Consumer Safety Confidence Framework

A draft consumer rating for Automated Lane Keeping Systems

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United Kingdom

Contents

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Executive summary

This document represents the creation of a Consumer Safety Confidence Rating Framework for automated vehicle technologies, aimed at ensuring that full societal benefits of such systems are fully realised through widespread adoption. It is recognised the important role that virtual testing will play in thoroughly exercising systems in a safe environment and providing confidence in automated technology. The complex nature of ALKS and other automated systems require a much broader approach to testing, verification and validation and virtual testing can provide part of the solution to this problem. This document outlines the key ideas and objectives for an independent consumer safety confidence rating for ALKS.

The key philosophy of the ALKS Consumer Safety Confidence Framework is that the safety rating of the vehicle under test must be a function of its Operational Design Domain (ODD). The ODD represents the operating environment within which ALKS can perform the dynamic driving task.

The framework begins with the Automation Claims, where the driving domain of the vehicle under test is defined against the assessment criteria. This ODD checklist will inform which tests are to be carried out virtually and validated physically. Additional to the checklist, further information such as marketing media will be procured and assessed. It is proposed that the virtual tests are executed by the vehicle manufacturer, who are provided with the scenarios which the must test, using an opensource format Scenario Description Language. Upon the generation and formatting of scenarios, they are then stored within the Safety Pool™ scenario database, where they can be easily assessed by all relevant groups.

The results of the virtual tests will then be spot-checked using independent physical testing. The method by which the select verification tests are chosen is not fully defined within this framework, but it will take a combination of random selection, edge case identification, failure point validation and other specifically recognised scenarios.

Vehicle manufacturers should be rewarded for providing not only a wide-ranging ODD, but also an accurately described one with effective performance within it. This balance between claimed ODD and the measured assessment performance will feed into the three sections User-in-Charge Engagement, Automation Competence and Safety Backup. These sections will in turn generate the overall rating.

Next steps in developing the concept include:

- Completed definition of an ALKS ODD.
- Expand virtual testing execution from a complete list of relevant scenarios and variables.
- Key performance criteria from virtually tested results which are to be validated with physical testing.

1 | Introduction

Euro NCAP launched its Assisted Driving grading scheme in 2020 to provide consumers with independent grading that enables them to compare systems, as well as drive best practise Assisted Driving technology within the industry. This technology is typically offered as an optional extra and is therefore not considered in the Euro NCAP five star rating system. Recently there has been the first introduction of regulatorily approved automated driving technology under UNECE Regulation 157 for Automated Lane Keeping Systems, which signifies the first major step towards fully automated vehicles. The key difference between Assisted and Automated systems is that with Automated, the responsibility for safe driving passes from the driver to the vehicle. The "driver" of the automated vehicle is now not responsible for the safe operation of the vehicle within a predefined Operational Design Domain (ODD).

In the context of this framework, the ODD represents the operating environment within which ALKS can perform the dynamic driving task. There may be functional requirements for such automated systems to safely operate which are not included in the ODD stated in this framework.

As ALKS is only partial-automation, that is to say that it can only take responsibility of driving in limited and well defined situations, Thatcham Research recognises the need to keep the driver (to some extent) engaged with the driving task when active. UNECE Regulation 157 requires by law that the driver is ready and able to resume the responsibility of driving, and so keeping the driver "in the loop" is vital to ensure these systems are used safely.

With the complication of the driving task changing between the driver and the vehicle, we recognise that the driver's designation is confusing. Therefore, we will refer to the driver as the ***User-in-Charge (UiC)*** for the remainder of this document.

