

## **ADAPTING APPROVAL REGULATIONS TO ACCOMMODATE AUTOMATED VEHICLES**

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### **ABSTRACT**

The UK government are committed to bringing forward legislation to allow the safe and secure deployment of self-driving vehicles, as set out in the recent policy paper Connected & Automated Mobility 2025: Realising the benefits of self-driving vehicles in the UK. As part of the Connected and Automated Vehicles Process for Assuring Safety and Security (CAVPASS) programme, TRL was commissioned to propose approaches to vehicle classification, and suitable technical requirements for aspects not related to the Automated Driving System (ADS). These included crashworthiness, occupant protection, protection of Vulnerable Road Users (VRUs), and the lighting, braking and steering systems.

The initial focus of this work was on Low-Speed Automated Vehicles (LSAVs). The work involved selection and adaptation of existing pre- and post-deployment regulation to enable it to be applied to LSAVs. A main part was the adaptation of the technical regulations for M- and N-category vehicles, laid down in Great Britain's Road Vehicles (Approval) Regulations 2020 (SI 2020 No. 818), which implements retained Regulation (EU) 2018/858.

The study proposed the introduction of two new vehicle categories (for LSAVs with and without occupants, respectively) to allow approval of designs not compatible with the M- and N-category definitions, such as passenger shuttles with six seats and space for standing passengers, or goods vehicles without any seats. Of 132 technical items collated from the existing body of regulations, 65 were found to be generally applicable for LSAVs with occupants, and 53 for LSAVs without occupants. Technical clarifications for regulations were developed relating to references to the driver or driver's seat, controls, warnings and tell-tales and relating to bi-directional vehicles in general. The study further found that a general permission to carry standing passengers in light vehicles could present unreasonable risks to occupants in braking manoeuvres or collisions, but that it could be safe in some Operational Design Domains (ODDs). A concept was proposed which offers manufacturers a choice between two Crashworthiness Approval Levels (CALs). The less demanding CAL allows standing passengers but restricts the subsequent ODD of the vehicles. VRU impact protection was a high priority due to the expected operation in areas with a high density of pedestrians and cyclists. However, LSAV aspects such as their typically flat-fronted shape cause issues for the application of the current regulation, so modifications were proposed.

Low-speed vehicles are not in widespread use today, which means no directly relevant real-world collision data was available to base safety decisions on. The guiding principle applied in this study was to provide 'at least equivalent safety', i.e. to offer safety levels relating to non-ADS aspects, which, based on the limited data available and expert judgement, are comparable to or better than those of current vehicles used in similar scenarios.

This study proposes a novel approach to link approval regulations to the vehicle's ODD and a set of technical requirements for non-ADS-related aspects of passenger- and goods-carrying LSAVs, which could help enable the approval of new vehicle concepts. The proposals have been presented to the United Kingdom Department for Transport for consideration.

## INTRODUCTION

The United Kingdom (UK) government are committed to bringing forward legislation to allow the safe and secure deployment of self-driving vehicles, as set out in the recent policy paper Connected & Automated Mobility 2025: Realising the benefits of self-driving vehicles in the UK [1]. As part of the Connected and Automated Vehicles Process for Assuring Safety and Security (CAVPASS<sup>1</sup>) programme, TRL was commissioned to propose approaches to vehicle classification and suitable technical requirements for aspects not related to the Automated Driving System (ADS). These included crashworthiness, occupant protection, protection of Vulnerable Road Users (VRUs), and the lighting, braking and steering systems. The focus of the work presented was on Low-Speed Automated Vehicles (LSAVs), i.e. fully electric vehicles with a maximum speed not greater than 20 miles per hour (approx. 32 kilometres per hour) to be used in mixed traffic on roads with a speed limit not higher than 30 miles per hour (approx. 48 kilometres per hour). This initial focus on low-speed vehicles was selected because they have been suggested as a potential early use case for self-driving technology by industry and, while not in widespread use today, there is an emerging class of speed-limited automated vehicles being developed. Table 1 provides additional details of the use cases and vehicle designs in scope. Further, it should be noted that LSAVs can be bi-directional, i.e. capable of travelling forwards and backwards at close to their maximum speed.

*Table 1.  
Scope of use cases and vehicle designs considered*

<b>Characteristic</b>	<b>Scope</b>
<b>Body shape</b>	To include novel vehicle designs which do not conform with legacy design conventions such as windscreens, long bonnets, driver controls, etc.
<b>Purpose</b>	Carriage of goods or passengers (seated, standing or mixed)
<b>Powertrain</b>	Fully electric
<b>Maximum speed</b>	20 mph
<b>Maximum mass (gross vehicle weight)</b>	5,000 kg for passenger-carrying vehicles 3,500 kg for goods vehicles
<b>Operating environment</b>	Roads with a speed limit up to 30 mph with mixed traffic (including VRUs), or Dedicated roadways (which may or may not have segregation barriers) Areas which may include high density of pedestrians Operating on a fixed route or within a fixed geographical area

This paper presents the work performed to develop a suitable set of pre-deployment regulations for LSAVs, drawing from the existing body of UN and EU type-approval regulations. Note that further work was performed to adapt post-deployment regulations, i.e. construction and use regulations, which is not reported in this paper.

