Certifying a Synthetic Environment for CAV Validation and Verification

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Abstract *– A key element supporting the introduction of Level 4/5 Connected and Autonomous Vehicles (CAVs) will be the ability to independently certify that such systems are safe, reliable and secure. Not only must system developers and service providers have methodologies for demonstrating that consumer products are safe, but the public must also have confidence in these vehicles and systems. While testing and development of CAVs has begun across many countries in Europe and globally, a certification approach is required to underpin widespread adoption of CAVs. Among the options for delivering certification cost-effectively and faster, is the use of synthetic environments, including CAV simulators. Conducting validation of vehicles in simulators enables the creation of an almost limitless number of testing scenarios that are flexible, repeatable and safe. Compared to real-world testing, simulated validation using simulators will enable vehicles to be tested rapidly and against a challenging set of conditions that would be difficult and costly to replicate in real life. This paper will examine the conditions required for creating such a testing environment, as well as prerequisites for developing a methodology for a simulator to be independently certified as an appropriate means of evaluating the safety of CAVs. This paper presents the identification and analysis of twelve existing standards for CAV testing as a pre-requisite for creating a simulator certification methodology.*

Keywords: *Simulator, Autonomous, Certification, Driving, Standards*

Introduction

Driving simulators, which can consist of various subsystems and models, which mimic the real-world driving environment as comprehensively as possible are key to accelerated innovations and validation for the next generation of connected, advanced driving assistance systems (ADAS) and autonomous features. Gathering and merging simultaneous real-time streams of data about the driving environment, for example terrain, traffic and/or infrastructure objects etc. to relay to the Vehicle-Under-Test (VUT) are essential elements of such a driving simulator. These elements can provide complete spatial definition of a vehicle's surroundings and crucially, a capability to create different driving scenarios that is far more flexible, repeatable and safer than with real users. The University of Warwick's WMG 3xD driving simulator for Intelligent Vehicles (IVs) aims to achieve much of this capability.

The current challenge is that there is no systematic or structured methodology for the validation of Autonomous Vehicles (AVs) using simulators that generate synthetic environments, which is critical both in the UK and globally.

Supporting the introduction of SAE Level 4 and Level 5 driving automation as defined in [Kha15], will be the formation of regulated criteria that provide confidence to the general public that such systems are safe, reliable and secure. The 3xD simulator is both a driver-in-the-loop and a vehicle-in-the-loop simulator for testing of SAE Level 1-5 vehicles. The ability to certify that Connected and Autonomous Vehicles (CAVs) meet these criteria is an essential precondition to regulating their entry into the global market.

Among the options for delivering certification is the use of simulation within driving simulators. A RAND Corporation report published in 2014 stated that it would be necessary to drive 8.8 billion miles in order to provide 95% confidence that a AV was 20% safer than existing human drivers – making simulation within CAV simulators a credible option for delivering validation of such systems [Kal14]. It is important to mention that driving simulators can only reproduce a subset of the billions of miles that need to be created in the virtual environment but it is about creating and testing the 'smart miles' or corner cases more effectively.

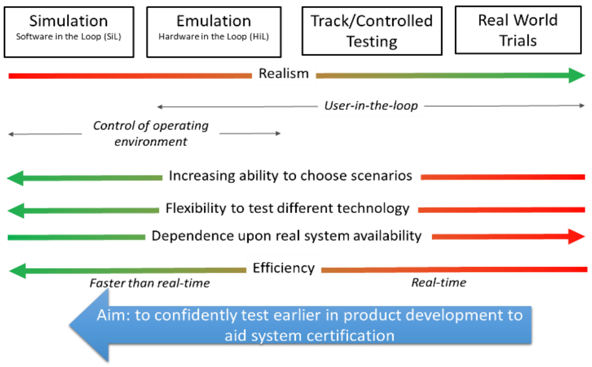

Figure 1: CAV Validation Stages – From Simulation to Real-World trials

However, using existing simulator systems might not be enough from a CAV certification point-of-view. The verification tools used throughout the validation stages, shown in Figure 1, will themselves need to be validated and certified against relevant standards first.