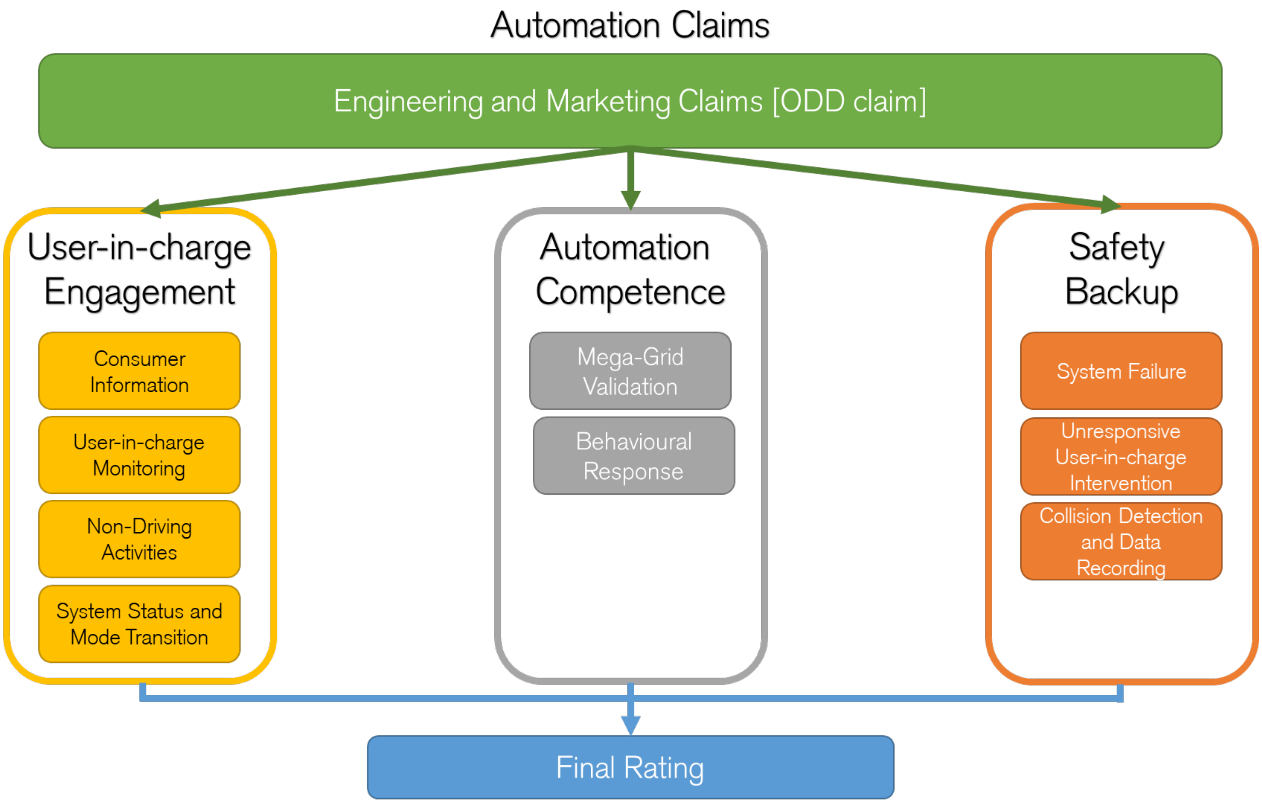
1.1 Key Philosophy

The key philosophy of the ALKS Consumer Safety Confidence Framework is that the safety rating of the vehicle under test must be a function of its Operational Design Domain (ODD). Each ALKS equipped vehicle will have its own unique ODD, in which the defined limits of when it can operate are described. However, there is a need to verify the claimed ODD of the manufacturer against the measured performance of the vehicle under test and share it with the public to enable understanding and build confidence.

The framework begins with the Automation Claims, where the driving domain of the vehicle under test is defined against the assessment criteria. This ODD checklist (detailed further in this document) forms the basis of the assessment framework. This checklist will inform which tests are to be carried out both virtually and physically. Additional to the checklist, further information such as marketing media will be procured and assessed.

It is recognised that each ALKS vehicle will have different technical capabilities and vehicle manufacturers should be rewarded for providing not only a wide-ranging ODD, but also an accurately described one. This balance between claimed ODD and the measured assessment performance will feed into the three sections User-in-Charge Engagement, Automation Competence and Safety Backup, which in turn will generate the over-all vehicle rating.

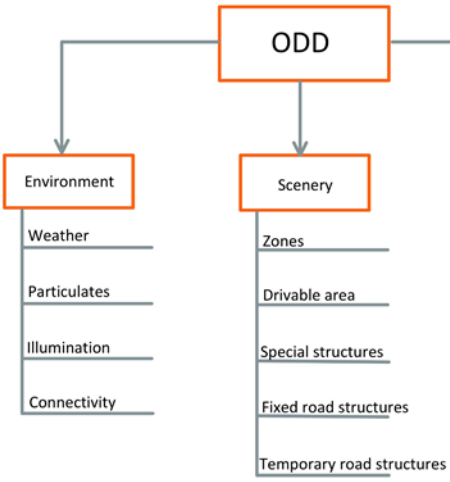
Figure 1 Thatcham Research draft framework structure



ODD Claim Example

The vehicle manufacturer will indicate the capabilities of the system to be assessed. This claimed ODD will then be used to derive the testing to be performed. The maximum score achievable by the system is limited to that of the claimed ODD. For example, a system that claims it can achieve 70% of the assessment specified ODD will be limited to a maximum final score of 70%.