## METHODS

### Vehicle Classification

Technical requirements for type-approval are organised by vehicle category. Which category a vehicle belongs to is determined by certain key design aspects, such as vehicle mass, number of seating positions, or primary purpose (passenger or goods transport). A market review identified the design characteristics of vehicles, either already on the market or announced by manufacturers, which would fall within the scope of the study. These designs and plausible iterations of them were compared with existing vehicle category definitions to identify if and how the vehicles would integrate with the current system: Great Britain's type-approval categories for passenger vehicles (M category) and goods vehicles (N category) are laid down in Retained Regulation (EU) 2018/858 [2]. Relevant aspects are contained in Article 3 (Definitions), Article 4 (Vehicle categories) and Annex I (General definitions, criteria for vehicle categorisation, types of vehicle and types of bodywork). Potentially relevant sub-categories, based on the LSAV mass-limited scope, are M<sub>1</sub> (passenger cars), M<sub>2</sub> (minibuses) and N<sub>1</sub> (vans). Note that L-category definitions, laid down in Retained Regulation (EU) 168/2013 [3], were also considered but deemed unsuitable due to the limited number of occupants and low maximum mass allowed under L-category definitions.

<sup>1</sup> <https://www.gov.uk/guidance/connected-and-automated-vehicles-process-for-assuring-safety-and-security-cavpass>



actuate, activate, switch, foremost, R-point, H-point, direction, forward, rearward, behind, fore, and aft. This search was backed up by a full manual analysis of the regulations which highlighted additional incompatibilities, e.g. with regard to applying the pedestrian impact test procedure to flat-fronted LSAV designs.

## RESULTS

### Vehicle Classification

Many envisaged LSAV designs have no conventional vehicle equivalents on-road, for example passenger shuttles with six seating positions and space for standing passengers, or goods vehicles without any seating positions. Barriers to classifying these vehicles in the existing system were identified within each relevant sub-category definition ( $M_1$ ,  $M_2$  and  $N_1$ ). The most common barrier consisted of references to a driver’s seating position, which is generally not present in LSAVs. Other barriers, relevant for certain LSAV designs, included:

- Standing passengers: The  $M_1$  vehicle category definition excludes standing passengers. To permit standing passengers, an LSAV would need to be classified as an  $M_2$  category vehicle. Whether a vehicle is classified as an  $M_1$  or  $M_2$  category is dependent on how many seating positions it offers: up to 9 seats:  $M_1$  category; 10 or more seats:  $M_2$  category. To carry standing passengers, vehicles therefore need at least 10 seating positions in the existing classification system.
- Low-speed vehicles: The definition of a motor vehicle with respect to M and N categories includes a prerequisite that the vehicle has a maximum design speed of more than 25 kilometres per hour (ca. 15.5 miles per hour). Thus, LSAVs with a maximum speed of 15.5 miles per hour or less would fall outside the scope of the categories.

Consequently, to accommodate LSAVs, the existing categories need to be amended or the classification system extended. Following careful consideration, it was recommended that new categories should be introduced because modifications of existing M and N categories could have too far-reaching impacts. New categories will also open a route to assign more suitable technical requirements specific to LSAVs, because some technical requirements associated with current M and N categories do not apply well, e.g. crashworthiness requirements are for more severe collisions than are likely to be experienced by an LSAV.

The most dominant factor determining how many and which technical requirements are needed was found to be the presence of occupants, because a substantial number of requirements are related to occupant protection. This aspect was deemed important enough to warrant the introduction of two separate LSAV categories: Passenger LSAV (for vehicles with occupant positions) and Goods LSAV (vehicles without occupant positions). Category definitions were proposed as detailed in Table 2.

**Table 2.**

**Proposed definitions for new vehicle categories including a top-level definition of LSAV applicable for both**

<b>Top-level definition</b>	'LSAV' means any power-driven vehicle that is designed and constructed to be moved by its own means and to be driven, in normal operation, only by an automated driving system without a driver, that has at least four wheels, is complete, completed or incomplete, has a maximum design speed of at least 10 mph but not more than 20 mph.	
<b>Vehicle category definitions</b>	'Passenger LSAV' means an LSAV intended to be used on public roads, with at least one occupant position (seated and/or standing), and having a maximum mass not exceeding 5,000 kg.	'Goods LSAV' means an LSAV intended to be used on public roads, without occupant positions, and having a maximum mass not exceeding 3,500 kg.

### Selection of Technical Regulations for Applicable Items

The full list of 132 regulatory items collated for consideration is provided in Appendix A. The table details the items’ proposed applicability for Passenger and Goods LSAVs, respectively. Out of the total 132 items considered, 65 were proposed to be applied for type-approval of Passenger LSAVs and 54 for Goods LSAVs. The dominant reasons found to exclude items in the applicability analysis were that they: were specific to heavier vehicles, vehicles with capability to tow trailers or vehicles propelled by a combustion engine or hydrogen drivetrain; were

intended to support a driver (e.g. mirrors, windscreen wipers) or to protect vehicle occupants (and thus not relevant for Goods LSAVs); or because they were related to the dynamic-driving task and therefore not within the scope of this study.

The technical regulations recommended for application following the ‘at least equivalent safety’ principle are detailed in the same table. These are mostly UN and EU regulations for M- and N-category vehicles. For Item 115, maximum vehicle speed limitation, an L-category regulation was proposed to be used as the available M/N category regulations were deemed unsuitable: Maximum vehicle speed is not a relevant categorisation criterion in the M/N-category framework and is therefore not regulated or routinely tested for type-approval. Tests according to UN R68<sup>2</sup> may be performed at the request of the manufacturer or, in some cases, the technical service, but commonly the maximum vehicle speed is declared by the manufacturer in the Information Document without an approval test. UN R68 is a technically robust regulation to determine the achievable maximum speed, but it does not contain technical stipulations as to how a reliable and tamper-proof speed limitation shall be achieved. UN R89 applies to top-speed limiters for heavy vehicles (M<sub>2</sub>, M<sub>3</sub>, N<sub>2</sub>, N<sub>3</sub>). It does not contain specific provisions for electric vehicles and the tolerances permitted in the regulation are too wide for low-speed vehicles.

