

SAFETY GRADING SCHEME FOR HIGHWAY ASSISTED DRIVING TECHNOLOGY

Dominic Tough

Colin Grover

Matthew Avery

Thatcham Research

United Kingdom

Paper Number 23-0274

ABSTRACT

There is increasing availability of assisted driving technology on vehicles and manufacturers are developing innovative features and functionality. When the driver engages assisted driving technology, the vehicle supports the driver with the steering and speed control, however the driver retains the responsibility for the safe driving. Assisted driving offers the potential safety benefits of improved speed and headway regulation and lane guidance, addressing the most common front-to-rear crash type and lane drifting and run-off road crashes. Because the systems relieve some of the driving workload, fatigue is also addressed. However, system implementation must be carefully considered to ensure the driver remains engaged with the driving task.

Assisted driving systems are implemented differently by individual vehicle manufactures. The objective of this research was to identify the key features that lead to safe implementation of assisted driving technology, enabling the development of a consumer safety grading scheme to guide vehicle manufacturers to safe implementation and provide an independent, objective means of assessing systems.

Vehicle Assistance and Driver Engagement were identified as the two critical aspects. The level of assistance provided must be matched by the perception of the driver and the ability of the system to keep the driver engaged. Vehicle Assistance assesses the steering support technology and the selection and application of appropriate speed control. Driver Engagement assesses driving collaboration, driver monitoring and system status in use, and also the consumer information including how the system is named, marketed and its appropriate usage described.

A third key area identified for safe implementation was Safety Backup, namely the advanced emergency support the system provides in case of an imminent collision beyond the capability of the assistance, in case of an unresponsive driver who becomes disengaged for a long period, or a system failure.

The research was implemented by developing test and assessment protocols in association with Euro NCAP acknowledging the results of broad range of research vehicle testing. A four-tier grading scheme was developed (Entry, Moderate, Good and Very Good) ranking vehicles on the sum of Assistance Competence (balancing Vehicle Assistance and Driver Engagement) and Safety Backup.

To date, 21 vehicles have been assessed and a range of results have been achieved that span across the four grades, indicating the relevance of the scheme and its ability to differentiate systems. The scheme has identified an apparent imbalance between Vehicle Assistance and Driver Engagement in one case. In another, a vehicle has been reassessed and gained an improved grading after an over-the-air update.

A limitation of the grading scheme is it is currently focused on highway functionality, whereas assisted driving technology can be utilised by the driver wherever the system deems it is capable of operating. In this first iteration of the grading scheme, only interaction on highway-like roads with other restricted vehicle types has been considered. Expanding the assessment beyond highway usage will necessarily involve assisted driving relevant interactions with a broader range of road types and features, traffic control and road users etc.

INTRODUCTION

Assisted driving technology can provide safety and comfort benefits to the driver by ensuring safe driving practice is observed. This leads to a reduction in the frequency of potential critical collision avoidance situations, therefore minimising the risk of common car to car crash types. For safe driving to be achieved, a balance is required between the level of assistance that the vehicle provides and keeping the driver engaged with the driving task through the systems interaction with the driver. *“Automation needs to be designed either so that it does not rely on the driver or so that the driver unmistakably understands that it is an assistance system that needs an active driver to lead and share control”.*^[1]