Figure 2 ODD Structure and sub-attributes



The engineering ODD claim format will be derived from PAS 1883:2020 and will be provided to the vehicle manufacturer in both an ODD language and a tabular format. For example:

Figure 3 ODD example checklist derived from PAS 1883:2020

Attribute	Sub-attribute 1	Sub-attribute 2	Capability	Score
Environment	Illumination	Day	Yes	65%
		Night	No	
	…	…	…	
Scenery	Drivable Area Geometry	Straight roads	Yes	75%
		Curves (<1/500 m radius of curve)	Yes	
	Lane dimensions	≥3.6 m width	Yes	
		<3.6 m width (temporary road marking)	No	
	…	…	…	
Dynamics	Traffic	Presence of emergency vehicles	Yes	75%
	…	…	…	
			Average Score	71.7%

With each primary attribute given equal weighting, this example would result in a maximum possible score of 71.7% for Automation Competence. The actual score will be calculated from the performance achieved in the Mega-Grid Validation and Behavioural Response assessments.

User-in-Charge Engagement and Safety Backup will be assessed against a variety of criteria outlined within this draft framework. The three sections will then be combined to calculate the final rating. Please note that User-in-Charge Engagement, Automation Competence and Safety Backup do not share equal weighting.

1.2 Overall Consumer Confidence Rating Scheme Grading

Estimated score required based on the Euro NCAP Assisted Driving grading scheme.

Figure 4 Overall grading score requirement

GRADING	TOTAL SCORE REQUIRED
VERY GOOD	*≥80%*
GOOD	*≥70%*
MODERATE	*≥60%*
ENTRY	*≥50%*

1.3 Test Point Allocation

Figure 5 Draft framework structure and respective point allocation

User-in-Charge Engagement	Proportion of Points
Consumer Information	30%
User-in-charge Monitoring	30%
Non-Driving Activities	20%
System Status and Mode Transition	20%
Total	**40%**

Automation Competence	Proportion of Points
Mega-Grid Validation	75%
Behavioural Response	25%
Total	**40%**

Safety Backup	Proportion of Points
System Failure	40%
Unresponsive User-in-charge Intervention	40%
Collision Detection and Data Recording	20%
Total	**20%**

The key philosophy of this framework is to encourage a wide and accurate ODD, demonstrating the technical capabilities of an ALKS equipped vehicle. However, a key factor in the consumer uptake and confidence will be their understanding of this technology. Therefore, the importance of user-in-charge education and ultimately engagement is crucial to the successful deployment of ALKS.

User-in-Charge Engagement and Automation Competence share equal weighting of 40% each. Safety Backup, although important for systems failure, will likely be heavily determined by factors such as regulation both locally and internationally. And therefore represents 20% of the score weighting.

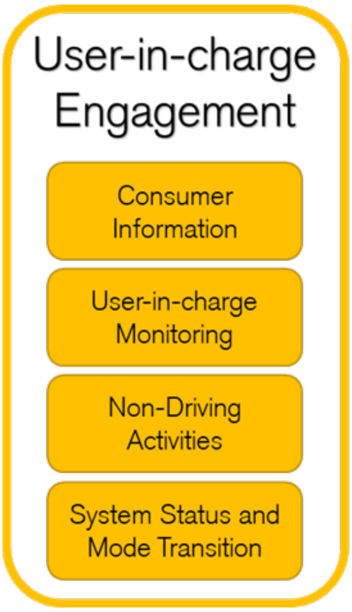
2 | User-in-Charge Engagement

Formerly known as Driver Engagement in the Euro NCAP Assisted Driving grading scheme, the term user-in-charge (UiC) recognises the transfer of responsibility of the driving task to the ALKS equipped vehicle. However, the UiC shares responsibility for safe operation of the vehicle during ALKS mode and should remain vigilant and ready to take control when instructed to do so.

This co-responsibility is due to the Operational Design Domain (ODD) of the ALKS vehicle, which defines the strict circumstances in which the vehicle can and cannot undertake automated operation. Within the ODD, the ALKS system takes responsibility for steering, speed control, braking and hazard identification. When approaching the boundary of the ODD, these responsibilities revert onto the UiC.

The transfer of driving responsibility from ALKS to the UiC is conducted through a transition demand. This transition demand can be planned (vehicle *leaving motorway*) or unplanned (sudden severe weather). Studies such as N Kinnear et al. (2020)† have shown that when the UiC is engaged in non-driving activities, their reaction time is greatly increased when required to resume control of the vehicle. Therefore, the need to ensure the UiC can easily and quickly retake control of the vehicle is essential for the safe use of ALKS. User-in-Charge Engagement equates to 40% of the total possible points.

Figure 6 UiC Engagement framework components



†Safe performance of other activities in conditionally automated vehicles, TRL PPR979. Available at: https://trl.co.uk/uploads/trl/documents/PPR979---ALKS-literature-review_final_updated_Apr21.pdf

2.1 Consumer Information

Understanding the limitations of ALKS is crucial not only for the safe operation of the system but also to understand how readily consumers will adopt the new technology. If users overestimate or underestimate the capabilities of ALKS, it could result in a dangerous situation. Therefore, it is important to assess how vehicle manufacturers advertise and explain this technology to consumers. Factors to be included are:

Collation and inspection of vehicle manufacturer material available on-line through websites and advertising, information in the vehicle handbooks and infotainment displays.

