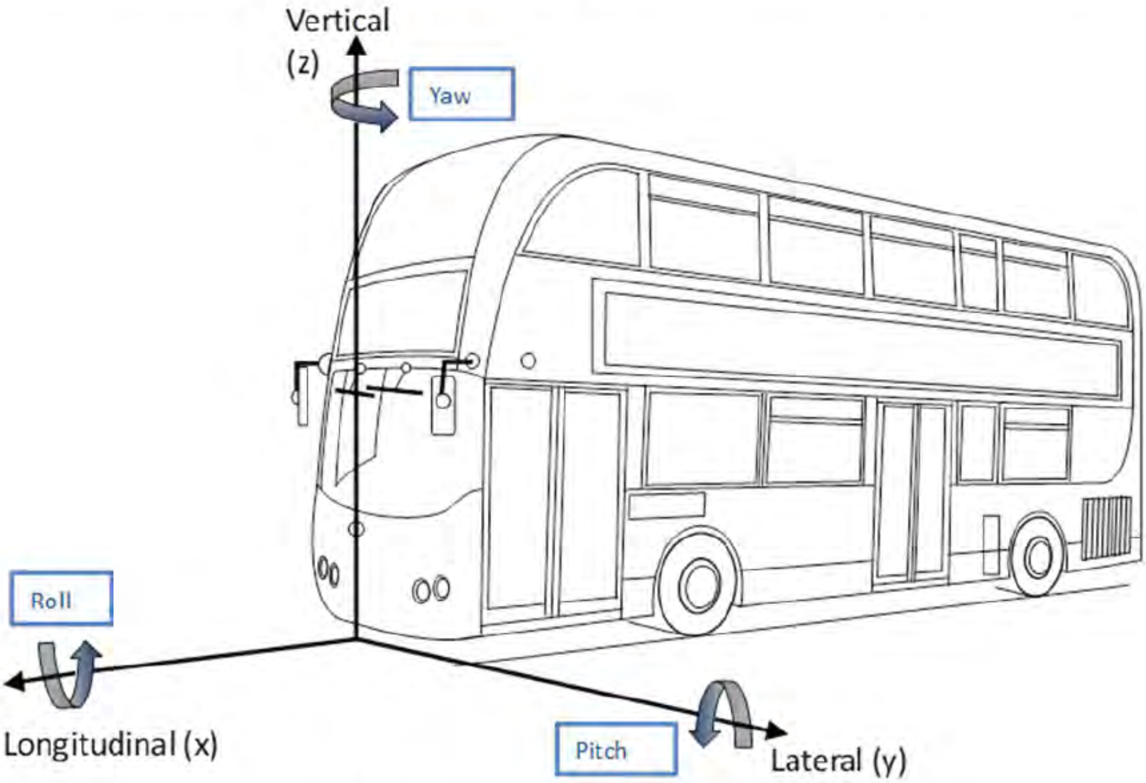

Figure 1: Local co-ordinate system and notation

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

4.2 Global co-ordinates

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

5 Measurements and variables

5.1 Variables to be measured

Table 1 and Table 2 show the variables which must be measured, along with the minimum operating ranges and measurement accuracy required.

Table 1: Variables to be measured continuously during each and every test with minimum operating ranges and measurement accuracy

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

Table 2: Variables to be measured periodically, ideally before each test but at least every 30 minutes, with minimum operating ranges and measurement accuracy

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

5.2 Measuring equipment

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

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

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

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

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

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

5.3 Variables to be derived from the measurements

5.3.1 General

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

Table 3: Variables to be derived from the measured data

Variable	Description	Definition/Derivation Method
A_{VUT_Long}	VUT Longitudinal Acceleration	The component of A_{VUTx} acting in the horizontal plane, or A_{VUTx} corrected for pitch angle
$A_{PEAK\_VUT\_Long}$	Peak Longitudinal Acceleration of VUT	The largest value of A_{VUT_Long} that occurs between the time T_{AEB} and the end of test
A_{VUT_Lat}	VUT Lateral Acceleration	The component of A_{VUTy} acting in the horizontal plane, or A_{VUTy} corrected for roll angle
T_0	The start of the test	Derived by recording the time T when the measured TTC first drops below 4s
TTC	Time To Collision	For every data point a calculation of the time taken for the VUT to reach the point of impact with the TT based on the current position of each and an assumption that the velocity of each (in the direction of travel of the VUT) remains constant
T_{AEB}	The time at which AEB activates	Find the first data point when the filtered A_{VUT_Long} is -1m/s^2 or larger, then move backwards in time to find the data point where the acceleration first crossed -0.3 m/s^2. The time at this point is T_{AEB}.
T_{FCW}	The time at which FCW activates	The time recorded at the first data point where FCW_A=True, based on recognition of the audible component of the warning. The means of recognition may need to vary depending on the exact system but may, for example, be achieved using a microphone in close proximity to the warning speaker where the signal is filtered with a pass band of 50Hz either side of the measured tone and dB(A) fast weighting applied, and noting the time when the weighted signal exceeds 50dB(A)
T_{Impact}	The time at which the VUT collides with the TT	See section 0.
V_{Test_VUT}	Nominal initial	Defined by specific test condition

Variable	Description	Definition/Derivation Method
	velocity of VUT before braking applied	
$V_{Test\_VUT\_Act}$	Actual initial velocity of VUT before braking applied	Average of V_{VUT} over the 1 second immediately before T_{AEB}
V_{Rel_Test}	The initial speed of the VUT relative to the initial speed of the TT	Subtract the component of V_{Test_TT} acting in the same direction as the V_{VUT} from. $V_{Test\_VUT\_Act}$
V_{Test_TT}	The initial speed of the TT	Average of V_{TT} between T_0 and T_{AEB}
V_{Impact_VUT}	VUT velocity at the moment that it collides with the Test Target	See section 0
V_{Impact_TT}	Test Target velocity at the moment that it collides with the VUT	See section 0.
V_{AEB_Red}	The reduction in VUT velocity achieved before impact as a consequence of AEB action	$(V_{Test\_VUT} – V_{Rel\_Impact})/V_{Test\_VUT}$
V_{Rel_Impact}	The relative impact speed between VUT and TT at the moment of impact	Subtract the component of V_{Impact_TT} acting in the same direction as the V_{VUT} from. V_{Impact_VUT}
Y_{Impact_Nom}	Nominal Impact Position on VUT if no braking occurred and V_{TT} remains constant	Locate T_{AEB} in the data file. Move forward in time in the data by the number of data points equivalent to the TTC recorded at the data point corresponding to T_{AEB}. Y_{Impact_Nom} is equal to the value Y_{TT} at this data point (actual for true positive tests, calculated for aborted crossing test).
Y_{Impact_Act}	Actual Impact Position on VUT	If no impact occurred this shall be recorded as not applicable. Where impact was deemed to occur, $Y_{Impact\_Act} = Y_{TT}$ when that impact first occurred.
Y_{VUT_Error}	Lateral path error of the VUT	Distance in y-axis between the centreline of the vehicle at the foremost point of the VUT

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

5.3.2 Determination of impact

Determining whether impact has occurred and, if so, at what time and speed, is undertaken using a virtual method. A virtual profile is defined around the VUT and each TT and related to the point on the VUT/TT that relates to the recording of its position (X_{VUT}, Y_{VUT}, X_{TT}, Y_{TT}). The first data point at which the recorded positions are such that the virtual profile of VUT and TT intersect is defined as the moment of collision. T_{Impact}, V_{Impact_VUT}, and V_{Impact_TT} are defined as the relevant time and speeds recorded at the moment of collision. This is illustrated in Figure 2, below:

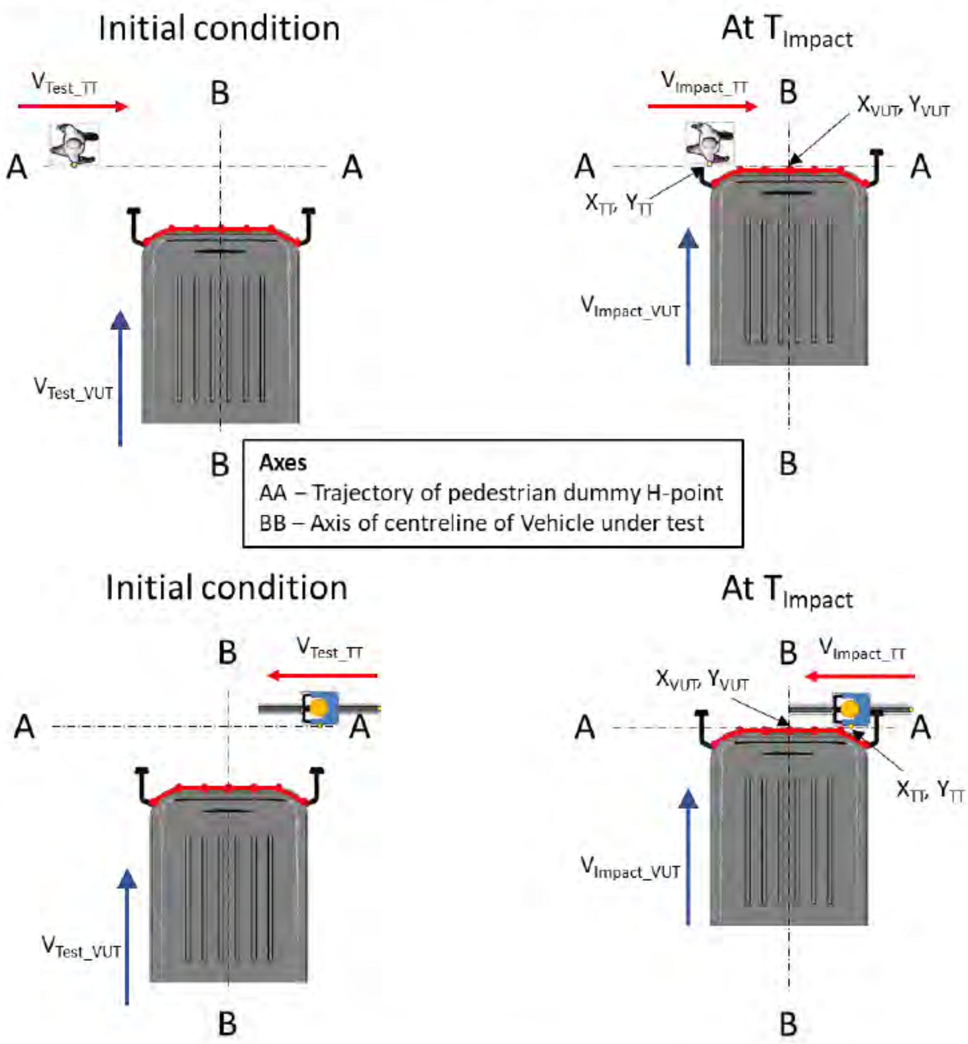

Figure 2: Illustration of the definition of the moment of impact (Pedestrian (top), Cyclist (bottom))