For certain aspects identified as additional risks for LSAVs, no suitable regulatory text was available in the existing body of regulations to draw from. For these items, new regulatory proposals were developed:

- Item 58: Pedestrian protection
- Item 116: Manual operation at very low speeds
- Item 117: Static vehicle stability

#### **Modification of Technical Regulations for Self-driving Vehicles**

Where existing UN or EU regulations were recommended for application, in many cases modifications were required to make them suitable for LSAVs: Some parts of regulations could be waived or alleviated due to the specific use cases (low-speed, goods vehicles without occupants); other parts needed to be modified because of novel vehicle shapes or the absence of a driver, driver’s seat and conventional vehicle controls. Common themes identified that caused incompatibility of regulatory text with self-driving vehicles included:

- References to:
  - driver’s seating position
  - driver controls (steering wheel, pedals, buttons, adjustment controls, etc.)
  - instrument panel
  - actions performed by the driver (e.g. full application of brake control, setting/unsetting of protective devices)
  - driver side/passenger side
  - front/rear, forward-/rear-facing (conflict with bi-directional vehicles)
- Information presented to the driver (tell-tales, indicator or warning lights, acoustic or haptic warnings); system reaction to failures not defined
- Reliance on muscular energy (e.g. braking)
- No consideration of bi-directional vehicles
- Occupant protection for goods vehicles (without occupants)
- Feasibility of type-approval tests in absence of driver controls

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<sup>2</sup> Shorthand for UN Regulation No 68, applied equivalently for other UN Regulations

Modifications to the existing regulatory texts were proposed to detail the application of each regulation for LSAVs. An example overview of the outcomes of the analysis and the proposed modifications to the regulation for braking systems is presented in Table 3.

**Table 3.**  
**Analysis and modification of technical regulations for LSAVs, example results for Item 9B, braking**

<b>UN Regulation No 13-H.01, consolidated to Supplement 1</b>	
<p><b>Content summary:</b> Requirements relating to the characteristics and performance of braking system for passenger cars and light goods vehicles to ensure safe design and minimum performance levels</p>	<p><b>Applicability for self-driving vehicles:</b></p> <ul style="list-style-type: none"> <li>• Passenger: Applicable</li> <li>• Goods: Applicable</li> </ul>
<p><b>Applicability and suitability of technical requirements/test procedures:</b></p> <ul style="list-style-type: none"> <li>• Aspects related to driver controls and tell-tales not applicable for self-driving vehicles</li> <li>• Functional safety and complex electronics – required, but propose to allow combined assessment of systems (e.g. steering / braking) for self-driving vehicles because of interdependencies</li> <li>• ‘Full-stroke actuation’ and ‘full application’ of brake controls, which is referred to throughout the regulation, not possible in the absence of controls and requires clarification</li> <li>• Alternative energy sources required to replace muscular operation</li> <li>• Pneumatic braking systems not covered in regulation</li> </ul>	
<p><b>Requirements to cover additional risks/considerations for self-driving vehicles:</b></p> <ul style="list-style-type: none"> <li>• For LSAVs equipped with compressed air braking systems: UN Regulation No 13, Paragraph 5.1.3., Annex 6, Annex 7 and Annex 10</li> </ul>	
<p><b>Definitions, modifications, exemptions and additions:</b></p> <ul style="list-style-type: none"> <li>• The safety of complex electronic systems with regard to braking, Paragraph 5.1.3. and Annex 8, shall not be assessed as part of the brake systems approval but instead as part of an overall assessment of the ADS.</li> <li>• All muscular generated performances in conventional vehicles (e.g. secondary brake) shall be replaced by alternative energy sources.</li> <li>• Paragraph 5.2.2.8. (two completely independent energy reserves) shall continue to apply even though the service brake system is not ‘controlled by the driver’ as stipulated in the regulation.</li> <li>• In the event of any failure or defect that would result in a red warning signal according to the regulatory requirements an electronic signal shall be sent to the ADS.</li> <li>• References to ‘full-stroke actuation’ and ‘full application’ of brake controls shall be interpreted as ‘automatically commanded maximum braking demand’ by the ADS; references to ‘release’ of the brake controls shall be interpreted as ‘applying no automatically commanded braking demand’.</li> <li>• Vehicles equipped with compressed-air braking systems shall fulfil, in addition to the requirements of UN Regulation No 13-H as modified above, the requirements for compressed-air braking systems set out in UN Regulation No 13 (11 series of amendments), Paragraph 5.1.3., Annex 6, Annex 7 and Annex 10.</li> </ul>	

Where equivalent aspects requiring modification were identified in multiple regulations, the authors found that these were best addressed in a single place in a uniform way. Item 0, cross-cutting prescriptions, was created to capture modifications intended to apply to all regulations concerned. The elements proposed to cover within this item include:

- Driver controls:
  - A driver’s seating position or driver controls shall not be required and thus requirements relating to the fitment of driver controls, their geometric positioning (e.g. achieve braking action from the driving seat) or their labelling, and requirements governing maximum permitted control application forces are not applicable.