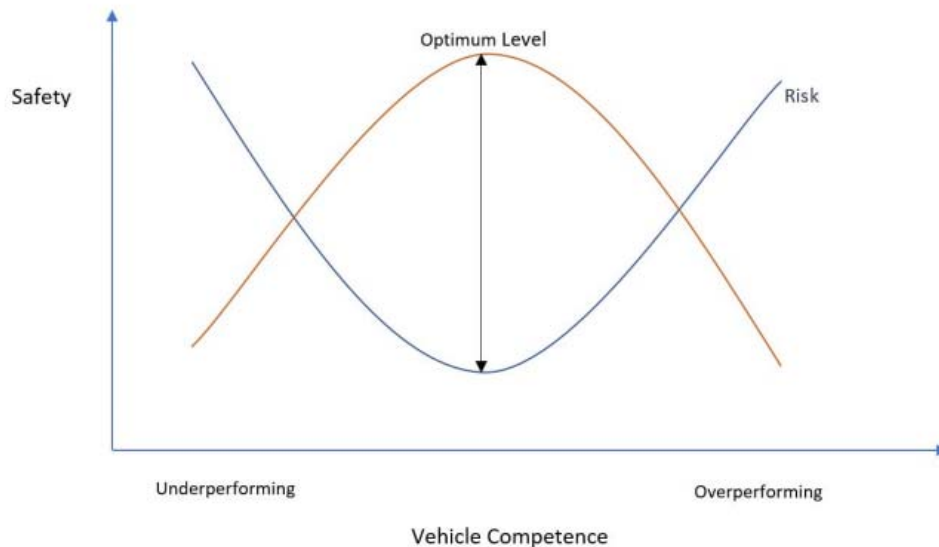


Figure 1 Assisted Driving - safety against vehicle competence.

Each Vehicle Manufacture has their own philosophy in both the way they implement their assisted driving system, which in turn affects the level of driver engagement, but also the technical capability of the system. To give the consumer a greater understanding of the capability and safety of the system, an independent grading system is needed to objectively measure each individual system accurately and fairly.

RESEARCH QUESTION/OBJECTIVE

There is an increasing number of vehicles giving the option of fitting assisted driving technology and manufacturers are developing innovative features and functionality to support the driver with steering and speed control.

Assisted driving offers the potential safety benefits of improved speed and headway regulation and lane guidance, addressing the most common crash types. Because systems relieve some of the driving workload, fatigue is also addressed on longer journeys which could potentially keep the driver from entering a critical accident scenario. However, system implementation must be carefully considered to ensure the driver remains engaged with the driving task. A balance should be achieved between the amount of vehicle competence and the level of driver engagement

The objective of this research was to identify the key features that lead to safe implementation of assisted driving technology, enabling the development of a consumer safety grading scheme to guide vehicle manufacturers to safe implementation and provide an independent, objective means of assessing systems.

METHODS AND DATA SOURCES

Building on previous work completed in 2018 ^[2] Vehicle Assistance and Driver Engagement were identified as two critical aspects for the grading scheme. In order for the system to be deemed balanced, the level of assistance provided must be matched by the driver perception and the ability of the system to keep the driver engaged. Vehicle Assistance assesses the steering support and the selection and application of appropriate speed control. Driver Engagement assesses driving collaboration, driver monitoring and system status, and also the consumer information including how the system is named, marketed and its appropriate usage described.

Assistance Competence - Vehicle Assistance

Vehicle Assistance focuses on the technical capability of the system as a whole. This section involves test scenarios to assess both the longitudinal (Adaptive Cruise Control) and lateral capability (lane centering) of the system. The Vehicle Assistance assessment consists of three elements:

- Speed Assistance
- Adaptive Cruise Control (ACC) Performance
- Steering Assistance

The Speed Assistance builds on the already well-established Speed Assist Systems (SAS) ^[3] assessment from the Euro NCAP 5-star safety rating scheme. Additional points are awarded to ACC systems which respond to the road environment, through the GPS navigation and windscreen mounted camera. Points are awarded for automatically reducing the vehicle speed prior to a slip road, sharp curve, roundabout, and adjusting the set ACC speed to both fixed and temporary speed signs.

Adaptive Cruise Control (ACC) Performance uses highway based car-to-car scenarios identified in previous work ^[2] with scoring based on the vehicle performance at each test speed. Maximum points awarded for full avoidance, half points awarded for mitigating impact, reducing impact by more than 5km/h, quarter points awarded for producing a Forward Collision Warning (FCW) 1.5s prior to impact. This part of the assessment takes into consideration only the capability of the ACC system, this is defined where braking levels stay below approximately -5m/s^2 or where it is confirmed that Autonomous Emergency Braking (AEB) did not intervene.