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

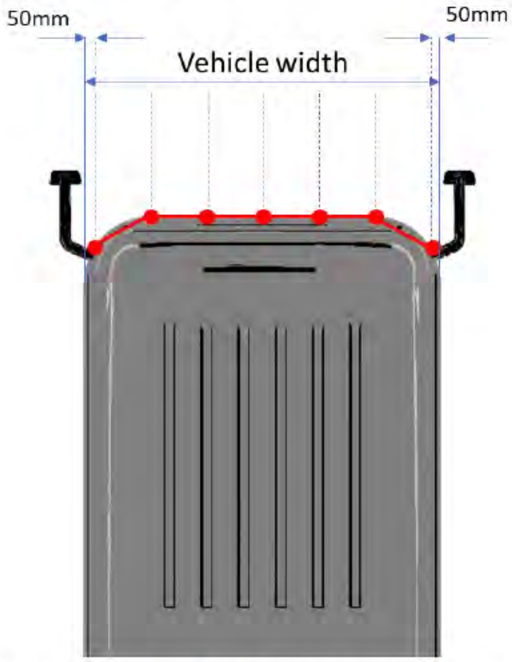

Figure 3: Virtual profile for determining impact for VUT

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

For the pedestrian targets (EPT) a virtual box is defined around the target with dimensions as shown in Figure 4, below. For crossing scenarios, the reference point is the x,y position of the hip and for longitudinal scenarios, it is a virtual point positioned where the centreline of the target meets the rear of the virtual box.

Figure 4: Virtual box around EPT

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

For the cyclist targets (EBT), the dimensions of the virtual box are shown in Figure 5, below. For crossing scenarios, the reference point of the EBT is the centre of the bottom bracket (crank shaft, indicated by a dashed line in Figure 5) and for the longitudinal scenario the most rearward point on the rear wheel is used.

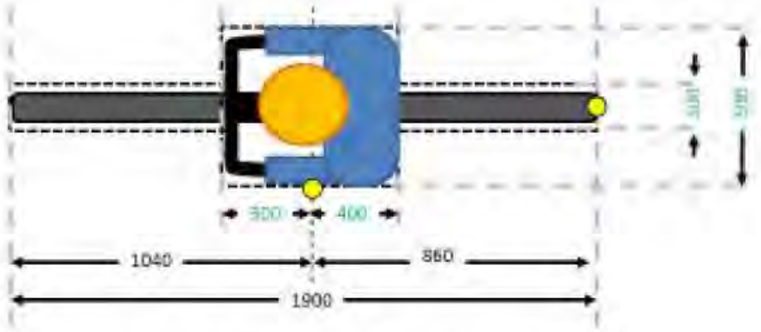

Figure 5: Virtual box around EBT

6 Test conditions

6.1 Test track

6.1.1 Tests shall be conducted on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%. The test surface shall have a minimal peak braking coefficient (PBC) of 0.9 in the region where data is recorded.

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

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

6.2 Weather and lighting conditions

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

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

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

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

6.3 Surroundings

6.3.1 Tests shall be conducted in surroundings such that there are no other vehicles, highway infrastructure (except lighting columns during the low ambient lighting condition tests), obstructions, other objects or persons protruding above the test surface that may give rise to abnormal sensor measurements within a minimum lateral distance of the VUT test path as per table below, 1.0m around of the EPT and EBT and within a longitudinal distance of 30m ahead of the VUT when the test ends (Figure 6).

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

Figure 6: Free surroundings

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

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

7 Vehicle preparation

7.1 Deployable protection systems

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

7.2 Tyres

Perform the testing with new (>90% original tread depth across the tread width) original fitment tyres of the make, model, size, speed and load rating as specified by the vehicle manufacturer. Replacement tyres are permitted and may be supplied by the manufacturer or acquired at an official dealer representing the manufacturer. Replacement tyres must be of identical make, model, size, speed and load rating to the original fitment. Tyres shall be inflated to the manufacturers recommended pressure. They shall be set when the tyres are cold and re-checked at the start of every test day.

7.3 Wheel alignment measurement

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

7.4 Vehicle mass

The AEB shall be operative at all states of load. However, it shall be tested and assessed unladen with only the driver and test equipment on board. Each axle of the vehicle shall be weighed in the condition as tested and the measurements recorded in the test report. At the discretion of the Approval Authority, additional tests may be undertaken in full or partial load conditions to assess the extent of any performance degradation compared to unladen.

7.5 AEB/FCW system check

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

7.6 Measuring front end geometry

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

8 Test procedure

8.1 VUT pre-test conditioning

8.1.1 Sensor calibration

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

8.1.2 Brake conditioning

It shall be ensured that the brake assemblies are suitably run-in (also referred to as bedded in) and brake surfaces are neither brand new or corroded.

8.1.3 Tyre conditioning

Tyres shall have been used in normal driving for at least a distance of 150km. At the start of each sequence of testing, tyres shall be warmed up by driving for 1 km repeatedly steering left and right with a lateral acceleration of approximately 3 m/s^2.

8.2 Alignment checks

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

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

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

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

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

8.3 Car tests

8.3.1 Test scenario

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

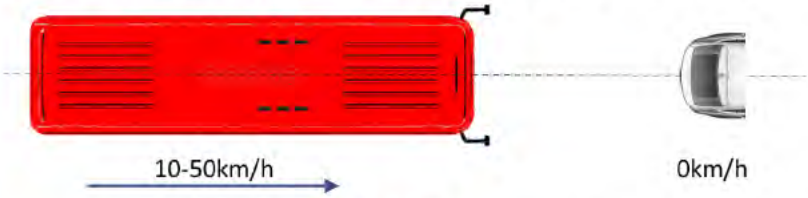

Figure 7: BCRs Scenario

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

8.3.2 Sequence and number of test runs

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

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

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

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

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

Tests shall not be undertaken at speeds in excess of 50 km/h. Only one valid test is required at each speed and the result from the first valid test shall be the result officially recorded. Additional tests may be undertaken in order to investigate unexpected results at the discretion of the Vehicle Manufacturer, Test Service or Approval Authority. If so, the Test Service shall provide all data from repeat runs to the Approval Authority for their consideration.

8.3.3 Test execution

(a) If requested by the Vehicle Manufacturer, an initialisation process shall be completed before the first, or every, test run. The initialisation shall involve driving the vehicle on a circular path of radius ≤ 30m for a distance of 190m, half of which involves a left turn and half a right turn. At the request of the Vehicle Manufacturer this may also involve driving past a small number of parked vehicles. The initialisation process shall be completed before the tyre warm up.

(b) The first test shall be commenced a minimum of 90 seconds and a maximum of 10 minutes after completion of the tyre warmup. Subsequent tests shall be completed within this same time window. If the time between tests exceeds 10 minutes, then repeat the tyre warmup procedure.

(c) Select the normal Drive mode of the vehicle/gearbox. Accelerate the VUT to the test speed, position it on the test path and achieve steady state conditions before T_0 (TTC=4s).

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

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

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

(g) VUT has made contact with the TT.

8.3.4 Validity of tests

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

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

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

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

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

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

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

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

8.4 VRU crossing tests

8.4.1 Test scenarios

The performance of the system shall be assessed in the four scenarios BPFA-50, BPNA-25, BPNA-75 and BPNC-50 and these are illustrated in Figure 8 to Figure 10, below. FCW is not assessed.

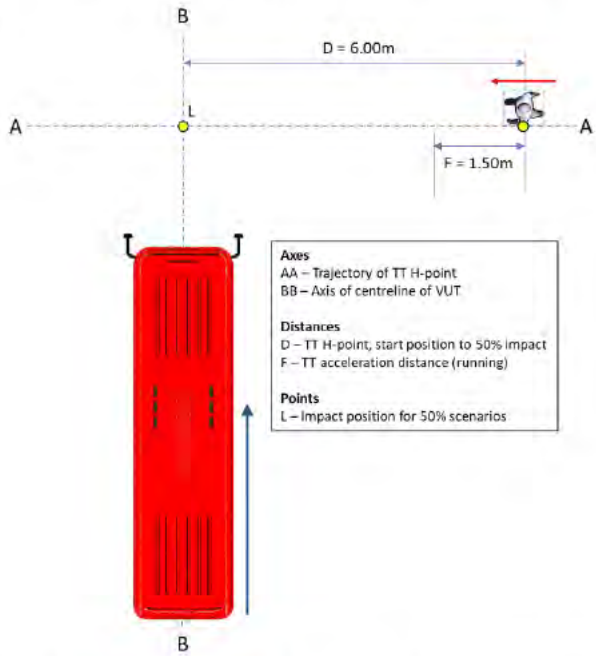

Figure 8: BPFA-50 scenario, adult running from the farside of the road

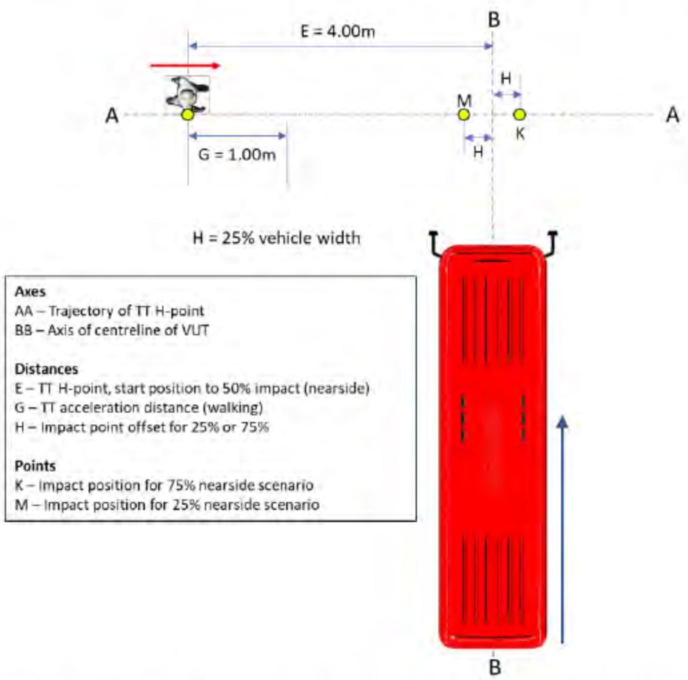

Figure 9: BPNA-25 & BPNA-75 scenario, adult walking from the nearside of the road