In order to examine the development of novel, cost-effective and rapid solutions to this certification challenge, this paper will build upon existing work carried out by WMG using the 3xD simulator. The research question of how synthetic environments of CAV simulators could potentially be certified in order to certify a CAV system will be addressed in this body of work. Previous work on certifying simulators and associated standards are limited to simulators for vehicle emissions [Fon18] and in the maritime [Ver05] and aerospace domain with standards such as 2012/010/R (CS-FSTD(A)) for Certification Specifications for Aeroplane Flight Simulator Training Devices, and so forth.

In this paper the authors will propose a process and apply it to current international standards in the area of automated driving and ADAS to support the identification of the requirements for a certifiable synthetic environment for testing and validation of CAVs in order to issue a certification.

This work will establish the centrality of synthetic environments to CAV certification - an approach that will enable fast, flexible and high-fidelity testing and validation. It is expected that this activity could open up a market worth around £35m over 10 years in the UK alone – with higher potential revenues from global adoption of standards governing certification in synthetic environments.

Background

Simulating using synthetic environments is based on data that generates scenarios used to exercise the System-Under-Test (SUT). The validity of these simulator scenarios are just as relevant as the validity of the simulator models and software [The SCSC Group18] .

A common strategy to demonstrate that a system is sufficiently safe is to evidence that an applicable safety standard has been followed, implicitly adopting the underlying safety argument strategy inherent in the standard. However, because both the technology and safety strategies for autonomous systems are still evolving, there are no fully encompassing safety standard published currently.

Autonomous vehicles utilise a combination of relatively mature technology (e.g. vehicle control systems) and novel technology (e.g. machine learning), safety arguments needs to be heterogeneous in nature. This means that different portions of the safety argument will likely take fundamentally different approaches for different system functions and components. It is this heterogeneous approach that raises the need for a simulator architecture with various configuration options due to the user needs spanning different configurations for the simulator synthetic environment.

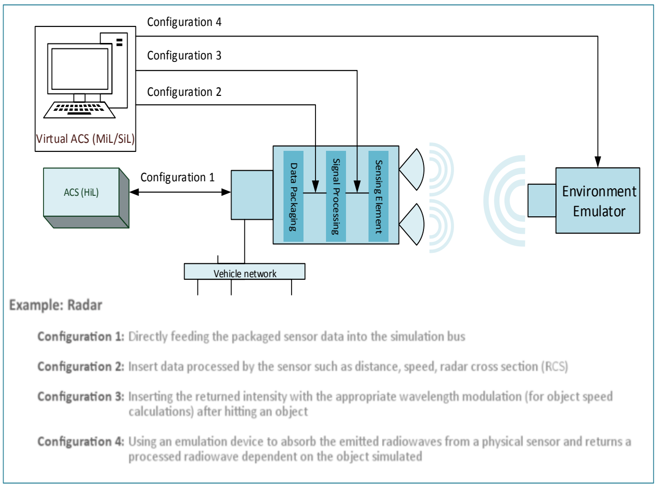

Figure 2: Sensor data feed-in configurations [adapted from [Han18]**]**

In order to test CAVs, the sensor data needs to be fed to the SUT/VUT. Thus the simulator needs to be able to simulate or emulate sensor data and inject data at various points in the system as illustrated in Figure 2. The fidelity of data is very important to ensure valid testing takes place. Test coverage is also an important factor but is out of scope for this paper.

From sensor models and real-world sensors typically used on vehicles (such as Radar, Camera, LiDAR, Ultrasonic and Inertial Measurement Unit (IMU)), relevant input and output sensor parameters and resolution for the simulator's sensors needs to be extracted. This work however will not form part of this paper's discussing. It will be part of a second paper.

Before the sensor fidelity requirements can be applied in a synthetic environment, the capability to replicate the scenarios described in the real-world test standards is vital if a simulator platform is to be used to verify and validate a CAV system. The following section describes the process to derive scenarios from existing ADAS and AV standards.

Process Solution

This paper describes part of a comprehensive process to support the creation of a CAV simulator certification architecture as illustrated in Figure 3.