- References to activation or operation of a system or device by the driver, driver's demands (e.g. driver's braking demand) and driver's intention shall be interpreted as activation or operation by the ADS, ADS's demands and ADS's intention. The moment when a control begins to be actuated shall be interpreted as the moment when the automatically commanded signal (e.g. brake or steering demand signal) is issued.
- Vehicles shall be so designed to allow the technical service to perform the required type-approval tests in the absence of conventional driver controls, for example by allowing temporary manual control for the technical service or by offering an automated test mode performed by the ADS which is fully representative of the performance characteristics in normal mode. In production vehicles intended for road use, these test modes or functions shall not be available.
- Requirements relating to information presented to the driver or other vehicle occupants, e.g. in the form of tell-tales, indicator or warning lights or acoustic warnings, shall not apply, unless stated otherwise in the context of specific regulations. Instead, relevant information on failures, defects or emergency situations shall, as appropriate to control the situation, be acted upon appropriately by the vehicle (e.g. initiate minimum risk manoeuvre) or made available to a remote control-centre. Other information, e.g. about the activation status of lights or on-board systems, may be made available to a remote control-centre (optional) or not be provided.
- 'Driver side' of a vehicle shall be understood as the right side with respect to the direction of travel; 'passenger side' shall be understood as the left side with respect to the direction of travel.
- Bi-directional vehicles, defined as vehicles that can travel in either direction, forwards or backwards, at a speed of 80 percent or more of the vehicles maximum speed, shall meet the applicable requirements in both driving directions unless stated otherwise in the context of specific regulations. Where the requirements represent different levels of safety, the more stringent requirements shall apply. Tests shall therefore also be performed in both directions or, at the discretion of the technical service, in the direction determined to represent the worst case.

### **Operational Design Domain-based Occupant Restraint and Crashworthiness Requirements**

The level of occupant protection and crashworthiness appropriate for a Passenger LSAV will change depending on its Operational Design Domains (ODD) – an aspect that is not catered for in the current type-approval system for M- and N-category vehicles where a single set of requirements applies to allow unrestricted (ODD-independent) operation.

A main factor determining appropriate requirements is the risk of injury from collisions which could cause large accelerations and/or occupant compartment intrusion. The ADS is responsible for primary safety for collision avoidance, but the action of other road users may still result in collisions which require mitigation through secondary safety measures. Thus, on the assumption that the vehicle drives well (e.g. in a manner which adheres to the traffic rules, avoids being the cause of a collision), the main types of collisions were anticipated to be 'not at fault' ones, i.e. other vehicles colliding into the LSAV. The typical collisions envisaged on which to base protection needs are a vehicle (most likely a car) travelling at 30 miles per hour impacting the side, front or rear of the LSAV.

The injury risk will be low in ODDs where the collision risk and/or consequence is reduced. Examples include separated lanes, where the collision risk will be reduced compared to open roads because less traffic is encountered, and 20 miles per hour zones or business/university campuses where the collision consequences will be reduced because of the low traffic speed. Conversely, in ODDs such as roads with 30 miles per hour speed limits on which mixed traffic is present, the injury risk will be much higher because the presence of many other vehicles increases the collision risk and because they are likely to be travelling faster at 30 miles per hour or potentially above, which also increases the collision consequences. Different levels of protection will be required for these different operating environments.

When considering whether or not standing or unrestrained passengers should be permitted in passenger LSAVs, the presence of VRUs in the ODD should be taken into account: VRUs' trajectories are more difficult to predict than motor vehicles' and their presence is thus expected to result in more automatic emergency braking manoeuvres by the LSAV which could cause occupants to fall and/or be thrown forward. Standing/unrestrained passengers could be

permitted only in environments with low/no prevalence of VRUs or a very low speed restriction could be imposed on vehicles with such passengers in areas with VRUs.

**Table 4.**  
**Proposed occupant restraint and crashworthiness requirements for LSAV approval to CAL Reduced and CAL Standard**

	<b>CAL Reduced</b>	<b>CAL Standard</b>
<b>Basis</b>	Category M <sub>2</sub> , Class A requirements for operating environments with a low risk of collision and/or low consequences	Category M <sub>1</sub> requirements for all operating environments, including those with a higher risk of collision and/or higher consequences
<b>Occupant restraint</b>	<ul style="list-style-type: none"> <li>• Standees:               <ul style="list-style-type: none"> <li>○ Permitted</li> <li>○ Requirements include handrails/handholds as per UN R107</li> </ul> </li> <li>• Seated:               <ul style="list-style-type: none"> <li>○ Side-facing seats permitted</li> <li>○ Requirements include guard or at least 2-point safety belt for exposed seats only</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Standees:               <ul style="list-style-type: none"> <li>○ Not permitted</li> </ul> </li> <li>• Seated:               <ul style="list-style-type: none"> <li>○ Side-facing seats not permitted</li> <li>○ Front and rear impact: Requirements include 3-point safety belts and head restraints for all seating positions (including rear-facing seats). Fit impact friendly interior for parts likely to be hit by passengers; relevant regulations: UN R14, UN R16, UN R17 and UN R21</li> <li>○ Side impact: Require side impact protection, e.g. meet dummy injury assessment reference values in side impact test; relevant regulations: UN R95</li> </ul> </li> </ul>
<b>Crash-worthiness</b>	No requirements	<ul style="list-style-type: none"> <li>• Front impact:               <ul style="list-style-type: none"> <li>○ Aim: Ensure structural integrity for electrical power train protection and to limit compartment intrusion to allow occupant restraint to function correctly</li> <li>○ Test: UN R95 type test at 50 km/h to the front of the vehicle and impose requirements for electrical power train safety as per the regulation, and structural performance through an assessment of intrusion</li> </ul> </li> <li>• Rear impact:               <ul style="list-style-type: none"> <li>○ Aim: Ensure structural integrity for electrical power train protection and to limit compartment intrusion to allow occupant restraint to function correctly</li> <li>○ Test: UN R95 type test at 50 km/h to the rear of the vehicle and impose requirements for electrical powertrain safety as per the regulation and structural performance through an assessment of intrusion as per UN R32</li> </ul> </li> <li>• Side impact:               <ul style="list-style-type: none"> <li>○ Aim: Ensure structural integrity for electrical power train protection together with associated padding / airbags for occupant protection</li> <li>○ Test: UN R95 test with electrical power train and occupant protection requirements as per the regulation</li> </ul> </li> </ul>