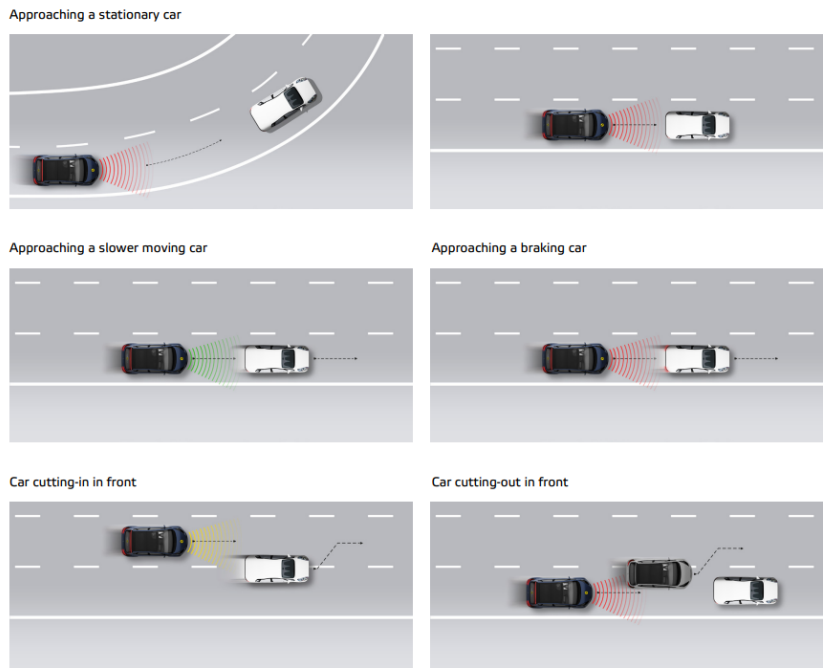


Figure 2 ACC performance car-to-car scenarios.

Steering Assistance assess the competency of the lateral support part of the system. A steering assistance function should support the driver to keep the vehicle in lane, not only on straight roads. If a car departs from its lane there is an increased risk of collision. It is not expected that vehicles are able to stay in the centre of the lane in all road corners, but expects the vehicle to always support the driver by directing the vehicle to the correct heading. Tests for the Steering Assistance are conducted in a so-called S-Bend at three different speeds, 80km/h, 100km/h & 120km/h.

Assistance Competence - Driver Engagement

Driver Engagement is the opposing component of the Assistance Competence balancing concept. To ensure safe driving is maintained throughout the use of the assisted driving system, the driver needs have a sufficient level of engagement with the road environment ahead. The level of Vehicle Assistance needs to equal the level of Driver Engagement. The level of Driver Engagement can be affected by both the pre-determined perception of the systems capability and the feedback from the vehicle whilst driving with the assisted system activated. The Driver Engagement assessment consists of four elements:

- Consumer Information
- System Status
- Driver Monitoring
- Driving Collaboration

Consumer Information looks at the consumers expectations of how much assistance the system will provide them, this expectation will be influenced by information they are subjected to before operating the system. An example of this is marketing on the vehicle manufacturers website and detailed information within the operations handbook. It should always be clear to any potential consumer that the system is an assistance system only and that driver oversight is always required. This assessment is designed to examine the information supplied to the consumer relating to the assistance system.

The System Status assessment is designed to evaluate the information supplied to the driver on a continuous basis, confirming the level of driving assistance being provided by the system. This is anticipated to be visual information only. This assessment is also designed to evaluate the information supplied to the driver in case the level of assistance by the system changes. This is commonly provided as visual, audible and/or haptic



information or warnings.

Figure 3 shows an example of the System Status, indicating the active lateral support via a green steering wheel and the longitudinal support via the display of a lead vehicle.