The simulator's synthetic environment software requirements developed in this paper will form part of the complete solution: a process to certify an CAV simulator. The CAV simulator consists of key elements such as spoofing of sensors in real-time through simulation, emulation or a combination of both. This paper focusses on the initial steps to identify the requirements which the system can be evaluated against to enable certification of the system itself.

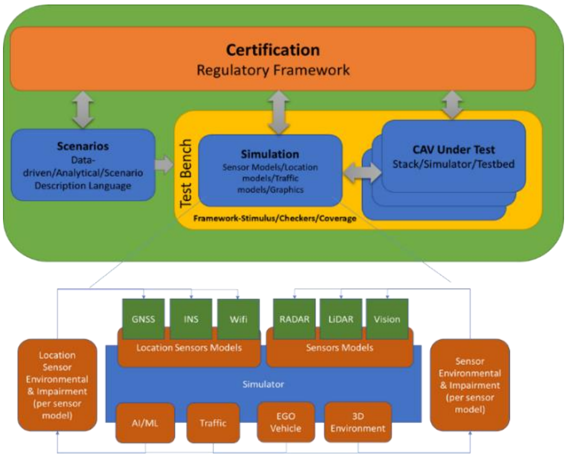

Figure 3: Generic CAV Certification Synthetic Environment Simulator Architecture

After the initial requirements from existing standards are identified, together with a review of other software capabilities such as sensor availability and user interfaces, requirements for other system elements eg. ISO26262, implications for the software itself will be considered and incorporated in the certification framework.

Methodology

The relevant standards were found through a systematic search using a range of different key words such as CAVs, modelling, simulator and simulation. The most relevant UK CAV standards landscape is captured in the document titled "Connected and autonomous vehicles, A UK standard strategy – Summary report" published by the British Standards Institution (BSI) [Cat17]. The report also acknowledges the significant lack of standards in the autonomous vehicles domain, providing recommendations for where standards need to be developed. The criteria used to select which standards should form the basis of a scenario, were those concerned with the use of ADAS and AV features that control an actuation on the vehicle.

Initially the scenario requirements were extracted from the relevant standards documents. Analysis of the standards involved a comprehensive review of the content, leading to a set of descriptions which form the outline of the scenarios. From these descriptions, the relevant parameters or variables were defined with their respective values and/or ranges.

Extracted scenario parameters were classified as either scenery or dynamic. Scenery parameters can be defined as those which are fixed during the course of the simulation in the simulator. For example, objects such as street lamps, furniture, vegetation and buildings are classified as scenery parameters. Similarly, parameters which may be of significance for vehicle performance such as road surface properties and visibility are also considered to be scenery parameters. Parameters such as cloud cover, time of day and weather that could affect road surface friction coefficients in the simulation falls under the dynamic parameters category.

Results and Discussion

In this section the final list of current relevant standards are discussed. This is followed by a discussion of the scenarios extracted from those standards and subsequent scenery and dynamic parameters identified in scenarios.

Applicable Standards

The final list of 12 standards (out of 67 evaluated standards) used for the extraction of test scenarios is presented in **Error! Reference source not found.**. Each standard was also evaluated in terms of which aspect of the vehicle it was applicable to i.e. hardware, software or system and whether it was related to sensors, scenarios or simulators.

Table 1. Safety Standards relevant to Evaluation of AV in a Synthetic Environment

Standard	Description
BS ISO 11270:2014	Intelligent Transport Systems (ITS) Lane Keeping Assistance Systems (LKAS) – The test procedures include the basic control strategy, minimum functionality requirement, driver interface, reaction to failure and performance test procedures.
BS ISO 16787:2017	ITS Assisted Parking System (APS) – performance requirements and test procedures.
BS ISO 22839:2013	ITS forward vehicle collision mitigation systems – Operation, performance and verification requirement.
ISO 19237:2017	ITS Pedestrian Detection and Collision Mitigation Systems (PDCMS) – specifies behaviours required for PDCMS and the systems test criteria.
ISO 15622:2018	ITS Adaptive Cruise Control (ACC) systems – performance requirements and test procedures. The test procedures include the basic control strategy, minimum functionality requirement, driver interface, reaction to failure and performance test procedures for ACC systems.
ISO 22178:2009	ITS ACC systems – performance requirements and test procedures. The test procedures include the basic control strategy, minimum functionality requirement, driver interface, reaction to failure and performance test procedures for Low Speed Following (LSF) systems.