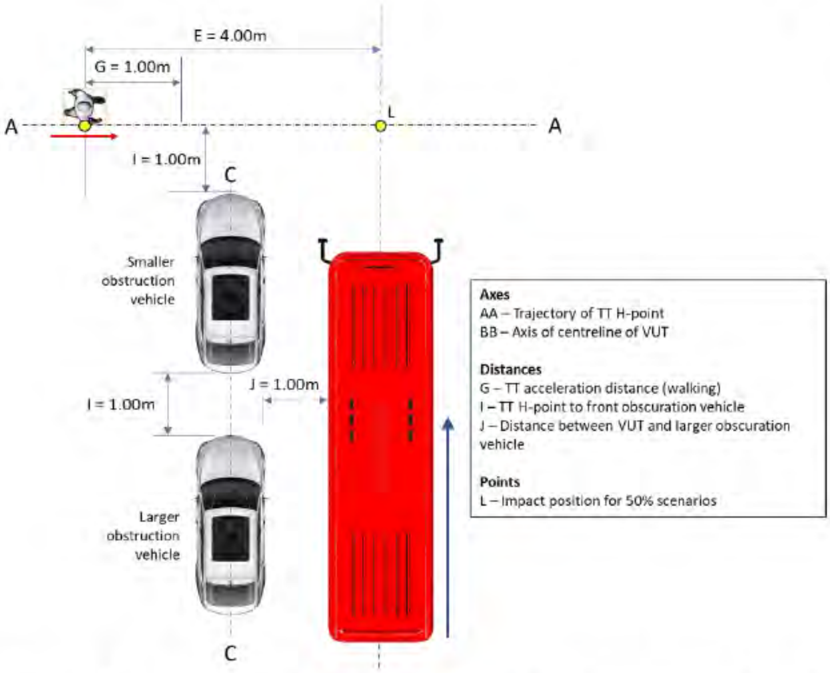

Figure 10: BPNC-50 scenario, child running from the nearside from behind obstructing vehicles

Figure 10 defines the relative position of the obstructing vehicles. The definition of the size and type of vehicles to be used is that specified in the Euro NCAP AEB VRU systems protocol (2018).

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

The details of the tests are shown in Table 4, below.

Table 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 4, then the BPNA-75 scenario shall be tested in daylight conditions with:

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

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

8.4.2 Sequence and number of test runs

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

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

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

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

The number of test runs to be completed in each test condition and the process of determining the result to be recorded for that condition shall be as defined in section 8.3.2.

8.4.3 Test execution

The process for executing each test shall be as defined in section 8.3.3. with the following exceptions.

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

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

(a) V_{VUT} = 0 km/h;

(b) VUT has made contact with the TT; or

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

8.4.4 Validity of tests

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

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

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

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

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

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

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

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

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

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

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

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

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

8.5 VRU longitudinal tests

8.5.1 Test scenarios

The VUT shall be assessed in two longitudinal scenarios. Both AEB and FCW shall be assessed. The TT shall be the Euro NCAP Bicyclist and bike Target (EBT). The test scenario is outlined in Figure 11, below.

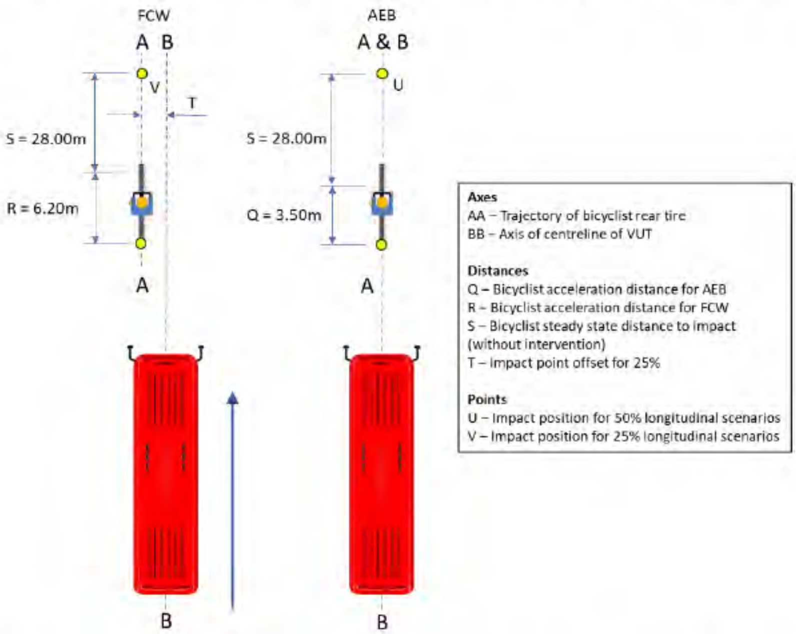

Figure 11: Longitudinal bicyclist scenarios; BBLA-25 (left) & BBLA-50 (right)

The tests to be undertaken are as defined in Table 5, below.

Table 5: Test Variables: Longitudinal scenarios

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

8.5.2 Sequence and number of test runs

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

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

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

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

The number of test runs to be completed in each test condition and the process of determining the result to be recorded for that condition shall be as defined in section 8.3.2.

8.5.3 Test execution

The test execution shall be as specified in section 8.3.3, except that steady state shall be achieved before the time T_0 – 1 seconds (that is, 1 second before T_0).

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

8.5.4 Validity of tests

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

(a) Test Speed ≤ V_{VUT} ≤ Test Speed + 0.5 km/h;

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

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

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

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

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

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

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

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

8.6 Aborted crossing test

8.6.1 Test scenario

This test scenario has the same geometry as that described for BPNA-25 and illustrated in Figure 9 previously. However, the TT shall be the EPTc. As per BPNA-25, the movement of the TT shall be timed such that if the TT continued at its constant steady state speed (V_{TEST_TT} = 5 km/h) and the VUT maintained constant speed (without braking) and lateral position, an impact would occur 25% across the width of the VUT.

Thus, the TT motion shall be initiated as for BPNA-25. However, instead of the TT continuing at 5 km/h until the end of the test, it shall be stopped with a mean deceleration of 3 m/s^2 at Point W, where distance N is the distance from the edge of the VUT path, as illustrated in Figure 12, below.

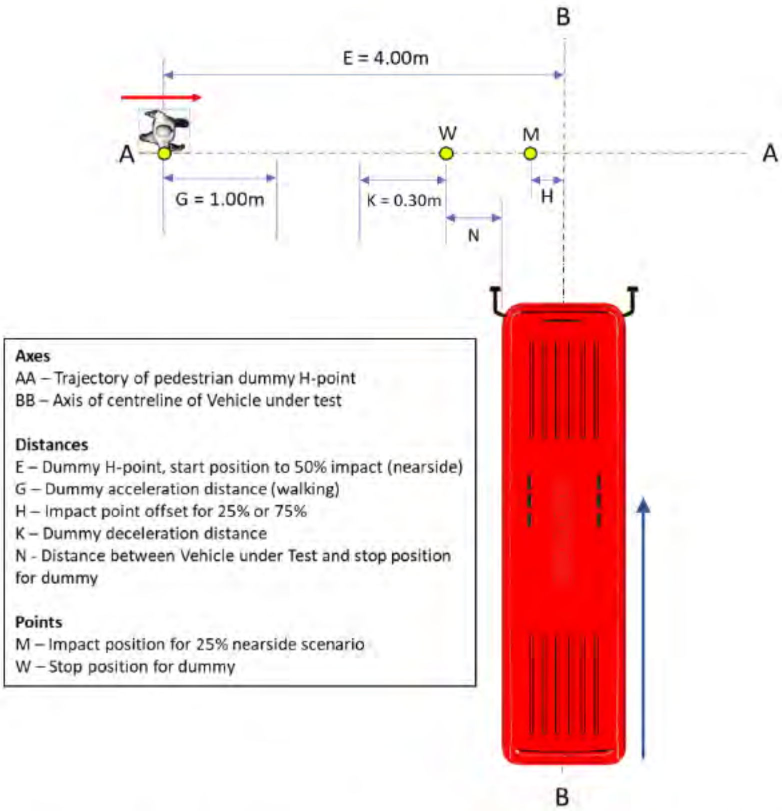

Figure 12: TT start and stop positions in aborted crossing test

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

8.6.2 Sequence and number of test runs

The first tests shall be undertaken at N = 0.6m and 3 identical tests shall be completed. Distance N shall be increased to the next increment if the AEB activates in any of the 3 tests. If AEB is not activated in any tests then testing can be ceased and the system will be deemed not to have activated in any of the tests at greater values of N.

8.6.3 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).

8.6.4 Validity of tests

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

(a) Test Speed ≤ V_{VUT} ≤ Test Speed + 0.5 km/h;

(b) Lateral deviation from VUT Test Path = 0 ± 0.05m;

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

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

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

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

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

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

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

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

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

8.7 Bus stop test

8.7.1 VUT path geometry

The bus stop test involves the VUT steering a defined curved path first left then right of 125m radius such that the nearside front corner of the vehicle describes the path illustrated in Figure 13, below and defined by the corridor specified in XY co-ordinates in Appendix A.

8.7.1.1 False positive test

The TT shall remain stationary at all times and shall be positioned such that the lateral separation (on global y-axis) between the centre of the TT and the nearside front corner of the VUT is initially 2m (Point C), which is reduced to 0.2m (Point D) at the moment the front nearside corner of the VUT is at the same position as the TT on the Global X-axis.

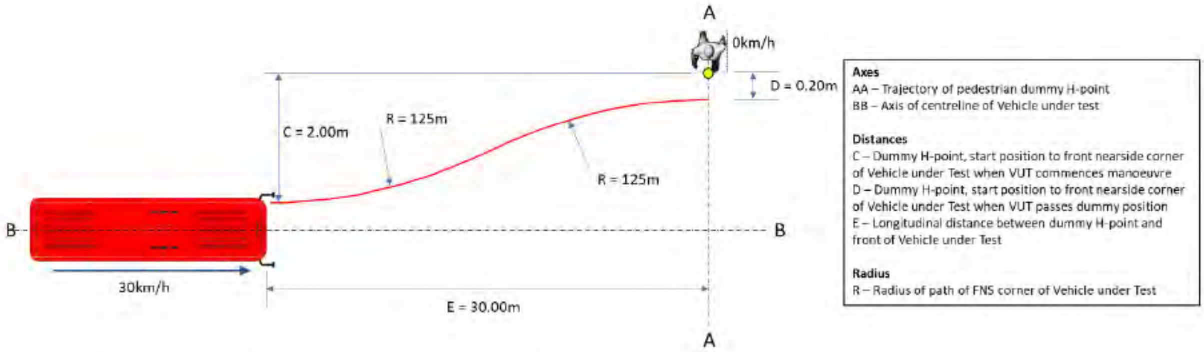

Figure 13: VUT Path and pedestrian position in false positive bus stop test

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

8.7.1.2 True positive test

In the true positive test the TT shall initially be positioned such that the lateral separation (on global y-axis) between the centre of the TT and the nearside front corner of the VUT is initially 4.55m (Point C) as defined in Figure 14, below.