System Name Required:

- Must adequately be able to discern the capabilities of the system from its name and not suggest any sort of feature beyond the scope of the system.
- No use of terms such as "full self-control" or "self-driving".
- "Traffic Chauffeur" is acceptable as long as transition demands are made clear.

Marketing Material:

- Must reference the production specification technology and not potential future capability and not show user-in-charge engaging in prohibited activities such as using a mobile device or sleeping while vehicle is in ALKS mode.
- Focus on information provided on OEM website and infographics to not exaggerate the capabilities of the vehicle.
- Clearer examples of what should be prohibited (e.g. imagery conveying use of mobile devices or sleeping is prohibited).
- Marketing material should focus on current capabilities and not "promised" future features.

Consumer Education:

- Quick Start Guide: A short video or supplementary textbook to the user manual showing main features of the car vehicle with emphasis placed on ALKS technology and how and when it can be used.
- Infotainment videos upon first startup of car showing modes of operation. New user-in-charge detection to prompt video/information.
- Limitation of functions until certain instructions are read or videos watched and acknowledged.
- Video watched could be a recorded parameter for incident investigation.
- Vehicle Handbook: Should adequately detail ALKS system and how it works for consumer confidence and understanding of capability. Available in both physical and digital versions.
- 'Automated' should be used within the context of maintaining attentiveness and not expecting the car to do everything i.e. no images of passenger fully reclined detached from driving.
- User-in-charge Education: Short introductory videos that demonstrate ALKS capability, boundary of operation and how a 'model user-in-charge' operates the system.

- Upon vehicle purchase dealerships/showrooms should provide demos that focus on correct ALKS usage. Made available to subsequent second-hand owners, hirers, or any other users of the vehicle.

2.2 User-in-Charge Monitoring

The UiC may participate in non-driving activities, but with ALKS they are required to resume control of the vehicle within a specified time. Therefore, the ALKS equipped vehicle must monitor the UiC to ensure they are available to resume control, once a command is issued. The capability of UiC monitoring systems may vary between manufacturers and some may be able to prevent prohibited activities.

Information provided by the vehicle manufacturer will be checked to comply with UK requirements and ensure any preconditions are met before testing takes place.

Physical testing on track will be used to verify the system capabilities both within and outside of parameters defined by the VM documentation.

Physical public road testing will be used to verify the system capabilities within the VM capabilities ONLY.

Preconditions:

Able to detect the following ranges and elements for:
- Age (16 to 80 years)
- Sex (All)
- Stature (AF05 to AM95)
- Skin Complexion (Fitzpatrick Skin Types 1 -6)
- Eye lid aperture (<14.0mm and >6.0mm)
- Lighting during daytime (100,000 lux) and night-time (1 lux)

Additional monitoring:

- Expansion from any regulation requirements e.g. facial occlusion, eyewear, make-up etc.
- Non-driving activity monitoring and identification can provide additional confidence for user-in-charge availability.
- Determination of which UiC characteristics can be used to verify that the UiC is ready and able to regain control.

Assessment Focus:

- Alignment to Euro NCAP Occupant Status Monitoring protocol.
- False positives and false negatives will be difficult to manage, mitigation of their impact should be considered during the assessment.
- Ongoing monitoring of the behaviour of the UiC could limit functionality for a certain period of time if they are deemed unsafe or continue to perform forbidden activities.

- "Eyes on, brain off" e.g. day dreaming with limited cognitive engagement has been shown to be an issue for extended driving periods. Ensuring that the UiC is kept focused enough so that they can readily and quickly retake control of the vehicle if required.
- Warning provided to the UiC in case of inability to detect driver e.g. obstructive facewear or requiring adjustment.

2.3 Non-Driving Activities

The UiC engaging in activities that do not relate to the driving task will be guided by regulatory requirements but may also be restricted by the system ODD. Therefore, it is important to assess the implementation by the vehicle manufacturer and the clarity of information to the UiC.

Information provided by the vehicle manufacturer will be checked to comply with UK requirements or any other local specifications.

Physical testing on track will be used to verify the system capabilities for both permitted and non-permitted activities.

Physical public road testing will be used to verify the system capabilities for permitted activities ONLY.

Preconditions:

- Mobile phones, reading books or through nomadic devices, eating and sleeping not permitted.
- Information in handbook or in infotainment clearly listing permitted and non-permitted activities.
- No contradictions between any media advertising or vehicle handbook stating permitted activities including icons and images.