EURO NCAP Test Protocol – AEB systems Version2.0.1	Autonomous Emergency Braking (AEB) – Car-to-Car test procedures includes control strategy, minimum functionality requirement, driver interface, pass and fail criteria.
EURO NCAP Test Protocol - AEB VRU systems Version2.0.3	Autonomous Emergency Braking (AEB) Vehicle Road User (VRU) system – test procedures regarding car to pedestrian impacts.
EURO NCAP Test Protocol – Lane Support systems Version2.0.2	Lane Support systems – Test procedures includes the control strategy, parameter requirements and pass and fail criteria.
ISO/AWI 19638	Intelligent transport systems – Road Boundary Departure Prevention Systems (RBDPS)
BS ISO 21717	Intelligent transport systems – Partially Automated In-lane Driving Systems (PADS)
PWI 21202	Intelligent transport systems – Partially Automated Lane Change Systems (PALS)

Parameters Extracted from Standard Scenarios

The scenery parameters extracted from the scenarios are: Road Surface, Air Temperature, Horizontal Visibility, Test Track, Road Gradient, Ambient Light Level, Light Sources, Illuminance, Wind Speed, Lane Markings, Lane Width, Lane Curvature, Kerb, Parked Vehicle, Parking Space and Road Marking

The dynamic parameters extracted from the evaluated standards are: Test Target Vehicle A (Typical Vehicle on motorway), Test Target Vehicle B (Motorcycle) and Adult Pedestrian Target. This is not an exhaustive list of potential targets but the only types covered in the reviewed standards.

In addition to the scenery and dynamic parameters, the following system features parameters were identified: User Interface – creating Vehicles and Manoeuvres, User Interface – Road Layout, Sensor Availability and Sensor Location.

These system features were highlighted as pertinent through workshops with key industry players. Each of these system features where in turn broken down into further subsections as demonstrated in Table 2.

Table 2. User interface system feature evaluation parameter breakdown

User Interface – Creating Vehicles and Manoeuvres
Speed setting
Setting acceleration for given duration/distance
Setting waypoint parameters
Event triggers
Different type of target: vehicle, pedestrian, cyclist
Different dynamics for different types of target: dynamic of van should be different to dynamic of car
Ability to navigate the dynamic elements: vehicle, pedestrian etc.
Road setting for location: e.g. UK, USA etc.
Traffic Law
Weather/atmospheric condition/ Time of day/ lighting source/wind speed
Vehicle state: lights, signal, doors etc.
Road conditions
Scripted AI
AI

Conclusions

There is a clear need for using synthetic environments for validation and verification of CAVs. Traditionally, vehicle systems were certified using tools that were also certified. The increasing need for using CAV simulators with synthetic environments to validate CAV systems, that is increasingly reliant on AI and machine learning technology, necessitates the need for a certification framework of these CAV simulators. The data presented in this paper is by no means the full solution to provide a framework for certifying CAV simulators but provides a robust foundation and rigorous parameter extraction methodology for a complete solution to be built upon. The clear lack of existing standards for L4 and L5 AVs have complicated the identification of appropriate existing international standards for identifying relevant test scenarios.

Future Work

The next steps are to take the identified scenario parameters and permitted range values and evaluate four identified software packages that can in their current form test autonomous vehicle systems. These packages span from state-of-the-art automotive testing software to open source packages. The first evaluation will be followed by extracting fidelity requirements from scenarios for the sensor inputs and evaluate the software against these fidelity requirements. In parallel, a systematic review of physical sensors and available sensor models will be performed to identify relevant input and output parameters and fidelity requirements. The software will also be evaluated to gauge if the required fidelity can be met. If the requirements can't be met, attempting to certify such a simulator will be futile.

The final step will be a review of current existing simulator architectures to formulate recommendations based on developed benchmarking requirements and results from the safety standards review.