The TT shall be accelerated to a speed of V_{TEST_TT} = 5 km/h at a time such that it is on a collision course with the front of the VUT where the nominal impact point (Point L) is 50%± 3% of bus width. V_{TEST_VUT} shall be 30 km/h.

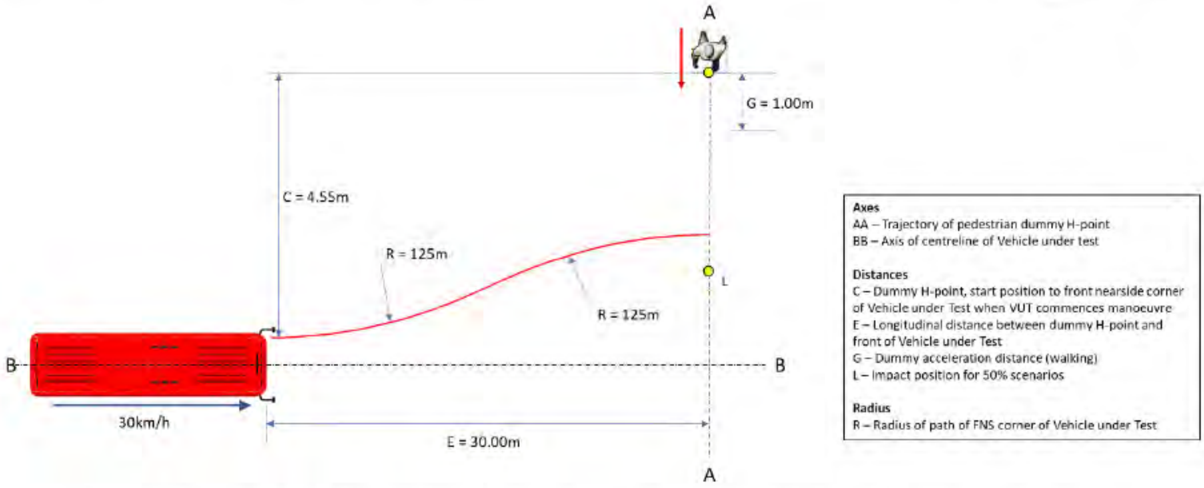

Figure 14: VUT path and TT position in true positive bus stop test

8.7.2 Sequence and number of test runs

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

8.7.3 Test execution

Accelerate the VUT to the test speed (V_{TEST_VUT}) in a straight line, position the front nearside corner at a point that complies with the requirements for the first lateral position defined by the corridor. When the front of the VUT reaches a position of 30m from that of the TT in the global x-axis, steering is applied such that the front nearside corner stays within the corridor defined by Appendix A. For buses with automatic transmission, select Drive (D). For buses with a manual transmission, select the highest gear that results in an engine speed of at least 1,000 RPM at the test speed.

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

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

8.7.4 Validity of tests

Post-processing of data shall be undertaken to demonstrate the validity of tests. Tests are considered valid when all of the following criteria are met at all X_{VUT} positions between that representing entry to the corridor defined in Appendix A and activation of AEB or the end of test, whichever comes first:

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

(b) Front nearside corner remains in defined corridor

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

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

8.8 Validation of Vehicle Manufacturer supplied test data

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

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

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

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

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

9 Assessment of results

9.1 Assessment criteria

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

9.1.2 For the longitudinal cyclist tests the test and impact speeds are defined as the relative speeds of the VUT and the TT. An example of this is shown in **Error! Reference source not found.**.

Table 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%

9.1.3 FCW shall be assessed on a binary basis, based upon the TTC at the moment the warning is issued (T_{FCW}). When $T_{FCW} \geq 1.7$seconds then the score shall be 100%. Where $T_{FCW} < 1.7$seconds, then the score shall be 0%.

9.2 Pre-conditions

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

9.2.1 In test BPNA-75 with V_{TEST_TT}= 3km/h and V_{TEST_VUT}=20 km/h then V_{AEB_Red} shall exceed 25% in both day & night conditions

9.2.2 In test BPNA-75 with V_{TEST_TT}= 5km/h and V_{TEST_VUT}=10 km/h then V_{AEB_Red} shall exceed 25% in both day & night conditions

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

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

9.2.5 V_{AEB_Red} shall be no less than 1 km/h in the true positive bus stop test.

9.3 Test scenario and crash type scores

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

9.3.1 Car tests

For scenario BCRS, the score for the test scenario shall be calculated from each individual test run according to **Error! Reference source not found.**, ontaining hypothetical results as a worked example.

Table 7: Scoring and weighting applicable to scenario BCRS

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

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

9.3.2 VRU crossing tests

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

Table 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. **Error! Reference source not found.** below shows the cenario weighting and the calculation with a worked example.

Table 9: Scoring and weighting to combine scenario scores to crash type score

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

9.3.3 VRU longitudinal tests

The VRU longitudinal tests assess both AEB and FCW. The principles for AEB are identical to the crossing scenarios. Forward collision warning shall be assessed according to T_{FCW}. The calculations are illustrated with a worked example in **Error! Reference source not found.**.

Table 10: Scoring and weighting for VRU longitudinal tests

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

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

9.3.4 False positive aborted crossing scenario

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

In tests where Y_{TTStop} = 0.6m

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

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

(c) In tests where $Y_{TTStop} > 0.6m$

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

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

(f) $A_{PEAK\_VUT\_Long} = 0 \ m/s^2$: 2 Points

The total score for each individual test configuration shall be summed and divided by the maximum possible score (18) and expressed as a percentage Scenario Score as shown in the worked example in **Error! Reference ource not found.**, below.

Table 11: Scoring for false positive aborted crossing tests

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

9.4 Overall score

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

Table 12: Scoring & Weighting to produce overall AEB result

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

10 Test report

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

(a) Performance data;

(b) Confirmation of protocol compliance; and

(c) Reference information.

10.2 The minimum performance data required is:

(a) The value V_{Impact} and $A_{PEAK\_VUT\_Long}$ for each and every individual test run, with the number of tests reported based on the rules in, for example, section 8.3.2; and

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

10.3 To confirm protocol compliance, the Test Service shall:

(a) Make available the video recordings as specified in section 5.2;

(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; and

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

10.4 The reference information required includes as a minimum:

(a) Vehicle make;

(b) Vehicle model;

(c) Vehicle model variant;

(d) AEB hardware version (e.g. sensor types, ECU references);

(e) AEB software version;

(f) Tyre make/model/size/pressure;

(g) Test weight;

(h) Make, model, serial number of key control and measurement equipment;

(i) Details of the Test Service; and

(j) Test date(s).

Annex 1 Co-ordinate corridor defining the path to be followed by the front nearside corner of the VUT

The co-ordinates defined below are based on the global co-ordinate system as defined in section 4.2, assuming the vehicle width is 2.5m. For different vehicle widths then all target Y values shall be adjusted by half the difference in width. However, the important element is not the initial offset in Y but the difference in Y between the TT and the VUT initial position and the difference between the VUT Y-position at any given X and its initial Y-Position at X=0.

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

Attachment 16

LONDON BUS SERVICES LIMITED

Guidance Notes:

Automated Emergency braking (AEB)

Preface

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

Where a vehicle operator or manufacturer perceives that a particular feature should be changed, this should be raised by the operator or manufacturer with the competent authority (TfL). The competent authority (TfL) will assess the problem based on their judgment and provide instruction or update.

These Guidance Notesshould be read in conjunction with the Test Protocol.

Version	**Published**	**Details**
1.1	19/12/2018	TfL AEB Guidance Notes

1 Introduction

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

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

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

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

2 Selection of buses/systems

Any bus that meets the TfL Bus Vehicle Specification.

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

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

2.1 Compliance and warranty

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

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

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

2.2 Normal Operation

A bus operator should ask to see evidence of how well the system performs when it is activating in the situations it is intended to activate in. This should include the results and scoring from the AEB solution test and assessment protocol document. This protocol includes a variety of physical tests designed to assess the ability of an

AEB system fitted to a bus to avoid or mitigate collisions with other road users while minimising risks to occupants of the bus from unnecessary brake interventions.

2.3 False positive activations

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

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

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

2.4 False negatives

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

2.5 Balancing risks

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

2.6 Monitoring

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

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

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

3 Training

3.1 For test houses

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

3.2 Bus drivers

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

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

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

3.3 Shift Supervisors

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

3.4 Bus maintenance engineers

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

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

4 Maintenance

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

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

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

5 Repair

If during system maintenance checks (4) any of the sensors are deemed to be faulty or failing they should be replaced as soon as possible. The AEB system's effectiveness and reliability is completely contingent on the performance of the sensors the system is connected to. However, unless the manufacturer advises to the contrary, the system should fail safe such that it is not necessary to stop the vehicle immediately, for example, at the side of the road.

Attachment 17

LONDON BUS SERVICES LIMITED

Assessment Protocol:

ISA – Intelligent Speed Assistance

Preface

This protocol covers the assessments to be carried out for ISA (Intelligent Speed Assistance).

Where a vehicle manufacturer perceives that a particular feature should be changed, this should be raised by the manufacturer with the competent authority (TfL) assessor present at the assessment, or in writing to the competent authority (TfL) Nominated Officer in the absence of an assessor. The competent authority (TfL) will assess the problem based on their judgment and provide instruction to the assessment facility.

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

Version	**Published**	**Details**
1.2	19/12/18	TfL ISA Test Protocol

Disclaimer

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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1 Introduction

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

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

1.1 Scope

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

1.2 Purpose

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

2 Normative references

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

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

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

3 Definitions

For the purpose of this Protocol:

1.1 **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.

1.2 **ISA: Intelligent Speed Assistance** – system fitted to a vehicle to restrict its speed to the prevailing speed limit.

1.3 **ROM: Restricted Operating Mode** – A condition where the ISA system actively prevents acceleration beyond the prevailing speed limit

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

1.5 **Test Speed** – The speed indicated on the VUT speedometer. The tolerances applied shall be the target speed $^{+0}_{-1}$ mph.

1.6 **Test Track** – Any sealed area of carriageway without general access to the public.

1.7 **TfL Digital Speed Map** – An electronic map provided by TfL which indicates the speed limit of roads within Greater London.

1.8 **VM: Vehicle Manufacturer** – The body responsible for providing a completed bus to a bus operator

1.9 **VUT: Vehicle Under Test** - means a vehicle that is being tested to this protocol.

4 Test Conditions

4.1 Test environment

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

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

(a) Be a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%; and

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

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

4.2 Weather and lighting

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

4.2.2 No precipitation shall be falling.

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

5 Pre-test submissions

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

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

5.1.2 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.

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

5.1.4 A statement describing how the ISA system operates.

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

5.1.6 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.

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

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

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

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

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

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

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

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

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

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

5.1.15 Instructions regarding how the ISA system is enabled and disabled.

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

5.1.17 A description of potential failure modes of the ISA system.

5.1.18 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.