Figure 3 Volvo's Pilot Assist system status ^[4]

Driver Monitoring technology at the time of developing the grading scheme was limited to indirect monitoring. The most frequently adopted form on indirect monitoring is a detected torque threshold in the steering column to indicate through steering inputs that the driver's hand(s) were on the wheel. Another technology used is touch capacitive sensors within the steering wheel to detect physical pressure on the wheel. Due to the current limited advances within this field and the industry knowledge of Direct Driver Monitoring systems, such as in cabin infra-red cameras to measure the drivers' eyes gaze, the maximum points awarded for driver monitoring was limited to 15/30 until future iterations of the grading scheme.

Driver Collaboration was found to be a key dynamic indicator to the driver of the systems capability whilst the system was active. It evaluates the resistive torque of the steering support system as the driver is interacting with the steering wheel. A full sine wave of steering angle to the vehicle steering wheel, with an amplitude of 5 degrees and frequency of 0.25Hz is applied, this allows the measurement of the resistive torque both with the system on and off whilst keeping the vehicle in the lane. Points are awarded based on the percentage difference in torque measurements with the system on and off. Using the difference instead of the absolute value allows manufactures the freedom to implement heavy or light steering when the system is not active.

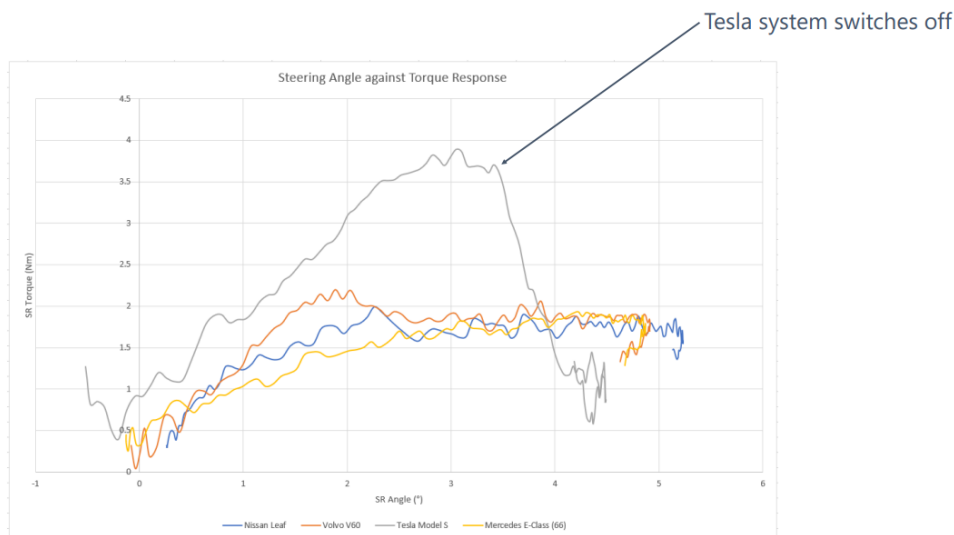


Figure 4 shows early research into steering support torque measurements of different vehicles.