With this in mind and based on the principle of achieving a safety level at least equivalent to current non-automated vehicles, it is proposed to introduce two ODD-based Crashworthiness Approval Levels (CALs) for passenger LSAVs with outline requirements as detailed in Table 4. It is envisaged that the manufacturer will be able to choose which CAL to approve the LSAV to, depending upon the intended use. An LSAV approved to CAL Reduced shall be limited to ODDs where the risk of collision and/or consequences within the domain are appropriately low



(considering the risk of impacting/being impacted by other vehicles and the risk of emergency braking manoeuvres endangering standing/unrestrained occupants). An LSAV approved to CAL Standard on the other hand shall be permitted to operate in all environments within the overall scope of this study, including the aforementioned low-risk ODDs.

**Adapting Requirements for VRU Protection**

LSAVs are expected to operate frequently in areas with a high density of VRUs which makes VRU protection a high priority. Given high exposure to VRUs, the risk of harm is greater when operating in these environments. Therefore, it is proposed that secondary safety countermeasures are required. The relevant technical areas to consider were: external projections (to reduce the risk of injury to a person hit by sharp edges and protrusions on the vehicle body work), VRU protection (to reduce risk of injury from impacts) and frontal protection systems (to prevent additional injury risk from these structures). The outline requirements proposed for these areas are summarised in Table 5.

**Table 5.**  
***Proposed VRU protection requirements for LSAV approval***

	<b>Proposed requirements</b>
<b>External projections</b>	<p>Apply requirements of UN R26 with newly added requirements for ADS sensors, which are not currently covered within the regulation. If vehicle features are present that are regulated only in UN R61, the Technical Service may consider the relevant prescriptions of UN R61 in their assessment.</p> <p>An exemption for certain features can be given by the Approval Authority where the special purpose of a vehicle makes it impossible to fully comply.</p> <p>In general, the Technical Service should pay specific attention to features likely to cause leg injuries because pedestrian leg impact testing will not be performed.</p>
<b>Vulnerable road user protection</b>	<p>For all vehicles with a maximum speed &gt; 16 km/h, submit documentation to demonstrate that frontal areas of the vehicle that are likely to be hit by a VRU’s head have safety levels in line with the principles of UN R127. The documentation will be assessed by the Technical Service.</p> <p>Assessed areas should include windscreen / window areas if likely to be hit, i.e. wrap-around distance of 800 mm to 2500 mm or a height above ground of 2000 mm for vehicles with close to vertical front shapes. Test areas to be defined using UN R127 procedures or, if not appropriate, an equivalent type of method.</p> <p>Safety levels may be demonstrated with headform tests or, for limited areas, with logical argumentation to the satisfaction of the Technical Service/Approval Authority.</p> <p>Headform test parameters may be adjusted where appropriate, e.g. impact angle for different vehicle front shapes, or impact speed to account for a vehicle’s maximum speed being &lt; 40 km/h, the nominal pedestrian impact speed used as the basis for the development of UN R127.</p> <p>For child and adult headform tests the Head Injury Criterion (HIC) recorded shall meet the requirement to not exceed 1000 over all of the test area. Note: This is different to UN R127 requirements, which are &lt; 1000 over 2/3 of test area and &lt; 1700 over remaining area, because it is anticipated that a reduced impact test speed will make it technically feasible to meet this requirement in the entire area.</p>
<b>Frontal protection systems</b>	Fitment of frontal protection systems not permitted.

For VRU protection it should be noted that UN R127 cannot be applied because many LSAVs are anticipated to have a close to vertical front shape (as opposed to a long bonnet type shape of typical passenger cars) which makes the current pedestrian safety protocol, including leg impact, very difficult to perform. Additionally, the maximum LSAV speed is lower than the pedestrian impact represented in the current protocol. Therefore, adapted procedures focussing on head protection have been proposed.

Frontal protection systems are defined as a separate structure or structures, such as a bull bar, or a supplementary bumper which, in addition to the original-equipment bumper, is intended to protect the external surface of the vehicle from damage in the event of a collision with an object, with the exception of structures having a mass of less than 0.5 kilograms, intended to protect only the vehicle's lights. It is not envisaged that frontal protection systems will be needed in the environments LSAVs are expected to operate in. To avoid an elevated injury risk to VRUs from these typically stiff structures, no frontal protection systems should be permitted on LSAVs.

## **DISCUSSION AND LIMITATIONS**

This paper proposes to create new vehicle categories for LSAVs because many envisaged designs do not have current, non-automated equivalents. In the future, dual mode vehicles, i.e. those that can self-drive in specified ODDs and be operated by a driver in other operating environments, are likely to be built by adapting current vehicles. Unlike LSAVs, these will likely fit into current vehicle categories well and hence for these vehicles, the better way forward may be to create automated vehicle sub-categories under existing vehicle categories.

Analysis of the regulatory body for M- and N-category vehicles found that more than half of the existing technical items were superfluous for LSAVs. The dominant reasons for eliminating items were not related to the low maximum design speed but to the absence of a driver or occupants in general, so would also hold for other self-driving vehicles.