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

5.1.20 Instructions with/in the application for the updating of the digital speed map, and include any equipment necessary to facilitate this updating for the test. Two off-road test track-specific maps shall be provided, with different zones and speed limits as agreed with the test body.

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

5.1.22 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.

6 System checks

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

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

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

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

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

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

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

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

(c) Amber – The ISA system has a fault.

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

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

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

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

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

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

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

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

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

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

7 Test procedure

7.1 Track testing

The following tests shall be undertaken at a suitable test track (see 4.1.1).

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

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

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

7.1.1 Option 1 tests

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

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

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

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

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

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

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

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

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

7.1.4 Option 2 tests

The tests and requirements described in 7.1.1 shall be applied.

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

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

7.2 Other tests

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

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

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

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

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

The system shall be deemed to have failed if the VUT exceeds a maximum acceleration of $1.2m/s^2$ under all load conditions.

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

7.2.4 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.

7.2.5 The VUT shall be driven in a 20mph (32.2km/h) restricted zone in ROM with the accelerator pedal fully depressed. The GPS isolation cable switch shall be operated to replicate a signal loss and the VUT speed shall be observed for 10 seconds and recorded. This test shall be repeated for the FMS and CAN cables as appropriate.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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

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

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

7.3 On road testing

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

The VUT shall be driven on the on road testing infrastructure (see 4.1.2).

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

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

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

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

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

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

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

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

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8 Assessment of results

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

8.1.1 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.

8.1.2 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 sytem checks checklist.

8.1.3 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.

8.1.4 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.

8.1.5 Overall Assessment

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

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.

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

9 Test report

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

(a) Completed pre-test submissions checklist

(b) Completed system checks checklist;

(c) Completed track tests checklist;

(d) Completed on-road tests checklist.

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

(f) Reference information.

9.2 The reference information required includes as a minimum:

(a) Vehicle make;

(b) Vehicle model;

(c) Vehicle model variant;

(g) ISA Hardware version;

(h) ISA Software version;

(i) iBus version (1 or 2);

(j) Braking option (1 or 2);

(k) Applicable mapping types;

(l) Details of the TS; and

(d) Test date(s).

Annex 1 Pre-test submissions checklist

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

	Pre-test submissions	Pass/Fail
15	Instructions are provided by the bus OEM regarding how the ISA system is enabled and disabled.	
16	The bus OEM has provided a test vehicle modified with additional in-line switches to individually isolate cabled connections to the GPS, FMS and/or CAN speed signal in to the ISA system.	
17	The bus OEM has provided a description of potential failure modes of the ISA system.	
18	The bus OEM has provided a description of all mapping formats from the list which can be used on the ISA system.	
19	The bus OEM has provided a statement regarding how any bus mapping can be updated on an ad-hoc basis.	
20	The bus OEM has provided adequate instructions with/in the application for the updating of the digital speed map, and include any equipment necessary to facilitate this updating for the test. 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.	

Result:

Annex 2 System checks

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

Result:

Annex 3 Track testing checklist

Type of intervention option selected: ☐

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

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

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

Result: ☐

Annex 4 On-road testing checklist

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

Result:

Attachment 18

LONDON BUS SERVICES LIMITED

Guidance Notes:

Intelligent Speed Assistance

Preface

This document sets out the guidance notes related to Intelligent Speed Assistance. These guidance notes are aimed at bus operators and manufacturers as a practical guide for implementation of the Bus Safety Standard.

Where a vehicle operator or manufacturer perceives that a particular feature should be changed, this should be raised by the operator or manufacturer with the competent authority (TfL). The competent authority (TfL) will assess the problem based on their judgment and provide instruction or update.

These Guidance Notes to be read in conjunction with the Test and Assessment Protocol, and the Bus Vehicle Specification

Version	Published	Details
1.1	19/12/18	TfL Intelligent Speed Assistance Guidance Notes

Disclaimer

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).

1 Introduction

This document sets out the guidance notes related to Intelligent Speed Assistance. These guidance notes are aimed at bus operators and manufacturers as a practical guide for implementation of the Bus Safety Standard.

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

2 ISA

Intelligent Speed Assistance (ISA) is a system fitted to buses which links an understanding of location (from GPS[1]) to an on-board map of speed limits (known as the Digital Speed Map), and a reading of the bus speed. It uses this information to limit the speed of the bus and at present it does this in two options:

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

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

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

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

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

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

[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.

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

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

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

3 Selection of buses/systems

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

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

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

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

4 Training

4.1 Driver training

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

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

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

4.2 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, enabling and disabling the system (likely to take around an hour in training). Additionally and depending upon any warranty and maintenance agreement, training may extend to fault finding/repair (and this may take far longer depending upon the complexity of the system).

5 Maintenance

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

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

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

Attachment 19

LONDON BUS SERVICES LIMITED

Test & Assessment Protocol:

Bus Vision Standard

(Direct and Indirect Vision Performance Requirements)

Preface

This protocol covers the assessments to be carried out in respect of the quantity and quality of vision that the driver has of the environment around the bus, both directly via the windows and indirectly via mirrors and/or camera-monitor systems (CMS).

Where a vehicle manufacturer perceives that a particular feature should be changed, this should be raised by the manufacturer with the competent authority (TfL) assessor present at the assessment, or in writing to the competent authority (TfL) Nominated Officer in the absence of an assessor. The competent authority (TfL) will assess the problem based on their judgment and provide instruction to the assessment facility.

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

This protocol has been adapted from a combination of the existing TfL protocol for the assessment of direct vision from HGVs and UN ECE Regulation 46 on indirect vision as well as the findings of original research specific to London bus safety.

Changes have been made based upon the different collision experiences of London buses compared with HGVs, differences in the characteristics of the vehicles and different levels of safety ambition between vision zero in London and pan-EU minimum standards for all vehicles.

In particular, there is a significant difference in the analytical technique used to test and assess direct vision from buses, which has been introduced because the direct vision problems experienced by HGVs (often related to height of the lower edge of the glazed areas) are different to those of buses (mainly related to vertical pillars).

Version	Published	Details
1.1	19/12/2018	TfL Vision Test & Assessment Protocol

Disclaimer

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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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).

1.1 Scope

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

1.2 Purpose

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

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

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

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

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

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

2 Normative References

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

- Directive 2007/46/EC of the European Parliament and of the Council establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- 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.

3 Definitions

For the purpose of this Protocol:

3.1 **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.

3.2 **AHP height -** vertical height in the Z axis between the ground plane and AHP.

3.3 **Ambinocular vision -** the total combined field of view that can be seen by at least one eye.

3.4 **Angle of incidence -** the angle which a sightline makes with a plane that is angled perpendicular to the surface at the obstruction point

3.5 **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.

3.6 **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.

3.7 **Assessment zone element -** an element of known volume, and with no single dimension exceeding [100]mm, that forms part of the overall assessment zone volume

3.8 **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.

3.9 **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

3.10 **Bus vision standard performance score -** the proportion of each assessment zone visible to the driver through the direct field of view.

3.11 **Camera -** a device that renders an image of the outside world and converts this image into a signal (e.g. video signal)

3.12 **Camera point -** a point representing the origin of the field of view of a camera

3.13 **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

3.14 **Coordinate system -** the three-dimensional vehicle coordinate system that is established in SAE J182.

3.15 **Daylight opening (DLO) -** an area of a vehicle, windscreen or other glazed surface, whose light transmittance (measured perpendicular to the surface) is not less than 70%. As defined in UN ECE Regulation 125.

3.16 **Direct field of view -** the field of view seen without the aid of any additional devices.

3.17 **Direct vision volume -** the proportion of the assessment zone visible to the driver through the direct field of view.

3.18 **Direct vision performance score -** the proportion of each assessment zone visible to the driver through the direct field of view.

3.19 **Eye points (E_L, E_R) -** two points representing the driver's left and right eyes. These are the points from which sightlines originate.

3.20 **ETRTO -** European Tyre and Rim Technical Organisation

3.21 **Gross vehicle weight (GVW) -** the maximum permitted mass of a vehicle when fully loaded.

3.22 **Ground plane -** horizontal plane, parallel to the XY plane, at ground level.

3.23 **Indirect field of view -** the field of view seen through the aid of an additional device such as mirrors or camera-monitor systems (CMS).

3.24 **Indirect vision volume -** the proportion of the assessment zone visible to the driver through the indirect field of view.

3.25 **Indirect vision performance score -** the proportion of each assessment zone visible to the driver through the indirect field of view.

3.26 **Monitor -** a device that converts a signal into images that are rendered into the visual spectrum.

3.27 **Monocular vision -** the total field of view that can be seen by a single eye or camera.

3.28 **Neck pivot point (P) -** point about which a driver's head turns on a horizontal plane.

3.29 **Obstruction point -** a point located on the vehicle structure that obstructs the driver field of view.

3.30 **Reference eye point (E_{ref}) -** midpoint between left and right eye points at centre line of driver.

3.31 **Reflection point -** a point located on a mirrored surface that reflects the driver field of view.

3.32 **Sightline -** a line representing the driver's line of sight from an eye point to an obstruction point, reflection point or a given angle.

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

3.34 **Total driver vision volume -** the proportion of the assessment zone visible to the driver through ether the direct or indirect fields of view.

3.35 **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.

3.36 **Vehicle structure -** all relevant vehicle glazing and bodywork, excluding all features listed in Appendix A.

3.37 **Vehicle under test (VUT) -** the vehicle tested according to this protocol.

3.38 **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.

4 Test conditions

4.1 Eye Points

4.1.1 The field of view of the driver shall be defined by ambinocular vision from two eye points (E_L and E_R), rotating about a neck pivot point (P), from which sightlines will originate. E_L, E_R and P locations and ranges of motion are defined in relation to the E_{ref} position, which in turn is defined in relation to the AHP.