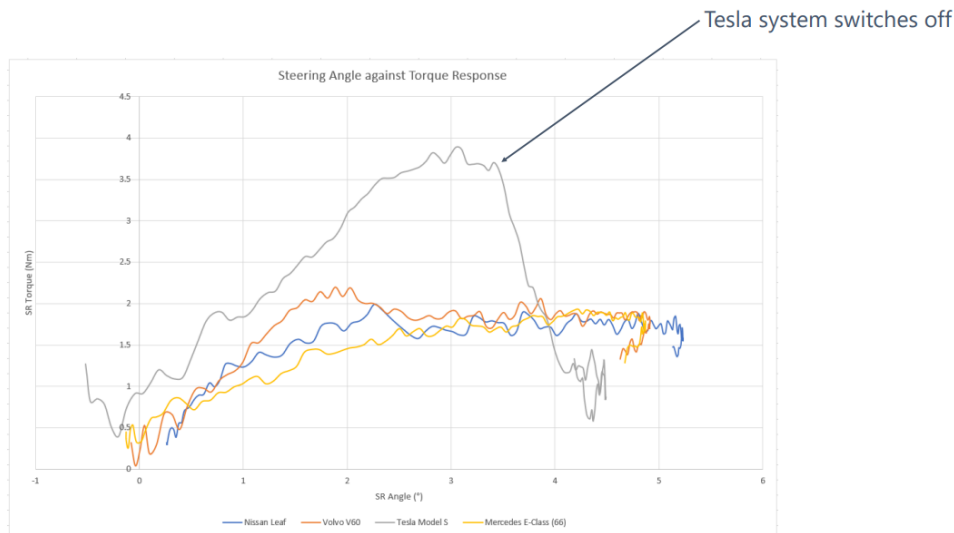


Figure 4 Assisted driving steering torque measurements

Safety Backup

A third key area identified for safe implementation was Safety Backup, namely the advanced emergency support provided in case of an imminent collision beyond the assistance capability, in case of an unresponsive driver or a system failure. The Safety Backup assessment consists of three elements:

- System Failure
- Unresponsive Driver Intervention
- Collision Avoidance

System Failure corresponds to the vehicles response to blockage of the sensors responsible for the lateral and longitudinal control of the systems. Typically, a forward-facing radar for the longitudinal aspect and a windscreen mounted camera for the lateral aspect. A common example is the front radar becoming blocked with snow whilst parked overnight. For a vehicle to score highly it will de-activate the relevant system within two minutes of becoming blocked. The driver needs to be informed with a visual warning within the instrument cluster within five minutes to score additional points. It is known that complete blockage of these sensors is not a common scenario and therefore future research will investigate partial sensor blockage, increase blockage overtime, and sensor degradation.

Unresponsive Driver Intervention builds on the basic UN ECE regulation no. 79^[4] for the vehicle escalation when “hands off” the steering wheel is detected. The grading scheme awards points if after the detection of an unresponsive driver the steering support continues whilst safely bringing the vehicle to a controlled stop. Current regulation of steering support systems requires the vehicle stay within its lane however, future amendments will allow the vehicle to automatically (if deemed safe) move out of the lane and stop on the hard shoulder or inside lane of a multi-laned highway. This will be rewarded in future developments of the Assisted Driving grading scheme.

Collision Avoidance uses the same car-to-car scenarios found in the ACC performance section. At this stage, the system is only being assessed for performance when driving on a highway, therefore only car-to-car performance is assessed. In this assessment “Collision Avoidance” the capability of the vehicle to avoid a collision using both assisted driving systems and emergency systems combined is assessed.

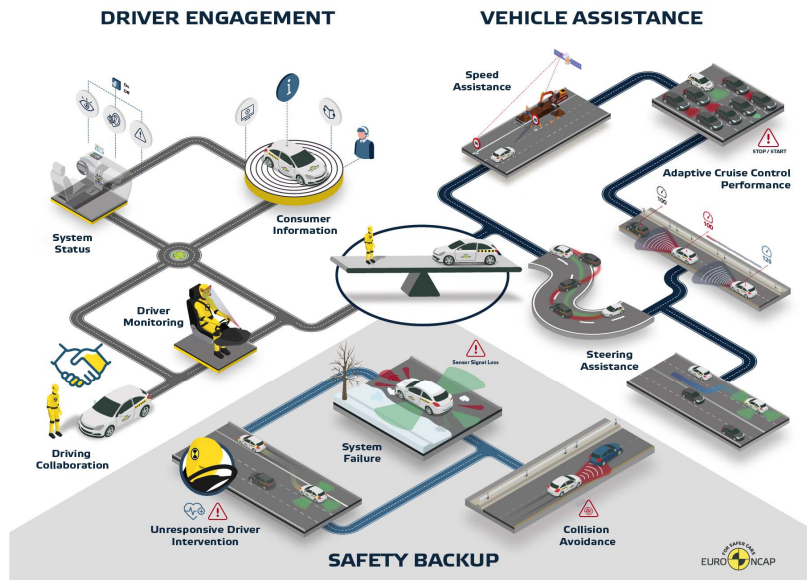


Figure 5 Euro NCAP Assisted driving grading scheme breakdown.