Assessment Focus:

- Methods of displaying relevant information to keep the user-in-charge in the loop.
- Activities blacklist to penalise certain forbidden activities. The forbidden activities will be dependent on regulation.
- Limit mobile device usage. Reward vehicle manufacturers who discourage the use of mobile devices. This is dependent on the allowance within international and local regulation. Determination of what is an appropriate response once mobile phone use is detected.
- System abuse mitigation and prevention should be encouraged and rewarded.
- Identification and classification of activities by the vehicle could provide further information to how people use the systems and what activity the UiC was doing in the event of a collision.

2.4 System Status and Mode Transition

The design and operation of the system should be so intelligible and clear that the UiC cannot mistake what they should do in the absence of any training or learning, with adequate back up/escalation/intervention in case they do not act appropriately. This will be primarily guided by the system warnings and indications inside the vehicle.

Information provided by the vehicle manufacturer will be checked to comply with UK requirements such as the Road Traffic Act and the Highway Code.

Physical testing on track allows for the documentation of all icons and symbols whilst the system is active for a wide range of controlled scenarios. Additionally, will be used to verify the system capabilities for both permitted and non-permitted activities.

Physical public road testing allows for the documentation of icons and symbols that are displayed during real world scenarios e.g., during heavy traffic and on smart motorways. Additionally, will be used to verify the system capabilities for permitted activities ONLY.

Preconditions:

- Relevant ALKS status symbols within ALKS capable vehicles (UNECE R157 compliance check) or UK VCA compliance check.
- Clearly distinct symbols and display modes between Automated and Assisted.
- Accidental ALKS activation should not be possible. Should require a clear and deliberate "offer and confirm" process to enable ALKS e.g., both buttons on steering wheel pressed simultaneously whilst eyes are looking forward.

Status indicators:

- Clear and visible display of what functionality is currently active in the system and any displayed warnings that may limit capability.
- Should vary in tone and symbols between alerts so user-in-charge can perceive audibly and visually what action to carry out and their urgency i.e. an unplanned transition demand should clearly require immediate action from the UiC, whereas a planned transition demand requires action in a brief period of time.
- Reward any system that keeps the user-in-charge engaged with driving as much as possible even when they are performing secondary activities by providing additional and continual information. Facilitating the smooth transition between vehicle control and UiC control.

Assessment Focus:

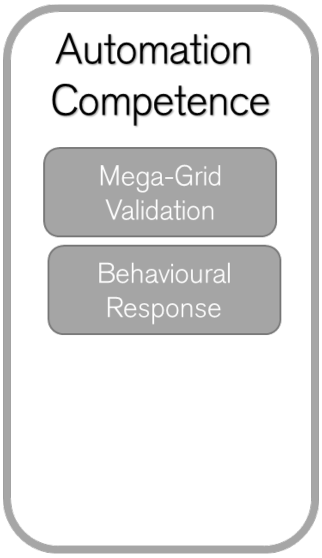
- Definition of a good and bad transition, how the user-in-charge is kept engaged and provided with information about the driving task.
- Definition of how many additional criteria that are required to deem a user-in-charge ready for a transition.
- Review of both planned and non-planned transition events.
- Emergency and failure mode handling during mode transition. Understanding vehicle response in the event that UiC attempts to intervene during automated driving mode.
- Will be a traffic offence to not respond to the transition demand, how does the vehicle encourage the user-in-charge to resume control as quickly as possible.

3 | Automation Competence

The automation competence will compare the ODD claims to the measurable performance of the ALKS equipped vehicle. The testing to be performed is derived from the ODD checklist provided by the vehicle manufacturer.

Automation Competence has been divided into two parts: mega-grid validation and behavioural response. Automation Competence equates to 40% of the total possible points.

Figure 7 Automation Competence framework components



3.1 Mega-Grid Validation

Information provided by the vehicle manufacturer to complete the ODD claims check list will be used to determine which tests should be conducted virtually and physically.

Virtual testing derived from the ODD claims of the vehicle manufacturer. The virtual tests will be executed by the vehicle manufacturer. Each scenario will be described in the simulation platform independent language (SDL).