Low-speed vehicles are not in widespread use today, which means no directly relevant real-world collision data were available to base safety decisions on. The guiding principle applied in this study was to provide 'at least equivalent safety', i.e. to offer safety levels relating to non-ADS aspects, which, based on the limited data available and expert judgement, are comparable or better than those of current vehicles used in similar scenarios. The technical requirements were mostly based on M<sub>1</sub>- and N<sub>1</sub>-category regulations mainly because of their mass similarity to LSAVs. Reduced occupant protection requirements (CAL Reduced) were drawn from M<sub>2</sub>-category regulations because the vehicles share similar use cases.

The concept of linking crashworthiness and occupant protection requirements at type approval to the future ODD of a vehicle by offering different CALs is a novel concept which does not exist in current type-approval frameworks. It remains to be seen if this concept proves practical in real-world application, i.e. if sufficient low-risk environments can be identified to warrant the design and production of restricted-use vehicles. If successful, it might allow the production of more cost-effective and mass-reduced vehicles for low-risk environments, and also enable the carriage of standing passengers in small vehicles to enable frequent and fast passenger changes. The risk of vehicle ODDs being expanded post-approval by software updates while the CAL, determined by the mechanical design of the vehicle, remains unchanged should be considered. This might require mitigation by appropriate post-deployment or licencing legislation.

The head impact requirements proposed for VRU protection should be regarded as a first step to ensuring secondary VRU safety for flat-fronted vehicles, which could otherwise not be assessed at all. In the medium to longer term, these should be updated with an appropriate regulation for a full assessment of VRU impact protection for LSAVs when lessons learnt from in-use safety monitoring can be taken into consideration.

## **CONCLUSIONS**

This independent study developed proposals for a comprehensive set of technical requirements to allow the safe deployment of LSAVs with a focus on non-ADS aspects, such as crashworthiness, occupant and VRU protection, and the lighting, braking and steering systems. The requirements were arranged in relation to two new vehicle categories with the ability to carry passengers being the main differentiator. For Passenger LSAVs, a novel approach was proposed to link approval regulations to the vehicle's ODD, which could help enable the approval of new vehicle concepts, such as small vehicles with standing passengers. The proposals have been presented to the UK Department for Transport for consideration.

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## REFERENCES

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**APPENDIX A**

**Table 6.**

*List of applicable and non-applicable regulatory items for Passenger and Goods LSAVs with proposed technical regulation for requirements and test procedures; item numbers: left column as per Retained Regulation (EU) 2018/858, Annex II, Part I [2] and consecutive numbers for additional items; right column provides corresponding updated item numbers as per Commission Delegated Regulation (EU) 2022/2236 [5] for reference*

<b>Item number</b>	<b>Subject</b>	<b>Regulation</b>	<b>Passenger LSAV</b>	<b>Goods LSAV</b>	
<b>0</b>	n/a	Cross-cutting prescriptions	New regulatory text	Applicable	Applicable
<b>1A</b>	G1, B14	Sound level	UN Regulation No 138	Applicable	Applicable
<b>2A</b>	G2–G12, H1	Emissions (Euro 5 and Euro 6) light duty vehicles/access to information	Regulation (EC) No 715/2007 (light duty vehicle emissions)	Applicable	Applicable
<b>3A</b>	A14	Prevention of fire risks (liquid fuel tanks)	n/a	Not applicable	Not applicable
<b>3B</b>	A12	Rear underrun protective devices (RUPDs) and their installation; rear underrun protection (RUP)	UN Regulation No 58	Applicable	Applicable
<b>4A</b>	F1	Space for mounting and fixing rear registration plates	Commission Regulation (EU) 1003/2010	Applicable	Applicable
<b>5A</b>	C1	Steering equipment	UN Regulation No 79	Applicable	Applicable
<b>6A</b>	F4	Vehicle access and manoeuvrability (steps, running boards and handholds)	Commission Regulation (EU) 130/2012, Annex II	Applicable	Not applicable
<b>6B</b>	F3	Door latches and door retention components	UN Regulation No 11	Applicable	Not applicable
<b>7A</b>	D1	Audible warning devices and signals	UN Regulation No 28	Applicable	Applicable
<b>8A</b>	B13	Devices for indirect vision and their installation	n/a	Not applicable	Not applicable
<b>9A</b>	C4	Braking of vehicles and trailers	n/a	Not applicable	Not applicable
<b>9B</b>	C4	Braking of passenger cars	UN Regulation No 13-H	Applicable	Applicable
<b>10A</b>	D2	Electromagnetic compatibility	UN Regulation No 10	Applicable	Applicable
<b>12A</b>	A1	Interior fittings	UN Regulation No 21	Applicable	Not applicable
<b>13A</b>	D3	Protection of motor vehicles against unauthorised use	UN Regulation No 18	Applicable	Applicable
<b>13B</b>	D3	Protection of motor vehicles against unauthorised use	UN Regulation No 116	Applicable	Applicable
<b>14A</b>	A22	Protection of the driver against the steering mechanism in the event of impact	n/a	Not applicable	Not applicable
<b>15A</b>	A2	Seats, their anchorages and any head restraints	UN Regulation No 17	Applicable	Not applicable