4.2 Reference Eye Point Location (E_{ref})

4.2.1 The reference eye point (E_{ref}) is defined as an offset from the AHP of [678]mm in the X axis and [1163.25]mm in the Z axis, as shown by Figure 1. 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:

4.2.2 $E_{ref\_x} = AHP_x + [678]mm$

4.2.3 $E_{ref\_z} = AHP_z + [1163.25]mm$

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

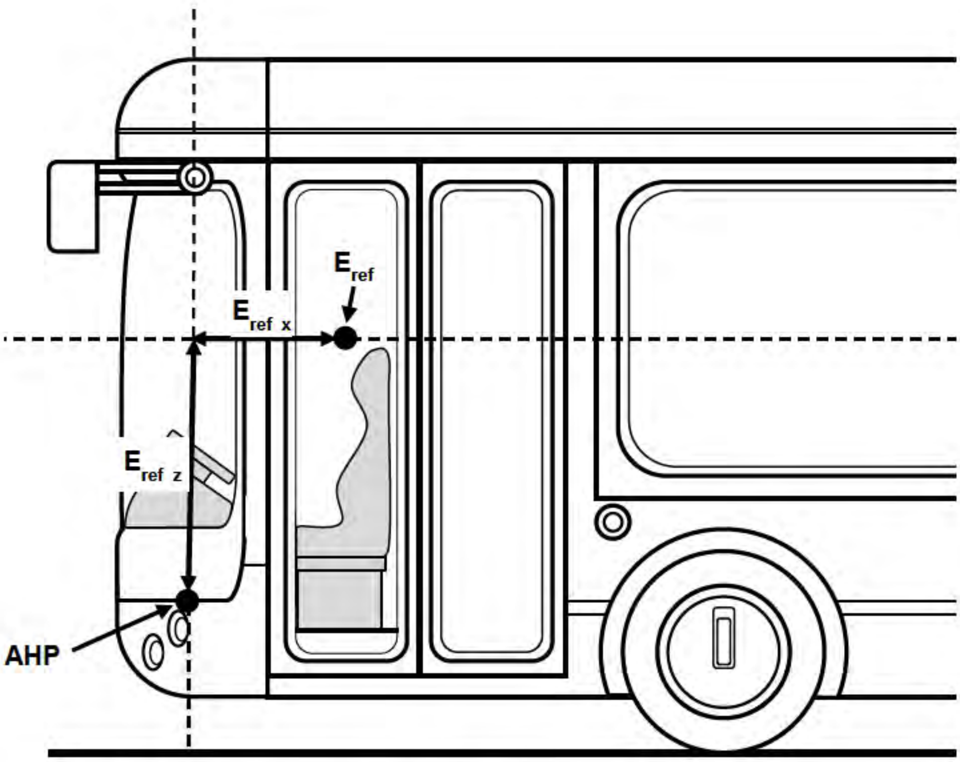

Figure 1: Definition of vertical (E_{ref_z}) and rearward (E_{ref_x}) offset of the reference eye point (E_{ref}) from the accelerator heel point (AHP)

4.3 Neck Pivot Point Location (P)

4.3.1 The neck pivot point (P) is defined as an offset of -98mm from the E_{ref} point in the X axis, as shown in Figure 2.

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

4.4.1 The left and right eye points (E_L and E_R) are defined as an offset of ±32.5mm from the E_{ref} point in the Y axis, as shown in Figure 2.

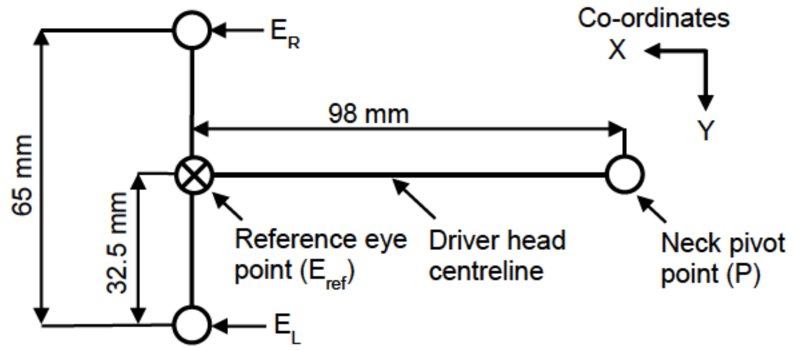

Figure 2: Definition of left and right eye point (E_L and E_R) positions relative to the neck pivot point (P) and reference eye point (E_{ref})

4.5 Neck Pivot Point Range of Motion (β)

4.5.1 The horizontal rotation (β) of the neck pivot point, which determines the relative motion of the eye points, is defined by a maximum range of motion of [±90°] rotation about the neck pivot point (P), as shown in Figure 3. For the assessment procedure, β shall be adjusted in increments of [10°].

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

4.6 Eye Point Range of Motion (θ)

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

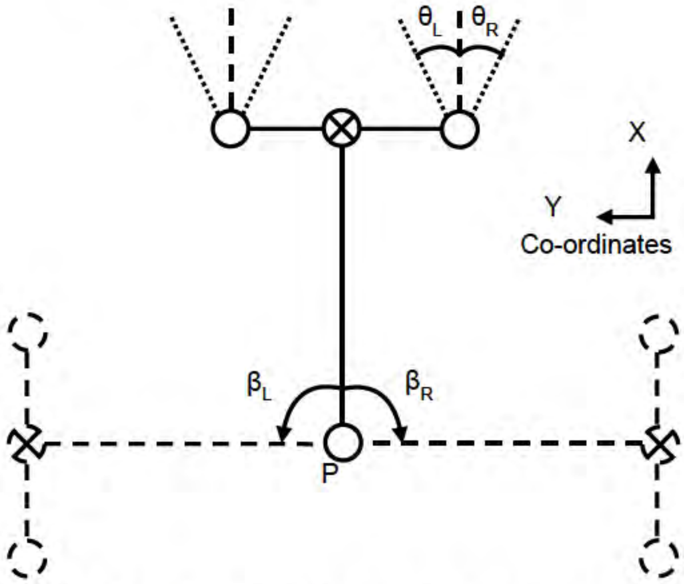

Figure 3: Plan view of horizontal neck point and eye point rotations

4.6.2 The vertical rotation (θ_U, θ_D) of both eye points is defined by a maximum range of motion of [45°] upwards and [60°] downwards about each eye point (E_L and E_R), as shown in Figure 4. For the assessment procedure, θ_U and θ_D will be adjusted in increments of [3°].

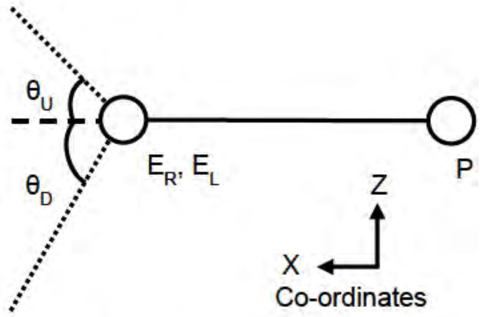

Figure 4: Side view of vertical eye point rotations

4.7 Camera Points

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

4.8 Camera Point Locations (C)

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

4.9 Camera Point Fields of View (α, λ)

4.9.1 The angle of the centre of the field of view shall be provided for each camera point (C_n) by the manufacturer, as shown in Figure 5 and Figure 6. The horizontal angle shall be formed between the centre of the field of view and XZ plane (α_n), with a positive value used when angled outboard relative to the longitudinal centreline of the VUT. The vertical angle shall be formed between the centre of the field of view and XY plane (λ_n), with a positive value used when angled downward relative to the XY plane.

4.9.2 The maximum range of the horizontal field of view, both inboard and outboard (α_{n_I}, α_{n_O}), for each camera point (C_n) shall be provided by the manufacturer, as shown in Figure 5. For the assessment procedure, α_{n_I} and α_{n_O} will be adjusted in increments of [3°] between the extents of the maximum ranges.

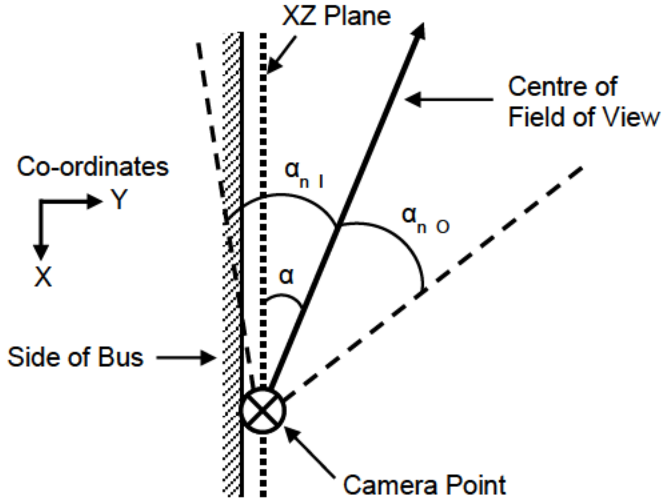

Figure 5: Plan view of horizontal field of view range for camera point

4.9.3 The maximum range of the vertical field of view, both upward and downward (λ_{n_U}, λ_{n_D}), for each camera point (C_n) shall be provided by the manufacturer, as shown in Figure 6. For the assessment procedure, λ_{n_U} and λ_{n_D} will be adjusted in increments of [3°] between the extents of the maximum range of motion.

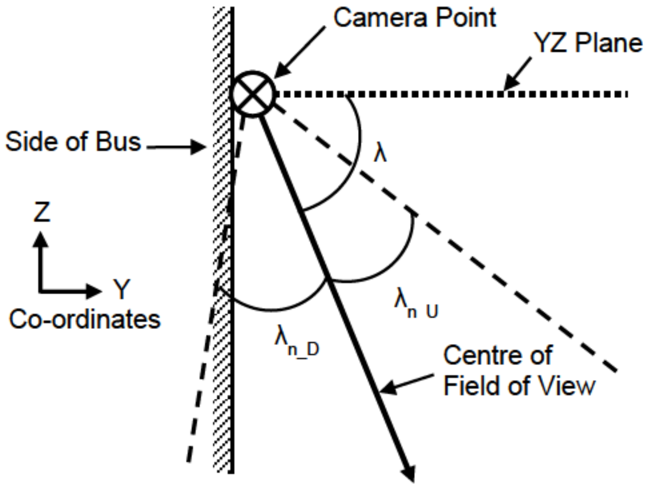

Figure 6: Frontal view of vertical field of view range for camera point

4.10 Assessment Zones

4.10.1 The following three assessment zones shall be defined:

(a) Forward Close Proximity Zone

(b) Rearward Close Proximity Zone

(c) Wide-Angle Zone

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

4.11 Assessment Zone Height

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

4.12 Forward Close Proximity Zone

4.12.1 The dimensions of the forward close proximity assessment zone are shown in Figure 7 and described below:

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

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

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

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

(e) The inner boundary is defined by a curve located 0.3m from the outermost aspect of the vehicle structure, when measured normal to the relevant vehicle structure (Figure 8).