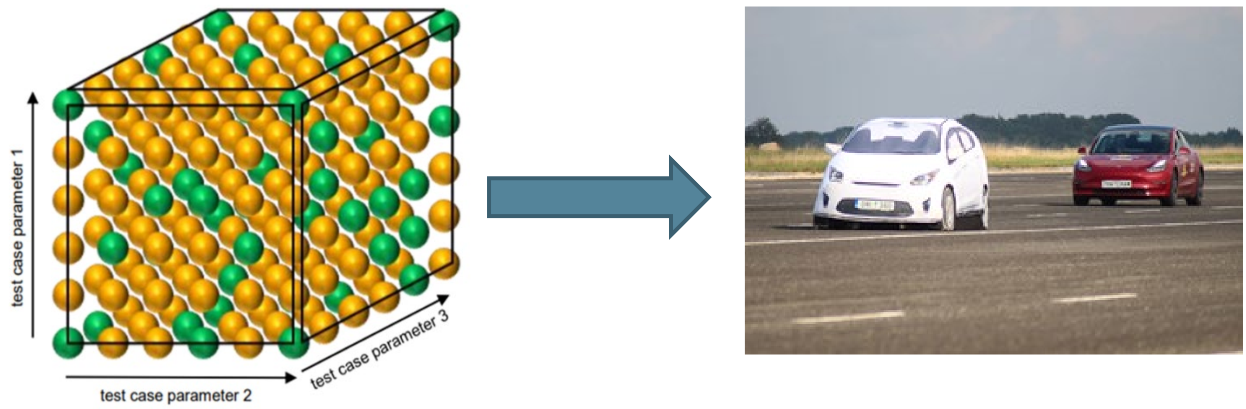
Physical testing on track compared against the ODD claims to the measurable performance of the ALKS equipped vehicle.

The mega-grid refers to a large number of scenarios with a large number of parameters for each, creating a web of test points. The ALKS equipped vehicle will be responsible for the entire driving task (within the ODD) and therefore many more scenarios must be assessed, to provide confidence that the technology can respond safely.

However, this mega-grid would increase the test burden significantly to the point where it will not be possible to physically verify each test point. Therefore, the majority of test points will be executed in a virtual testing environment. It is proposed that the responsibility of executing the virtual tests is given to vehicle manufacturer or tier one supplier. The results from these tests will be delivered in a specified template, ensuring that the key performance metrics such as collision avoidance, speed reduction and maximum deceleration values are provided. For virtual testing, the two-level abstraction scenario description language (SDL) developed and maintained by WMG provides a freely available method of sharing scenarios. The scenarios will be provided to the vehicle manufacturer in SDL, detailed further in the Appendix A.

These virtual results will then be spot-checked using physical testing, to ensure confidence in the virtual testing results. The key scoring influence will be the actual measured performance from the physical testing. Access to the vehicle model algorithm is not required to assess the performance against the ODD claims, and there is no intention to require such access for this assessment framework.

Figure 8 Mega-grid testing many points to physical validation of fewer selected points



Scenario Selection

The Mega-Grid of scenarios will cover a broad number of parameters that an ALKS equipped vehicle would typically experience. There will also be consideration for edge-case scenarios. The Draft ALKS ODD Checklist provides an overview of the expected capabilities of an ALKS equipped vehicle. From this checklist, a list of scenarios will be created based of its contents. Scenario selection will be primarily driven by the ODD checklist, however additional methods of relevant scenario identification will include:

- Accident databases
- Real world data such as telematics and insurance claims
- Standards, regulation and other guidelines
- Real world deployment and trials data

Draft ALKS ODD Checklist

Below is a draft of the ALKS ODD Checklist based on the PAS 1883:2020 Operational Design Domain (ODD) taxonomy for an automated driving system (ADS):

Figure 9 Draft ALKS ODD checklist

Attribute	Sub-attribute 1	Sub-attribute 2	Sub-attribute 3
Scenery	Drivable area type	Motorways (M)	-
	Lane specification	Number of lanes	>2
		Lane dimensions	UNECE R130 compliant
		Lane type	Motorway lane
			Emergency lane
		Direction of Travel	Right-hand traffic
			Left-hand traffic
	Drivable area geometry	Horizontal plane	Straight lanes
			Curved lanes
		Vertical plane	Up-slope
			Down-slope
			Level plane
		Cross-section	Divided/undivided
			Lane barrier
	Drivable area surface type	Tarmac	-
		Concrete	
	Drivable area signs	Type	Regulatory
			Warning
			Information
		Time of operation	Part-time
			Full-time

		State	Variable
			Uniform
Environment	Wind	Intensity	calm 0-0.2 m/s
			light air 0.3-1.5 m/s
			light breeze 1.6-3.3 m/s
			gentle breeze 3.4-5.4 m/s
			moderate breeze 5.5-7.9 m/s
			fresh breeze 8.0-10.7 m/s
			strong breeze 10.8-13.8 m/s
			near gale 13.9-17.1 m/s
			gale 17.2-20.7 m/s
			strong gale 20.8-24.4 m/s
			storm 24.5-28.4 m/s
			violent storm 28.5-32.6 m/s
			hurricane force ≥ 32.7 m/s
	Rainfall	Intensity	light rain < 2.5 mm/h
			moderate rain 2.5-7.6 mm/h
			heavy rain 7.6-50 mm/h
			violent rain 50-100 mm/h
			cloudburst > 100 mm/h
	Snowfall	Intensity	light snow, visibility > 1km
			moderate snow, visibility 0.5-1km

			heavy snow < 0.5km
	Particulates	Type	Marine
			Non-precipitating water droplets or ice crystals
			Sand and dust
			Smoke and pollution
			Volcanic ash
	Illumination	Day	elevation of sun above horizon
			position of the sun
		Night or low-ambient lighting condition	<1 lux
		Cloudiness	clear, 0-1 oktas
			few clouds, 1-2 oktas
			scattered clouds, 3-4 oktas
			broken clouds, 5-7 oktas
			overcast, 8 oktas
		Artificial illumination	streetlights
			oncoming vehicle lights
	Connectivity	Communication	V2V
			V2X
		Positioning	GPS
Dynamics	Traffic	Density of traffic	Low
			Moderate