Grading Scheme

The research was implemented by developing test and assessment protocols in association with Euro NCAP acknowledging the results of a broad range of research vehicle testing. A four-tier grading scheme was developed (Entry, Moderate, Good and Very Good) ranking vehicles on the sum of Assistance Competence (balancing Vehicle Assistance and Driver Engagement) and Safety Backup. The naming for the four tiers of grades was agreed through Euro NCAP and industry members such that the wording was applicable throughout different European languages. Entry is given to the most basic of systems in acknowledgement that assisted driving systems are an optional extra and the additional safety benefit given to the consumer by these basic systems is not to be discouraged.

The Assistance Competence score is the balance between Vehicle Assistance and Driver Engagement. The higher the level of assistance, the more the driver must be engaged by the system. In principle, the Assistance Competence score equals the Vehicle Assistance score, but only when the Driver Engagement score (at least) matches Vehicle Assistance. Where Vehicle Assistance outscores Driver Engagement, the Assistance Competence score is limited to the Driver Engagement performance.

A total of 200 points is available to each system with a maximum of 100 points available for Assistance Competence and a maximum of 100 for Safety Backup. The sum of Assistance Competence and Safety backup determines the Grading.

The breakdown of the grading boundaries are set to the following:

- ≥ 100 Entry
- ≥ 120 Moderate
- ≥ 140 Good
- ≥ 160 Very Good

The complete assisted driving assessment and detailed classification of points allocation can be found on the Euro NCAP website: [Euro NCAP AD Test and Assessment Protocol v1.1](#) ^[6]

RESULTS

Table 1. Euro NCAP Assisted Driving Results to Date

Vehicle	Year Tested	Score /200	Grading
Mercedes-EQ EQE	2022	185	Very Good
Mercedes-Benz GLE	2020	174	Very Good
BMW 3 Series	2020	172	Very Good
BMW iX3	2021	169	Very Good
Nissan Qashqai	2022	167	Very Good
Audi Q8	2020	162	Very Good
VW ID.5	2022	161	Very Good
Ford Kuga	2020	152	Good
Ford Mustang Mach-E	2021	152	Good
Cupra Formentor	2021	144	Good
Polestar 2 (OTA Update)	2022	141	Good
VW Passat	2020	137	Good
Hyundai IONIQ 5	2021	137	Moderate
Tesla Model 3	2020	135	Moderate
Nissan Juke	2020	134	Moderate
Volvo V60	2020	121	Moderate
Jaguar I-Pace	2022	112	Entry
Toyota Yaris	2021	109	Entry
Renault Clio	2020	105	Entry
Opel Mokka-e	2021	101	Entry
Peugeot 2008	2020	101	Entry

To date 21 vehicles have been assessed and a range of results achieved that span across the four gradings as shown in Table 1. Euro NCAP Assisted Driving Results to Date. Most systems have been appropriately balanced albeit of differing assistance capability.

Overall, there is a range in performance between each system, showing both the qualities and limitations of each assisted driving system. The results show that “very good” gradings are not limited to high end expensive vehicles but can be achieved in affordable family vehicles such as the Nissan Qashqai and the Ford Kuga.