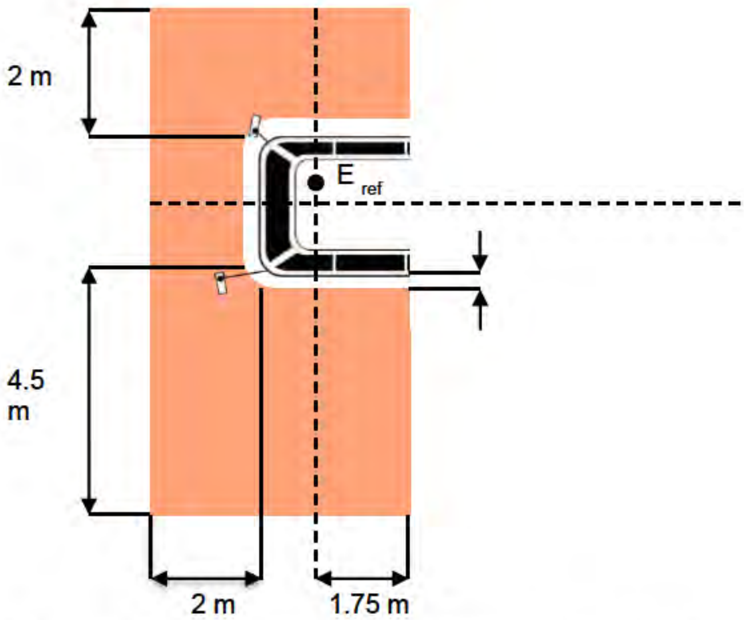

Figure 7: Plan view of forward close proximity assessment zone

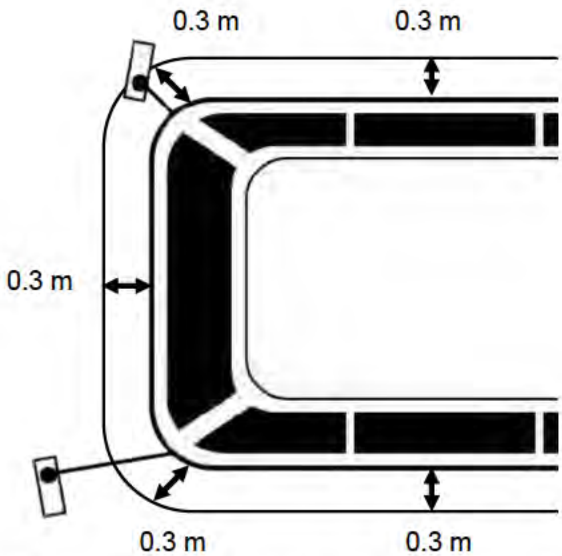

Figure 8: Illustration of profile for defining inner boundary of assessment zones

4.13 Rearward Close Proximity Zone

4.13.1 The dimensions of the rearward close proximity assessment zone are shown in Figure 9 and described below:

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

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

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

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

(e) The inner boundary is defined by a curve located 0.3m from the outermost aspect of the vehicle structure, when measured normal to the relevant vehicle structure (Figure 9).

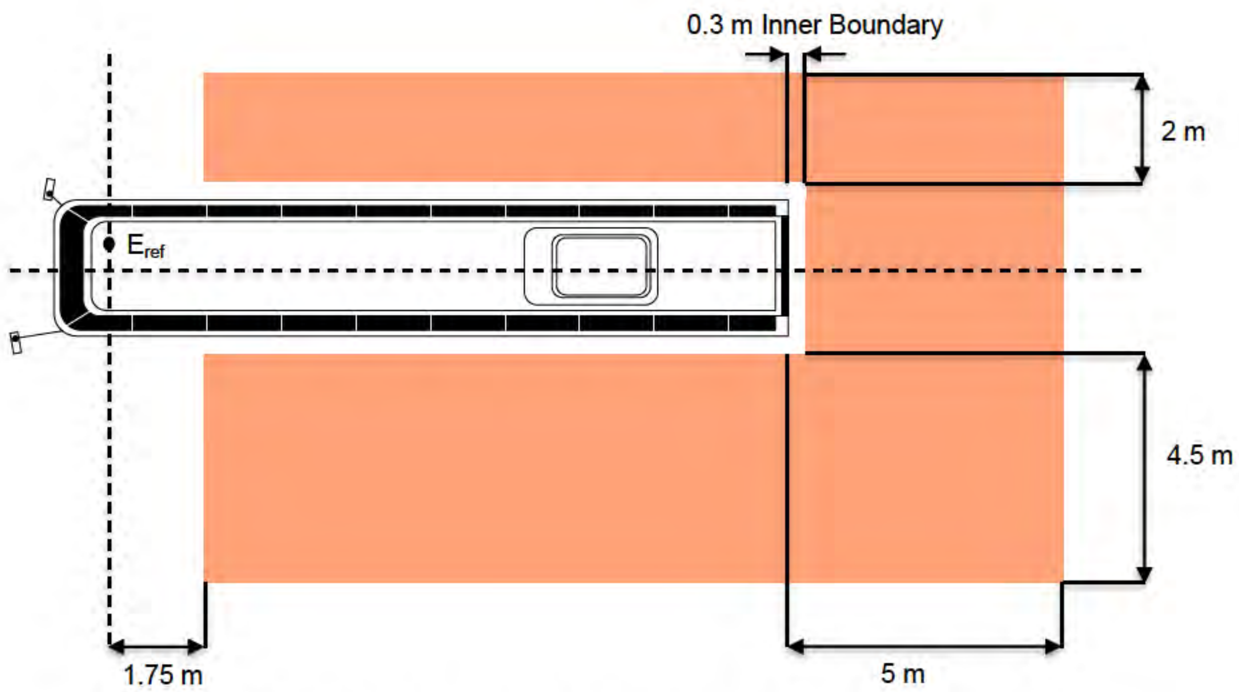

Figure 9: Plan view of rearward close proximity assessment zone

4.14 Wide-Angle Zone

4.14.1 The dimensions of the wide-angle assessment zones, which are principally based on the field of vision zones specified for Class IV mirrors in UN ECE Regulation 46, are shown in Figure 10 and described below:

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

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

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

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

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

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

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

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

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

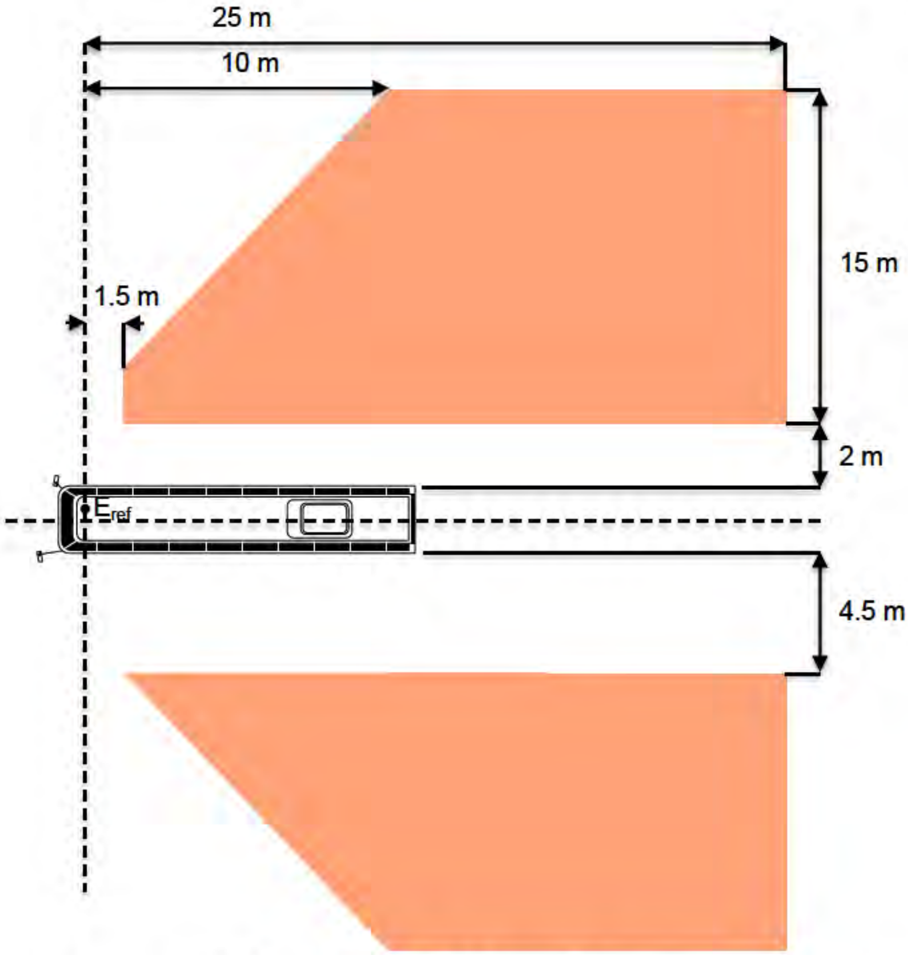

Figure 10: Plan view of wide-angle assessment zone

4.15 Assessment Zone Elements

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

5 Vehicle preparation

5.1 Coordinate System

5.1.1 A global coordinate system (X,Y,Z) for the VUT shall be defined such that the X axis points toward the front of the vehicle, the Y axis towards the left (nearside) and the Z axis upwards, as shown in Figure 11.

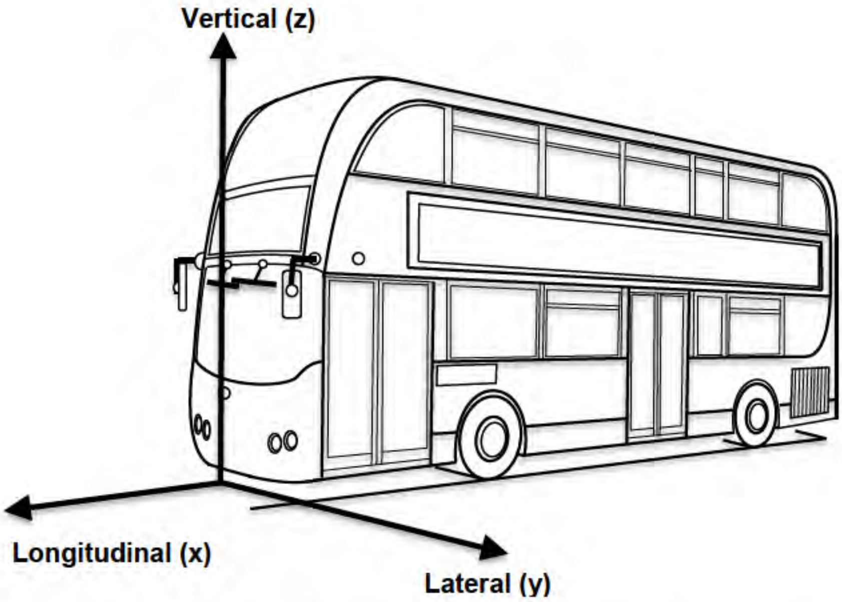

Figure 11: Global coordinate system and notation

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

5.2 CAD Model

5.2.1 The assessment requires a CAD model of the VUT that is of sufficient detail to allow accurate measurement of the direct and indirect fields of view available to the driver. This can either be supplied by the manufacturer or generated from laser scanning a physical vehicle where independent evaluation is considered necessary. The resulting CAD data must include any interior and exterior component geometry which may obstruct or reflect the sightline (Figure 12), including but not limited to:

(a) Exterior panels that bound any transparent area

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

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

(d) Exterior mirrored surfaces that may reflect driver vision

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

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

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

Figure 12: Example CAD data required for bus vision standard assessment

5.3 Glazing Frit

5.3.1 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 13 below.