			High
		Volume of traffic	Low
			Moderate
			High
		Flow Rate	Low
			Moderate
			High
		Traffic type	P2Ws (Powered two wheelers)
			HGVs (Heavy goods vehicles
			Passenger Vehicles
		Prescence of special vehicles	Ambulances
			Police vehicles

Scenario Description

In order for the vehicle manufacturer to execute the virtual tests according to the assessment specification, each scenario must be provided in an opensource language format. This format must also be usable across any simulation platforms and human readable.

Scenario Description Language (SDL) provides a two-level abstraction to detail the environment, weather and dynamics of each scenario. Level 1 utilises a natural language format which is easy for non-technical end users. Level 2 syntax is more logic based, containing more detailed information and utilising a formal machine readable format. Upon the generation and formatting of scenarios, they are then stored within the Safety Pool™ scenario database. This database is freely assessable by vehicle manufacturers and tier one suppliers. Further details on SDL can be found at the end of this framework.

Result Verification

The virtual testing results will be compared against independent physical testing. It is acknowledged that it will not be possible to replicate all the virtual tests on a physical test track, especially when parameters such as weather are considered. Therefore, a spot-check method will be used, where only a select number of tests are physically verified. The method of selection of these spot-checks will take the form of a combination of:

- Random test selection
- Edge case selection
- Failure point validation
- Scenarios of key interest e.g. where accident data suggests the most common type

Further work must be done to establish the accepted level of discrepancy between the virtual and physical results. In the event that the two results do not align, what amount of error will be accepted is yet to be determined. This will likely be unique for different scenarios, depending on their complexity. Additional work will provide a baseline list of physical results, which can be used to show initial alignment with already established scenarios, providing further confidence in the virtual testing results. These baseline results may include tests such as static Automatic Emergency Braking (AEB).

3.2 Behavioural Response

Information provided by the vehicle manufacturer to complete the ODD claims check list will be used to determine which tests should be conducted virtually and physically.

Virtual testing derived from the ODD claims of the vehicle manufacturer. The virtual tests will be executed by the vehicle manufacturer. Each scenario will be described in the simulation platform independent language (SDL).

Physical testing on track compared against the ODD claims to the measurable performance of the ALKS equipped vehicle.

The behavioural response allows for more complex scenarios to be assessed, where the outcome of the test may not be as definitive as the mega-grid method. Ensuring that this rating system is modular and has the ability to expand beyond ALKS for other more advanced automated technology is crucial.

The final framework will define what a good and bad behavioural response should be. Good and bad behaviour will be defined based on the particular scenario being assessed, although general behaviours will be established through the following methods:

- Human driver characteristics (a competent and attentive driver model).
- Aligning with key framework philosophies of ensuring the UiC is kept engaged with the driving task.
- Legal requirements and best practises from road traffic rules such as The Highway Code.

Scenario Selection

The Behavioural Response scenarios will cover a narrower selection than that of the Mega-Grid. A similar methodology will be used in the creation of these scenarios, with the key difference being that the outcome of such scenarios will be less quantitative. For example, Behavioural Response will focus more on the decision making and ultimate outcome of each scenario tested.

This allows the vehicle under test to perform the action it deems most suitable to the situation presented to it, outside of the typical collision avoidance scenarios. These will include:

- Complex multi-vehicle scenarios
- Parameters not contained with the ODD checklist
- Scenarios that transition in and out of the ODD

The validation of these scenarios with physical testing will be difficult and sometimes impossible, especially for scenarios that transition in and out of the ODD. However, assessing the behavioural decision making of automated vehicles is crucial for further developments towards fully-autonomous vehicle testing.

4 | Safety Backup

The capabilities of ALKS requires numerous and highly advanced sensors such as radar, LiDAR and cameras. During real world driving one or more of these sensors or actuators may deteriorate over time or become damaged or blocked in adverse weather conditions. The capabilities of ALKS may be affected in these cases, and therefore it is important that the safe operation of the system is not diminished. Safety Backup equates to 20% of the total possible points.