Item number		Subject	Regulation	Passenger LSAV	Goods LSAV
15B	A3	Seats of large passenger vehicles	n/a	Not applicable	Not applicable
16A	F5	External projections	UN Regulation No 26	Applicable	Applicable
17A	F2	Vehicle access and manoeuvrability (reverse gear)	Commission Regulation (EU) 130/2012, Annex III	Applicable	Applicable
17B	D5, D6	Speedometer equipment including its installation	n/a	Not applicable	Not applicable
18A	F7	Manufacturer's statutory plate and VIN	Commission Regulation (EU) 19/2011	Applicable	Applicable
19A	A4	Safety-belt anchorages	UN Regulation No 14	Applicable	Not applicable
20A	D15	Installation of lighting and light-signalling devices on vehicles	UN Regulation No 48	Applicable	Applicable
21A	D13	Retro-reflecting devices for power-driven vehicles and their trailers	UN Regulation No 3	Applicable	Applicable
22A	D11	Front and rear position lamps, stop-lamps and end-outline marker lamps for motor vehicles and their trailers	UN Regulation No 7	Applicable	Applicable
22B	D11	Daytime running lamps for power-driven vehicles	UN Regulation No 87	Applicable	Applicable
22C	D11	Side-marker lamps for motor vehicles and their trailers	UN Regulation No 91	Applicable	Applicable
23A	D11	Direction indicators for power-driven vehicles and their trailers	UN Regulation No 6	Applicable	Applicable
24A	D11	Illumination of rear-registration plates of power-driven vehicles and their trailers	UN Regulation No 4	Applicable	Applicable
25A	D12	Power-driven vehicle's sealed-beam headlamps (SB) emitting an European asymmetrical passing beam or a driving beam or both	UN Regulation No 31	Applicable	Applicable
25B	D14	Filament lamps for use in approved lamp units of power-driven vehicles and their trailers	UN Regulation No 37	Applicable	Applicable
25C	D12	Motor vehicle headlamps equipped with gas-discharge light sources	UN Regulation No 98	Applicable	Applicable
25D	D14	Gas-discharge light sources for use in approved gas-discharge lamp units of power-driven vehicles	UN Regulation No 99	Applicable	Applicable
25E	D12	Motor vehicle headlamps emitting an asymmetrical passing beam or a driving beam or both and equipped with filament lamps and/or LED modules	UN Regulation No 112	Applicable	Applicable
25F	D12	Adaptive front-lighting systems (AFS) for motor vehicles	UN Regulation No 123	Applicable	Applicable
26A	D11	Power-driven vehicle front fog lamps	UN Regulation No 19	Applicable	Applicable
27A	F8	Towing device	Commission Regulation (EU) 1005/2010	Applicable	Applicable
28A	D11	Rear fog lamps for power-driven vehicles and their trailers	UN Regulation No 38	Applicable	Applicable

Item number		Subject	Regulation	Passenger LSAV	Goods LSAV
29A	D11	Reversing lights for power-driven vehicles and their trailers	UN Regulation No 23	Applicable	Applicable
30A	D11	Parking lamps for power-driven vehicles	UN Regulation No 77	Applicable	Applicable
31A	A5, A9	Safety-belts, restraint systems, child restraint systems and ISOFIX child restraint systems	UN Regulation No 16	Applicable	Not applicable
32A	B8	Forward field of vision	n/a	Not applicable	Not applicable
33A	D9	Location and identification of hand controls, tell-tales and indicators	n/a	Not applicable	Not applicable
34A	B11	Windscreen defrosting and demisting systems	n/a	Not applicable	Not applicable
35A	B12	Windscreen wiper and washer systems	n/a	Not applicable	Not applicable
36A	D10	Heating systems	UN Regulation No 122	Applicable	Applicable
37A	F9	Wheel guards	Commission Regulation (EU) 1009/2010	Applicable	Applicable
38A	A2	Head restraints (headrests), whether or not incorporated in vehicle seats	UN Regulation No 25	Applicable	Not applicable
41A	G2–G12, H1	Emissions (Euro VI) heavy duty vehicles/access to information	n/a	Not applicable	Not applicable
42A	A13	Lateral protection of goods vehicles	n/a	Not applicable	Not applicable
43A	F10	Spray suppression systems	n/a	Not applicable	Not applicable
44A	F11	Masses and dimensions (M1)	Commission Regulation (EU) 1230/2012	Applicable	Applicable
45A	B10	Safety glazing materials and their installation on vehicles	UN Regulation No 43	Applicable	Applicable
46A	C15	Installation of tyres	UN Regulation No 142	Applicable	Applicable
46B	C10	Pneumatic tyres for motor vehicles and their trailers (Class C1)	UN Regulation No 30	Applicable	Applicable
46C	C10	Pneumatic tyres for commercial vehicles and their trailers (Classes C2 and C3)	UN Regulation No 54	Applicable	Applicable
46D	C10	Tyre rolling sound emissions, adhesion on wet surfaces and rolling resistance (Classes C1, C2 and C3)	UN Regulation No 117	Applicable	Applicable
46E	C11	Temporary-use spare unit, run-flat tyres/system	UN Regulation No 64	Applicable	Applicable
47A	D7	Speed limitation of vehicles	n/a	Not applicable	Not applicable
48A	F11	Masses and dimensions (non-M1)	n/a	Not applicable	Not applicable
49A	F6	Commercial vehicles with regard to their external projections	n/a	Not applicable	Not applicable
50A	F12	Mechanical coupling components of combinations of vehicles	n/a	Not applicable	Not applicable