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Appendix A – Identified Scenarios

Scenario Number	Brief Outline of Scenario	Scenery Parameter	Range or Value	Dynamic Parameter	Range or Value	Pass/Fail Criteria	Standard Source
01a	Target Acquisition - Adaptive cruise control • Assign Target Vehicle as test target A at d[max] or test target B at d[0], d[1], d[2], where d[2] is fixed at 75m in front of the vehicle • Target A travels at speed v[stopping] = 10 m/s • Subject (test) vehicle cruise behind target vehicle in steady-state following control mode • Desired time-gap is τ[min] ≥ 0.8 s for the whole test • Lateral displacement of centrelines are <0.5m of test vehicle • Target Vehicle A shall brake to stop with an acceleration between -2.0 m/s2 and -2.5m/s2	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility	**1)** Flat, Dry Asphalt/concrete **2)**−20 °C and +40 °C **3)** > 1 km	**1)** Test Target Vehicle A (Typical Vehicle on motorway) **2)** Test Target Vehicle B (Motorcycle)	**1)** Minimum XSA 20 cm2, RCS of 10 m2, **2)** Minimum XSA 20cm2, RCS of 3 m2	• Subject vehicle stopped by the system behind the preceding vehicle	BS ISO 15622:2018
01b	Target Discrimination • Two same mode vehicles (forward and target) travel alongside each other at speed v[vehicle_start] with a longitudinal centreline spacing of 3.5 m ± 0.25 m • The subject vehicle cruises behind the target vehicles in steady state • Lateral displacement of centrelines are < 0.5 m of target vehicle • Time gap of τ[max](v[vehicle_start]) = v(max)/d(max) and set speed > v [vehicle_end], where v[vehicle_end] = 27 ms-1 (22 ms-1 if 27 ms-1 is not possible, v[vehicle_start] = v[vehicle_end] – 3 ms-1 • Target vehicle accelerates to v[vehicle_end]	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility	**1)** Flat, Dry Asphalt/concrete **2)** −20 °C and +40 °C **3)** > 1 km	**1)** Test Target Vehicle A (Typical Vehicle on motorway)	**1)**Minimum XSA 20 cm2, RCS of 10 m2	• Target acquisition time should not exceed 2 s after presentation of target • Subject vehicle passes the forward vehicle in adjacent lane under ACC control	BS ISO 15622:2018 BS ISO 22178:2009
01c	Curve Capability • Assign target vehicle as test target A • The subject vehicle follows target vehicle along same path in following control mode • Subject and target vehicle conforms to start conditions • Initial target vehicle speed v[circle_start] = min((a[lateral_max]*R)1/2, v[vehicle_max)]) ± 1 ms-1, where a[lateral_max] = 2ms-1 • Decrease velocity by 3.5 ms-1 ± 0.5 ms-1 for 2 s	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility **4)** Test Track	1) Flat, Dry Asphalt/concrete 2) Between −20 °C and +40 °C 3) > 1 km 4) Circular track or constant radius sufficiently long for the test, between 80% to 100% of 500 m radius	**1)** Test Target Vehicle A (Typical Vehicle on motorway)	**1)** Minimum XSA 20 cm2, RCS of 10 m3	• The subject vehicle shall start to decelerate due to the decreasing distance to the target vehicle before the time gap falls below 2/3 *τ(max)*	BS ISO 15622:2018