Figure 10 Safety Backup framework components

4.1 System Failure

The capabilities of ALKS requires numerous and highly advanced sensors such as radar, LiDAR and cameras. During real world driving one or more of these sensors may deteriorate by age or become damaged or blocked in adverse weather conditions. The capabilities of ALKS may be affected in these cases, and therefore it is important that the safe operation of the system is not diminished. Understanding how the system responds to certain errors will be covered by regulation, but further expansion and requiring specific information to be provided the driver will result in greater reassurance in the event of a system error or failure.

Physical testing on track using sensor blocking materials to initiate a system failure response e.g. radar absorbing foam to block radar signals and opaque materials to stop camera functions.

- Sensor blocking is an easy way to initiate failure signals into the vehicle but is not exhaustive of potential sensor failure modes. This will involve blocking the sensors using an absorber cushion to absorb and scatter the radar energy.
- Signal deterioration through environment effect such as fog or snow.
- Operation under limited features due to failure – what is allowed via regulation for specific circumstances. Grey area of operational capability needs to be identified.
- Reward specific status symbols and notifications for system failures e.g. "rear camera is blocked" specifically. Provide clear instructions "Fault X, but you can continue driving."

4.2 Unresponsive User-in-Charge

The implementation of the Minimum Risk Manoeuvre (MRM) and Risk Mitigation Function (RMF) will differ between manufacturers, and with updates to UNECE R157, additional capabilities such as lane changing may be possible. Therefore, understanding the intention of the VUT whilst performing an MRM is critical.

Physical testing on track to initiate the Minimum Risk Manoeuvre (MRM) to establish under which conditions the MRM triggers and exact action the Risk Mitigation Function (RMF) takes. Allows the persons conducting the test to imitate unresponsiveness e.g. sleeping

- Hazard warning light activation immediately once user-in-charge is assumed unresponsive
- Minimum Risk Manoeuvre (MRM) should be safe and take into account other road users but also not be hesitant and slow
- System response in the event that the user-in-charge attempts to intervene during the MRM. System response if user-in-charge demonstrates attentiveness during the MRM.
- E-call a requirement – additional reward for Advanced E-Call (and D-Call) and ISO Rescue Sheet compliance

4.3 Collision Detection and Data Recording

Requirements for collision detection and data recording beyond the regulation will provide additional confidence for first responders, collision investigators, and vehicle insurers. Encouraging manufacturers to offer beyond what is required allows the supporting industries of automation to have confidence in the safety of the systems.

Information provided by the vehicle manufacturer to demonstrate collision detection capabilities.

- Must ensure data from Data Storage System for Automated Driving (DSSAD) abides by the minimum R157 requirements and encourages additional data to recorded
- Common language and readability for manufacturers, insurers and first responders
- DSSAD must be tamper proof and be sent to a third-party cloud service with insurer access
- Record any software updates and updated capability
- EDR regulations could be relevant for additional data access
- Cyber security risks should be considered

Appendix A

Scenario Description Language

For virtual testing, the two-level abstraction scenario description language (SDL) developed and maintained by WMG provides a freely available method of sharing scenarios.

Within a scenario based development and testing process, scenarios are used throughout system development and validation. Various end users sit at different positions within this cycle, the two-level abstraction SDL considers such diversity of end users, including regulators, system developers, test engineers and most importantly the public. Due to the competing requirements from these end users, the syntax for SDL is split into two levels of abstraction. Level 1 utilises a structure natural language format which sits at the abstract scenario category, it is easy for non-technical end users to understand while still maintaining machine readability. Level 2 syntax sits at the logical scenario level, it contains more detailed information and utilises a formal machine readable format. It describes scenery layout, environmental conditions, dynamic actors and their behaviours, effectively covering the scope of ODD and behaviour.

SDL and its different levels of abstraction give the benefit of detail where needed for technical users as well as a top-level understanding via level 1 for regulators and non-technical users. This allows them to extract important information without needing to understand SDL scenario execution. It also provides a standardised and modular system allowing for more scenarios and developments within ALKS vehicles into the future.

The SDL level 2 can be directly executed, or its execution can also be achieved using the converted OpenSCENARIO 1.1 and OpenDRIVE 1.6 files via a conversion toolchain. The conversion toolchain contains formalised grammar of both SDL levels, as well as a schematic for the OpenSCENARIO 1.1 and OpenDRIVE 1.6 format. A mapping process has been developed between SDL level 2 classes and the OpenX formats. Through the parsing of the SDL level 2 description, followed by the conversion to OpenX equivalent terms and classes, followed by the creation of the OpenX description, the end-to-end conversion between the two formats is achieved.

Safety Pool™ scenario database

Upon the generation and formatting of scenarios, they are then stored within the Safety Pool™ scenario database. It uses an ODD and behaviour based scenario labelling process to associate each scenario with their corresponding labels. Users can then retrieve scenarios based on searching criteria either in a manual fashion, or via a dedicated API for automation applications.

Table of Figures

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