

# EURO NCAP'S FIRST STEP TO ASSESS AUTOMATED DRIVING SYSTEMS

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## ABSTRACT

Technology is evolving quickly and more and more of the driving function is being handed to the vehicle. Given that a significant portion of road accidents are attributable to "driver error", the potential safety benefits of increased automation are clear, if the automation is at least as competent as the driver in complex traffic situations. It is therefore in Euro NCAP's interests to raise awareness of the technologies that exists and to promote their introduction in such a way that these safety benefits are realised.

Based on the Euro NCAP's existing active safety testing protocols, extended test scenarios were derived that cover the Operational Design Domain of currently available SAE Level 2 systems. These systems are designed for use on motorways where speeds up to 130 km/h are most typical on European roads. With the first round of evaluating Assisted Driving technologies, Euro NCAP is entering a whole new area of safety and safety assessments where public expectations are high yet understanding may be low. Euro NCAP is striving to promote automated driving technologies while at the same time raise awareness of their safety benefits and moreover their limitations.

## BACKGROUND

More than 70% of car drivers believe that it is already possible to purchase a car that can drive itself, according to a consumer survey commissioned by Euro NCAP, Global NCAP and Thatcham Research in 2018. The findings of the survey, which coincided with Euro NCAP's first assessment of automated driving technology, are in stark contrast to the current capabilities of such systems and highlight the significant confusion that exists amongst motoring consumers when it comes to the reality of automated or autonomous driving.

On the question: "Which of the following brands currently sell cars with technology that enables the car to drive itself, without the driver having to do anything?", 1107 respondents from Europe (France, Germany, Italy, Spain and UK), US and China believed that this type of technology is currently available, depending on the vehicle brand 10-40%. Only 11% of the respondents clearly stated that this is not offered in any of these brands. This underlines the need for better and more objective information for consumers on state of advanced driving technology.

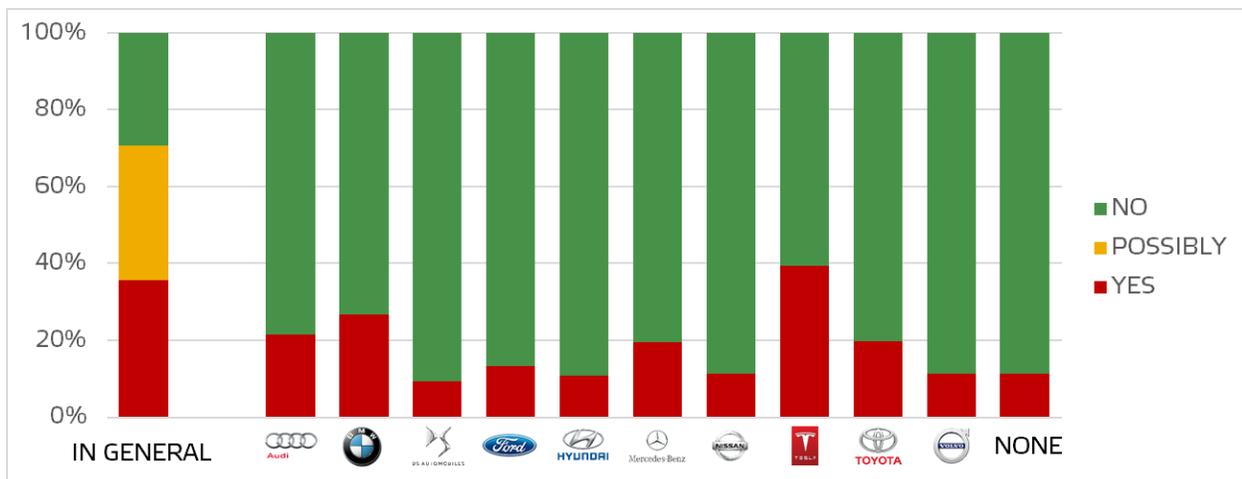


Figure 1. Survey results on the consumers perception on the availability of self-driving technology

As part of its ongoing commitment to independently assess the benefits of new vehicle safety technologies, Euro NCAP has tested the comparative performance of so-called Highway Assist systems in ten cars: the Audi A6, BMW 5 Series, DS 7 Crossback, Ford Focus, Hyundai NEXO, Mercedes-Benz C Class, Nissan LEAF, Tesla Model S, Toyota Corolla and the Volvo V60. The Highway Assist tested combine Adaptive Cruise Control, Lane Centering and Speed Assist Systems to support the driver in driving situations on motorways.

Dedicated test and assessment procedures were developed to grade different driver assistance systems that are currently available by a Working Group consisting of Euro NCAP members, labs and supported by car manufacturers and suppliers.