Scenario Number	Brief Outline of Scenario	Scenery Parameter	Range or Value	Dynamic Parameter	Range or Value	Pass/Fail Criteria	Standard Source
	• Then v[circle] = constant = v[circle_start] – 3.5 ms-1 ± 1.0 ms-1						
02a	DAYTIME - Pedestrian mitigation system • Subject Vehicle (SV) travels in a straight line with deviation of < ±1 % • Pedestrian Target moves in a perpendicular direction to the vehicle • Test is started from initial parameters and completed when a collision happens or the vehicle fully stops	1) Road Surface 2) Road Slope 3) Temperature 4) Horizontal Visibility 5) Light Level 6) Minimal peak braking coefficient 7) Wind Speed	1) dry, uniform solid paved surface 2) consistent between level and 1 % 3) Between 0 °C and +40 °C 4) > 1 km 5) > 2000 lx 6) 0.9 7) <10m/s	**1)** Adult Pedestrian Target	2) Follow ISO 19206-2	• Speed of vehicle < 10 km/h, speed reduction of 20 km/h or • a collision between the pedestrian and vehicle is avoided	BS ISO 19237:2017 EURO NCAP Test Protocol - AEB VRU systems Version2.0.3
02b	Daytime, Twilight or Nighttime • Subject Vehicle (SV) travels in a straight line with deviation of < ±1 % • Pedestrian Target moves in a perpendicular direction to the vehicle • Test is started from initial parameters and completed when a collision happens or the vehicle fully stops	1) Road Surface 2) Road Slope 3) Temperature 4) Horizontal Visibility 5) Ambient Light Level 6) Street Lamp 7) Illuminance from Lighting 8) Minimal peak braking coefficient 9) Wind Speed	1) dry, uniform solid paved surface 2) consistent between level and 1 % 3) Between 0 °C and +40 °C 4) > 1 km 5) < 1 lx 6) Height deviation < 0.2 m, evenly spaced, lamp (light) must be < 2 m away from the pole towards vehicle path, Colour temp of 4500 K ± 1000 K, Ratio of brightest and darkest points at < 0.2 m should be under 10 7) Vehicle Path, 0.2 m above ground: 16 lx to 25 lx (average across 11 measurements) Pedestrian path, 0.2 m & 1.5 m above ground: ≥ 5 lx (at each measurement) 8) 0.9 9) <10m/s	**1)** Adult Pedestrian Target	**2)** Follow to ISO 19206-2 (maybe link with ISO 15536-2:2007)	• Speed of vehicle < 10 km/h, speed reduction of 20 km/h or • a collision between the pedestrian and vehicle is avoided	BS ISO 19237:2017 EURO NCAP Test Protocol - AEB VRU systems Version2.0.3

Scenario Number	Brief Outline of Scenario	Scenery Parameter	Range or Value	Dynamic Parameter	Range or Value	Pass/Fail Criteria	Standard Source
02c	Autonomous Emergency Braking (AEB) - car to car •Test 1 - CCRs (Car-to-Car rear Stationary) :Subject vehicle travels in a stright line towards target vehicle. Subject vehicle travesl betwwen 10 - 50 km/h and the target vehicle is stationary •Test 2 - CCRm (Car-to-Car Rear Moving): Subject vehicle travels between 30-80km/h and the target vehicle travels at 20km/h •Test 3 - CCRb (Car-to-Car Rear Braking) : Subject vehicle travels at 50 km/h and target vehicle travels at 50kmh. the distance Test will be performed wiith all combinations of 2 and 6m/s2 deceleration (decelearation of target vehicle) and 12 and 40m headway (distance between vehicles).	1) Road Surface 2) Ambient Temperature 3) Horizontal visibility 4) Wind Speed	1) Flat, dry asphalt/concrete 2) Between -20 °C and +40 °C 3) > 1 km 4) <10m/s	**1)** Target Types	**1)** Motorcycle, cars, light trucks, buses, moto coaches and other heavy vehicle	•Contact occur between vehicles •Subject vehicle come to stop or lower speed than target vehicle	EURO NCAP Test Protocol - AEB systems Version2.0. 1
03a	Automatic Deceleration - Low speed following • Target vehicle travels at v(max) with the subject vehicle following under steady condition at a time gap of τ[min](v[max]), v[max] should not exceed 1.39 m/s • Target vehicle decelerate to a stop at a rate of 2.5 m/s2	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility	**1)** Flat, Dry clean asphalt/concrete surface **2)** Between -20 °C and +40 °C **3)** > 1 km	**1)**Test Target (Vehicle)	**1)** Minimum XSA 20 cm2, RCS of 3 m2, Reflectivity coefficient CTT = 1 ± 0.1 m2/sr, width between 1.4 m and 2.0 m	• Subject vehicle decelerates to a stop behind the target vehicle	BS ISO 22178:2009
03b	Automatic Retargeting Capability • Target vehicle travels at v(max) with the subject vehicle following under steady condition at a time gap of τ[min](v[max]), v[max] should not exceed 1.39 m/s, lateral displacement of centrelines under 0.5 m • A low speed moving vehicle shall travel between 1.4 m/s and 2.8 m/s ahead of the target vehicle at a distance higher than the distance that the target vehicle will travel in 3 seconds • once the distance between the target vehicle and low speed vehicle is 3 s times v[max], the target vehicle will change lane	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility	**1)** Flat, Dry clean asphalt/concrete surface **2)** Between -20 °C and +40 °C **3)** > 1 km	**1)**Test Target (Vehicle)	**1)** Minimum XSA 20 cm2, RCS of 3 m2, Reflectivity coefficient CTT = 1 ± 0.1 m2/sr, width between 1.4 m and 2.0 m	• Subject vehicle changes target and follow the low speed vehicle with the appropriate clearance	BS ISO 22178:2009
04a	Straight Road - Lane Keeping • Subject vehicle travel straight along a straight road at a speed of 20 m/s to 22 m/s, in the centre of the lane or along lane marking opposite to the lane marking that will be crossed at time of lane departure • Maintaining the designated speed at a stable posture, the vehicle is steered to gently depart	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility **4)** Wind Speeds **5)** Lane Markings **6)** Lane width	**1)** Flat, Dry clean asphalt/concrete surface **2)** Between -20 °C and +40 °C **3)** > 1 km **4)** < 3 m/s for ISO, <10m/s for NCAP **5)** According to local			• longitudinal deceleration < 3 m/s2 • when longitudinal deceleration > 1 m/s2, speed reduction < 5 m/s • max lateral acceleration of 3 m/s2, max lateral jerk of 5	BS ISO 11270:2014 EURO NCAP Test Protocol - Lane Support systems