In the short time the assisted driving protocol has been in place, it is evident that there is an incentive for the vehicle manufacturers to improve their system to achieve a higher score and ultimately improve the grading of the vehicle. One example is the Nissan Juke which was tested as part of the first ever set of vehicles to be assessed using this protocol in 2020 where it achieved a 134/200 score. This gave it a Moderate rating due to having a balanced system but was limited in some technical capability. From the latest set of results in 2022 Nissan improved the technical capability of the system for example, adding ACC functionality for junctions and roundabouts, whilst still retaining a high level of driver engagement. This improvement resulted in an increased score of 167/200 and a Very Good rating, a similar level to high end luxury vehicles.

Other examples of improvement to vehicle performance have been achieved through the use of Over The Air (OTA) updates. One manufacture improved the steering component of their assisted driving system to allow the vehicle to cope with complex road layouts which upgraded their rating from and Moderate to Good.

The scheme identified an apparent imbalance between Vehicle Assistance and Driver Engagement in one case.

Detailed datasheets of every vehicle can be found on the Euro NCAP website: [Euro NCAP | Assisted Driving Gradings](#)

DISCUSSION AND LIMITATIONS

The scheme yielded a range of safety grading results which indicates its relevance and ability to differentiate systems. The grading scheme highlights the capability and limitations of each system to the consumer to give them greater understanding of the functionality of the system such that they do not overestimate the system's ability on the road.

During the limited time the grading scheme has been implemented, it has been evident that vehicle manufactures are developing their systems to further improve both the level of Assistance Competency but also balancing with appropriate levels of Driver Engagement. This should bring about the additional safety benefits which assisted driving systems can provide and subsequently reduce the frequency or severity of accidents on roads.

A limitation of the grading scheme is that it is currently focused on highway functionality only, whereas assisted driving technology can be utilised by the driver wherever the system deems it is capable of operating. In this first iteration of the grading scheme, only interaction on highway-like roads with other restricted vehicle types has been considered. Expanding the assessment beyond highway usage will potentially involve assisted driving relevant interactions with a broader range of road types and features, traffic control and road users etc. Therefore, further research is required to identify future test scenarios and the use of additional road users to further expand the grading scheme beyond highway usage only.

CONCLUSIONS

Assisted driving systems can provide road safety benefits and reduce the number of vehicle accidents on the road. Each system is implemented differently by individual vehicle manufacturers and the independent grading scheme successfully differentiates those systems offering the essential elements from those incorporating more advanced features, acknowledging the necessary balance to achieve safe adoption. This drives vehicle manufacturers towards implementing safe systems and supports consumers making safer choices.

Whilst the grading scheme is currently only limited to highway type scenarios it is acknowledged that these systems can be used on non-highway road types and also provide a safety benefit. Future research work will develop the grading scheme to assess the system performance on non-highway road types to further differentiate those systems incorporated higher functionality.

REFERENCES

- [1] Tivesten, E., Victor, T. W., Gustavsson, P., Johansson, J., Sangberg, F., & Aust, M. L. (2018). Automation Expectation Mismatch: Incorrect Prediction Despite Eyes on Threat and Hands on Wheel. *Sage Journals*, 1081-1243.
- [2] Grover, C., Avery, M., & Tough, D. (2018). *AN ASSESSEMENT APPROACH TO ASSISTED DRIVING SYSTEMS*. NHTSA.
- [3] Euro NCAP. (2018, January). Retrieved from Euro NCAP: <https://cdn.euroncap.com/media/32290/euro-ncap-sas-test-protocol-v20.pdf>
- [4] Volvo Cars. (2022, June 27). *Tips for using Pilot Assist*. Retrieved from Volvo Cars: <https://www.volvocars.com/uk/support/topics/use-your-car/car-functions/tips-for-using-pilot-assist>
- [5] United Nations Economic Commission for Europe . (2018). Regulation No 79 of the Economic Commission for Europe of the United Nations (UN/ECE) — . *Official Journal of the European Union*.
- [6] Euro NCAP. (2023, January). *Euro NCAP*. Retrieved from Euro NCAP: <https://cdn.euroncap.com/media/75441/euro-ncap-ad-test-and-assessment-protocol-v11.pdf>