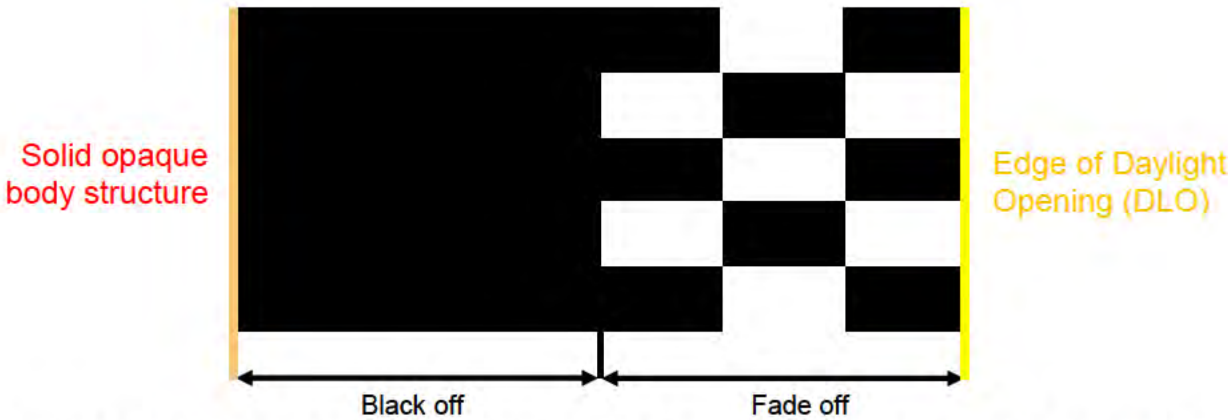

Figure 13: Definition of daylight opening (DLO) at window edges with black-off or fade-off areas

5.4 Tinting

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

5.5 Glazing Angle

5.5.1 Where the angle of incidence (θ_I) between the surface of [any section of glazing] and the sightline from at least one eye is angled at greater than [70°], [when looking at the surface from any angle,] this area shall be considered opaque (Figure 14). The DLO boundary is therefore further defined by the boundaries of any glazed surfaces defined as opaque.

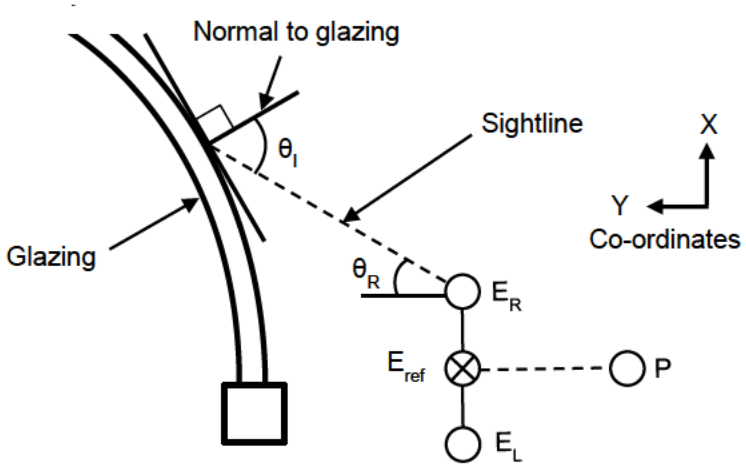

Figure 14: Illustration of angle of incidence between the sightline and glazing

5.6 Mirror Positioning

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

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

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

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

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

5.7 Camera-Monitor Systems (CMS)

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

5.8 Accelerator Heel Point (AHP) Height

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

(a) the suspension enabling the vehicle ground clearance to be adjusted, if applicable, is set to the highest setting for normal driving

(b) the specified tyres should be at their maximum ETRTO diameter

(c) the tyre pressures are set according to manufacturer's recommendations

(d) the fuel tank is filled to no greater than 10% of the capacity specified by the manufacturer

(e) other fluid levels, such as lubricants, coolants, etc., are set according to manufacturer's recommendations

(f) the driver seat is occupied with a driver of 68 kg mass

(g) no additional payload or passenger ballast is added

5.9 Steering Wheel Position

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

5.10 Driver Seat Position

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

5.11 Accelerator Heel Point (AHP)

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

5.12 Other Vehicle Components

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

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

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

6 Test procedure

6.1 Sightline Projections

6.1.1 Every combination of neck pivot point and eye point angles (β, θ), within the ranges defined in Section 4.1, and camera field of vision angles (α, λ), within the ranges specified by the manufacturer, shall be analysed according to the following protocol. It is recommended that this process is automated through a computer programme. A breakdown of the neck pivot point and eye point angles to be assessed is provided in Appendix B.

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

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

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

6.2 Determining the Direct Vision Volume (V_D)

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

6.3 Determining the Indirect Vision Volume (V_I)

6.3.1 Mirrors (V_{I_M})

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

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

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

6.5 Indirect Vision Volume (V_I)

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

6.5.2 Thus, for each assessment volume:

6.5.3 $V_I = V_{I\_M} + V_{I\_C}$

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

6.6 Determining the Total Driver Vision Volume (V_T)

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

6.6.2 Thus, for each assessment volume:

6.6.3 $V_T = V_D + V_I$

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

6.7 Determining the Blind Spot Volume (V_B)

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

6.7.2 Thus, for each assessment volume:

6.7.3 $V_B = V_T + V_A$

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

7 Assessment of results

7.1 Direct Vision Performance Score (DVS)

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

7.1.2 Thus, for each assessment volume:

7.1.3 $DVS = \frac{V_D}{V_A}$ %

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

7.2 Indirect Vision Performance Score (IVS)

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

7.2.2 Thus, for each assessment volume:

7.2.3 $IVS = \frac{V_I}{V_A}$ %

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

7.3 Total Driver Vision Performance Score (TVS)

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

7.3.2 Thus, for each assessment volume:

7.3.3 $TVS = \frac{V_T}{V_A}$ %

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

7.4 Bus Vision Standard Performance Rating Score (BVS)

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

7.4.2 [London collision data has been used to weight the importance of each assessment zone with respect to the potential casualty prevention potential of each zone around the vehicle.] This has been combined with research further weighting the differences in importance between direct and indirect vision with respect to their relative casualty prevention potentials. These weighting factors are shown in Table 1.

Table 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

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

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

7.4.5 Table 2 shows hypothetical results as a worked example.

Table 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%

8 Test report

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

(a) Performance data

(b) Confirmation of protocol compliance

(c) Reference information

8.2 Performance Data

8.2.1 Table 3 shows the performance data to be produced for each vehicle assessed.

Table 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) /mm^3			
Direct Vision Volume (V_D) /mm^3		-	-
Indirect Vision Volume for Mirrors ($V_{I\ M}$) /mm^3			
Indirect Vision Volume for Cameras ($V_{I\ C}$) /mm^3			
Indirect Vision Volume (V_I) /mm^3			
Total Driver Vision Volume (V_T) /mm^3			
Blind Spot Volume (V_B) /mm^3			
Direct Vision Performance Score (DVS) /%			
Indirect Vision Performance Score (IVS) /%			
Total Driver Vision Performance Score (TVS) /%			
Bus Vision Standard Performance Score (BVS) /%			
Overall Bus Vision Standard Performance Score (BVS) /%			

8.2.2 In addition to the necessary performance data, the Test Service shall provide images with the Test Report illustrating the visible volumes and blind spots associated with each assessment volume. As a minimum requirement, these images shall include a plan view of the blind spot volumes associated with each assessment zone, but may also be combined with images including isometric views, side views, etc. to support understanding of the principle causes of the blind spots. Such images shall be colour coded to distinguish between the visible and blind spot volumes and may also be separated by whether areas are visible by direct or indirect vision (mirrors/cameras). A legend to the colour coding shall be provided within the Test Report. Hypothetical examples are shown in Figure 15.

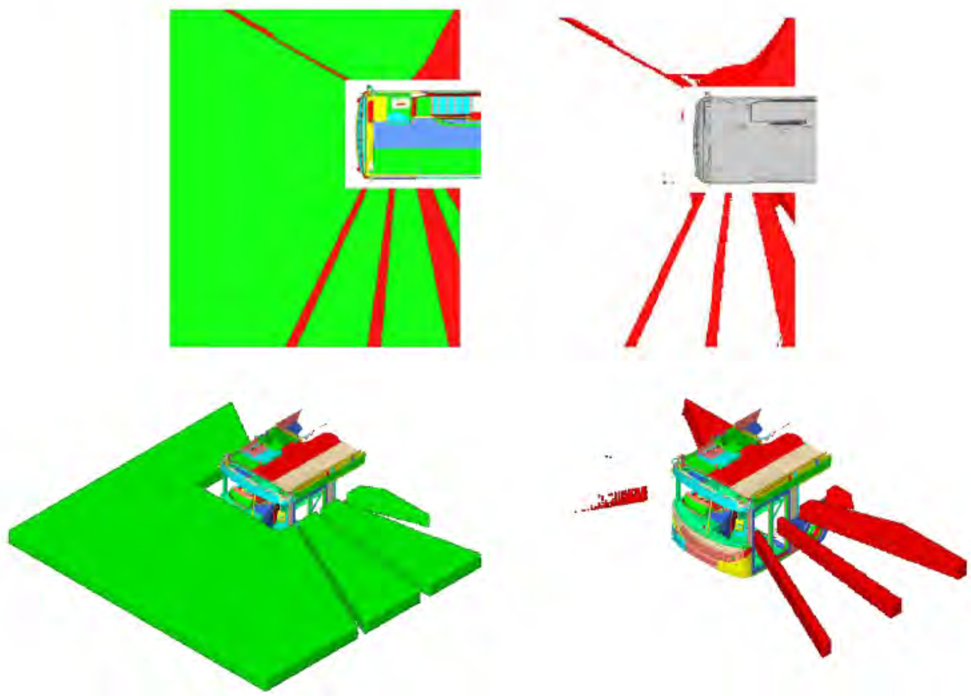

Figure 15: Example images showing Direct Vision Volume (green) and Blind Spot Volume (red) for the forward close proximity assessment zone

8.3 Protocol Compliance

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

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

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

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

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

8.4 Reference Information

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

(a) Vehicle make;

(b) Vehicle model;

(c) Vehicle model variant;

(d) Vehicle running order information;

(e) Vehicle steering wheel and driver seat positions;

(f) AHP location;

(g) Mirror and mirror arm model/s fitted;

(h) CMS model/s fitted, if applicable;

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

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

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

(l) Details of the Test Service; and

(m) Test date(s).

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: 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