Scenario Number	Brief Outline of Scenario	Scenery Parameter	Range or Value	Dynamic Parameter	Range or Value	Pass/Fail Criteria	Standard Source
	from the lane at a rate of v[depart] = 0.4 m/s ± 0.2 m/s to the left and tested four times • This is repeated by testing to depart on the right four times for a total of eight tests		regulation **6)** Between 3.4 m and 3.9 m for highway like road			m/s3 • Light Vehicle should not exceed lane boundary (markings) by 0.4 m • Heavy Vehicle should not exceed lane boundary by 1.1 m • All eight test passes	Version2.0.2
04b	Curved Road - Lane Keeping • Subject vehicle travel straight along a straight road at a speed of 20 m/s to 22 m/s, in the centre of the lane parallel to the lane markings and no steering wheel angle • Vehicle enters a left curve and drives for 5 seconds as the first test • Vehicle enters a right curve and drives for 5 seconds as the second test	**1)** Road Surface **2)** Temperature **3)** Horizontal Visibility **4)** Wind Speeds **5)** Lane Markings **6)** Lane width **7)** Lane Curvature	**1)** Flat, Dry clean asphalt/concrete surface **2)** Between -20 °C and +40 °C **3)** > 1 km **4)** < 3 m/s for ISO, <10m/s for NCAP **5)** According to local regulation **6)** Between 3.4 m and 3.9 m for highway like road **7)** Constant curvature, vehicle will not exceed 1.0 m/s2 lateral acceleration			• longitudinal deceleration < 3 m/s2 • when longitudinal deceleration > 1 m/s2, speed reduction < 5 m/s • max lateral acceleration of 3 m/s2, max lateral jerk of 5 m/s3 • Light Vehicle should not exceed lane boundary (markings) by 0.4 m • Heavy Vehicle should not exceed lane boundary by 1.1 m • Both test passes	BS ISO 11270:2014 EURO NCAP Test Protocol - Lane Support systems Version2.0.2
05a	Functional Ability - Type 3 Braking system • Subject vehicle travels at 20 ± 2 m/s and 8 ± 1 m/s for target vehicle (relative velocity of -12 m/s) • Subject approach target vehicle from far behind	**1)** Road Surface **2)** Ambient Temperature **3)** Horizontal visibility	**1)** Flat, dry asphalt/concrete **2)** Between -20 °C and +40 °C **3)** > 1 km	**1)** Target Types	**1)** Motorcycle, cars, light trucks, buses, moto coaches and other heavy vehicle	• Speed reduction braking occurs, see supporting material • Mitigation braking occurs - light vehicles deceleration of > 5.0m/s to reduced speed by at least 2.0 m/s, heavy vehicle deceleration of >3.3m/s2 for a speed reduction of at least 1.0 m/s • Mitigation and speed reduction braking combined to slow by at least 4.0 m/s	BS ISO 22839:2013