Item number		Subject	Regulation	Passenger LSAV	Goods LSAV
50B	F12	Close-coupling device (CCD); fitting of an approved type of CCD	n/a	Not applicable	Not applicable
51A	F16	Burning behaviour of materials used in the interior construction of certain categories of motor vehicles	n/a	Not applicable	Not applicable
52A	F14	M2 and M3 vehicles Regulation (EC)	UN Regulation No 107	Applicable	Not applicable
52B	F15	Strength of the superstructure of large passenger vehicles	n/a	Not applicable	Not applicable
53A	A20	Protection of occupants in the event of a frontal collision	n/a	Not applicable	Not applicable
54A	A25	Protection of occupants in the event of lateral, frontal or rear collision	UN Regulation No 95	Applicable	Not applicable
56A	F13	Vehicles for the carriage of dangerous goods	n/a	Not applicable	Not applicable
57A	A11	Front underrun protective devices (FUPDs) and their installation; front underrun protection (FUP)	n/a	Not applicable	Not applicable
58	B1	Pedestrian protection	New regulatory text	Applicable	Applicable
59	G13	Recyclability	UN Regulation No 133	Applicable	Applicable
61	G14	Air-conditioning systems	Directive 2006/40/EC	Applicable	Applicable
62	A17	Hydrogen system	n/a	Not applicable	Not applicable
63	n/a	General Safety	n/a	Not applicable	Not applicable
64	D18	Gear shift indicators	n/a	Not applicable	Not applicable
65	C8	Advanced emergency braking system (heavy vehicles)	n/a	Not applicable	Not applicable
66	C2	Lane departure warning system (heavy vehicles)	n/a	Not applicable	Not applicable
67	A15	Specific components for liquefied petroleum gases (LPG) and their installation on motor vehicles	n/a	Not applicable	Not applicable
68	D3	Vehicle alarm systems (VAS)	UN Regulation No 97	Applicable	Applicable
69	A19	Electric safety	UN Regulation No 100	Applicable	Applicable
70	A16	Specific components for CNG and their installation on motor vehicles	n/a	Not applicable	Not applicable
71	A24	Cab strength	n/a	Not applicable	Not applicable
72	A28	eCall system	n/a	Not applicable	Not applicable
73	A7	Partitioning systems	n/a	Not applicable	Not applicable
74	A10	Enhanced child restraint systems	n/a	Not applicable	Not applicable
75	A18	Hydrogen system material qualification	n/a	Not applicable	Not applicable

Item number		Subject	Regulation	Passenger LSAV	Goods LSAV
76	A21	Frontal full-width impact	n/a	Not applicable	Not applicable
77	A23	Replacement airbag	n/a	Not applicable	Not applicable
78	A26	Pole side impact	n/a	Not applicable	Not applicable
79	A27	Rear impact	n/a	Not applicable	Not applicable
80	B2	Enlarged head impact zone	n/a	Not applicable	Not applicable
81	B4	Advanced emergency braking for pedestrians and cyclists ahead (AEBS PC)	n/a	Not applicable	Not applicable
82	B5	Pedestrian and cyclist collision warning (MOIS)	n/a	Not applicable	Not applicable
83	B6	Blind spot information system (BSIS)	n/a	Not applicable	Not applicable
84	B7	Reversing safety	n/a	Not applicable	Not applicable
85	B9	Heavy duty vehicles direct vision	n/a	Not applicable	Not applicable
86	C3	Emergency lane keeping	n/a	Not applicable	Not applicable
87	C9	Advanced emergency braking on light duty vehicles (AEBS)	n/a	Not applicable	Not applicable
88	C12	Retreaded tyres	n/a	Not applicable	Not applicable
89	C13, C14	Tyre pressure monitoring	n/a	Not applicable	Not applicable
90	C16	Replacement wheels	n/a	Not applicable	Not applicable
91	D4	Protection of vehicle against cyberattacks	UN Regulation No 155	Applicable	Applicable
92	D8	Intelligent speed assistance	n/a	Not applicable	Not applicable
93	D16	Emergency stop signal	n/a	Not applicable	Not applicable
94	D17	Headlamp cleaners	UN Regulation No 45	Applicable	Applicable
95	E1	Alcohol interlock installation facilitation	n/a	Not applicable	Not applicable
96	E2	Driver drowsiness and attention warning	n/a	Not applicable	Not applicable
97	E3	Advanced driver distraction warning	n/a	Not applicable	Not applicable
98	E4	Driver availability monitoring system	n/a	Not applicable	Not applicable
99	E5	Event data recorder	n/a	Not applicable	Not applicable
100	E6	Systems to replace driver's control	n/a	Not applicable	Not applicable
101	E7	Systems to provide the vehicle with information on state of vehicle and surrounding area	n/a	Not applicable	Not applicable



Item number		Subject	Regulation	Passenger LSAV	Goods LSAV
102	E8	Platooning	n/a	Not applicable	Not applicable
103	E9	Systems to provide safety information to other road users	n/a	Not applicable	Not applicable
104	A6	Safety-belt reminders	UN Regulation No 16	Applicable	Not applicable
105	A17	Hydrogen safety	n/a	Not applicable	Not applicable
106	B3	Frontal protection system	n/a	Not applicable	Not applicable
107	C5	Replacement braking parts	n/a	Not applicable	Not applicable
108	C6	Brake Assist	n/a	Not applicable	Not applicable
109	C7	Stability control	n/a	Not applicable	Not applicable
110	D12	Cornering lamps	UN Regulation No 119	Applicable	Applicable
111	D13	Retro-reflective markings (heavy and long vehicles)	n/a	Not applicable	Not applicable
112	D14	LED light sources	UN Regulation No 128	Applicable	Applicable
113	A8	Child restraint anchorages	UN Regulation No 145	Applicable	Not applicable
114	H2	Software update and software updates management system	UN Regulation No 156	Applicable	Applicable
115	n/a	Maximum vehicle speed limitation	Commission Delegated Regulation (EU) No 3/2014, Annex XVIII	Applicable	Applicable
116	n/a	Manual operation at very low speeds	New regulatory text	Applicable	Applicable
117	n/a	Static vehicle stability	New regulatory text	Applicable	Applicable