Scenario Number	Brief Outline of Scenario	Scenery Parameter	Range or Value	Dynamic Parameter	Range or Value	Pass/Fail Criteria	Standard Source
06a	Between two Vehicles - Parallel • Parking slot and type identified by the system and informs driver of potential slots, actual slot used may be confirmed by human interaction • The system controls the steering to park and not the speed • 10 Test trials are to be conducted in the same parking slots	**1)** Kerb **2)** Parked Vehicle **3)** Parking Slot **4)** Wind Speed **5)** Temperature **6)** Weather **7)** Road Surface	**1) N/A** **2) N/A** **3) N/A** (Length (x[0]) = subject vehicle length + Δx_p (see notes), width (y[0])= width of subject vehicle + 0.2 m **4)** < 5.4 m/s **5)** Between +5 °C and +30 °C **6)** Non precipitating (i.e. not raining, sleeting, snowing, etc.) **7)** flat and dry			• 9 out of 10 test has to be successful • Mean parked angle α in range of -3° to 3°, with a standard deviation of < 1.5° • Mean distance for D_r and D_f from the kerb should be between 0.05m and 0.3 m, with a standard deviation of < 0.1m	BS ISO 16787:2017
06b	Between two Vehicles - Perpendicular • Parking slot and type identified by the system and informs driver of potential slots, actual slot used may be confirmed by human interaction • The system controls the steering to park and not the speed • 10 Test trials are to be conducted in the same parking slots	**1)** Parked Vehicle **2)** Parking Slot **3)** Wind Speed **4)** Temperature **5)** Weather **6)** Road Surface	**1) N/A** **2) N/A** Depth (y[0]) = subject vehicle length, width (x[0])= width of subject vehicle + 1.2 m **3)** < 5.4 m/s **4)** Between +5 °C and +30 °C **5)** Non precipitating (i.e. not raining, sleeting, snowing, etc.) **6)** flat and dry			• 9 out of 10 test has to be successful • Vehicle must be at a minimum of 0.3 m away from the vehicles on both side • Front or rear of the subject vehicle cannot exceed the front/rear of the stationary vehicles by more than 0.4 m • Mean parked angle β in range of -3° to 3°, with a standard deviation of under 1.5°	BS ISO 16787:2018
06c	Between Markings - Parallel • Parking slot and type identified by the system and informs driver of potential slots, actual slot used may be confirmed by human interaction • The system controls the steering to park and not the speed	**1)** Road Marking **2)** Kerb **3)** Road Surface **4)** Weather	**1) N/A** **2) N/A** **3)** Flat, uniform, asphalt or concrete paved surface **4)** Non precipitating (i.e. not raining, sleeting, snowing, etc.)			• Vehicle does not enter restricted areas such as other parking space • Criteria: $-3{,}0° \leq \theta \leq 3{,}0°$, Mf > 0 m, Mr > 0 m, Me > 0 m	BS ISO 16787:2017

Scenario Number	**Brief Outline of Scenario**	**Scenery Parameter**	**Range or Value**	**Dynamic Parameter**	**Range or Value**	**Pass/Fail Criteria**	**Standard Source**
06d	Between Markings - Perpendicular • Parking slot and type identified by the system and informs driver of potential slots, actual slot used may be confirmed by human interaction • The system controls the steering to park and not the speed	**1)** Road Marking **2)** Kerb **3)** Road Surface **4)** Weather	**1) N/A** **2) N/A** **3)** Flat, uniform, asphalt or concrete paved surface **4)** Non precipitating (i.e. not raining, sleeting, snowing, etc.)			• Vehicle does not enter restricted areas such as other parking space • Criteria: $-3,0° \leq \theta \leq 3,0°$, Mfl > m0, Mfr > m0, Mrl > m0, Mrr > m0 (m0 = 0,1 m), Me > me (me = 0,1 m), see supporting material	BS ISO 16787:2017