## LEVELS OF AUTOMATION

It is difficult enough for engineers to understand the different levels of automation as defined by Society of Automotive Engineers in SAE J3016 [1], let alone for the typical consumer. For that reason, it was decided to develop a simpler and easier to understand definition around the possible levels of Automation in a car.

### SAE J3016 Levels of Driving Automation

The latest update of the SAE J3016 Levels of Driving Automation already provide a clear distinction of driver support and automated driving, but Euro NCAP believes that further simplification is needed for the general public to understand the limitations and proper use of the systems they may have available on their vehicle.

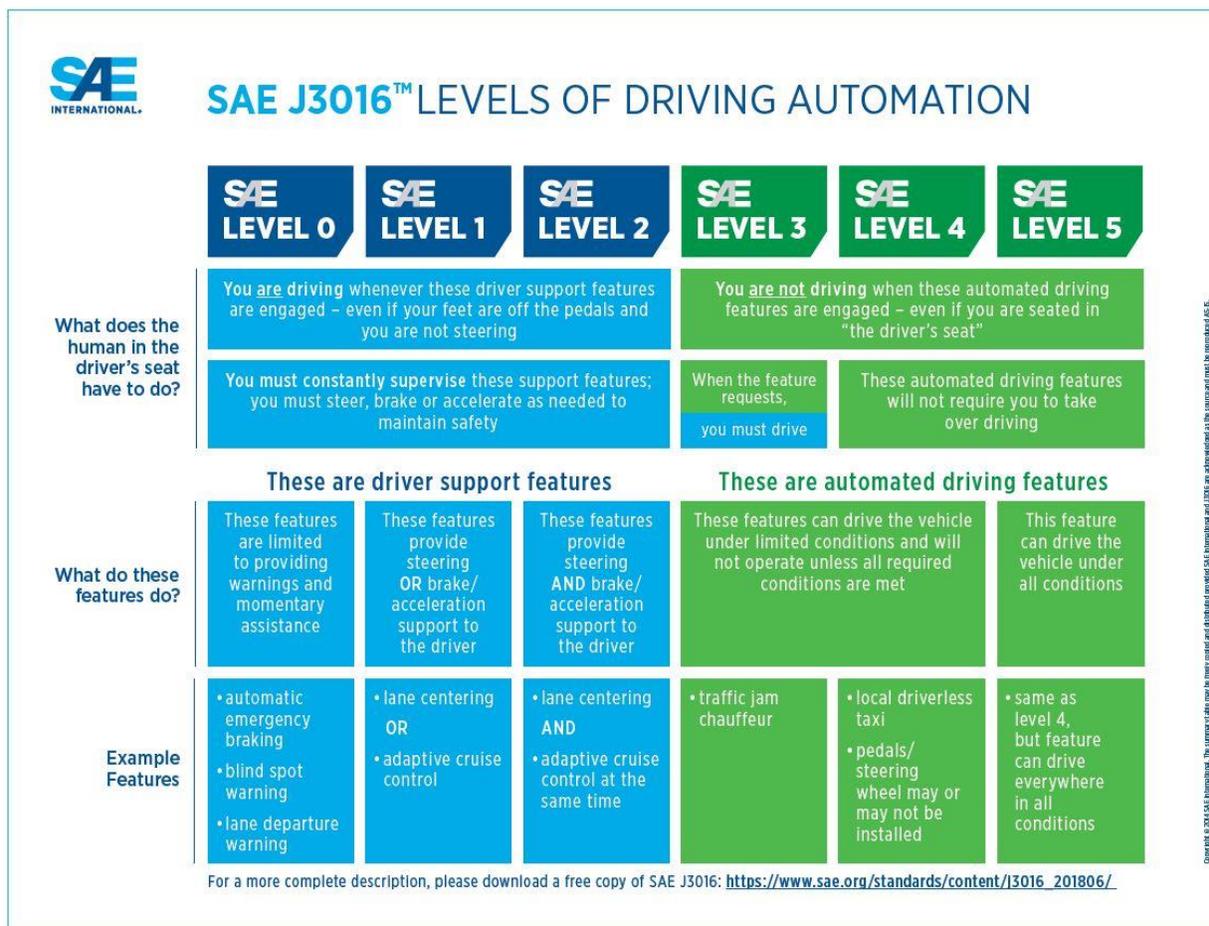


Figure 2. SAE J3016 Levels of Driving Automation

### Euro NCAP Driving Modes

The clear separation between driver support and automated driving which is now part of SAE J3016 is supported by Euro NCAP, but a clear understanding of the Operational Design Domain is still missing as this may be different per system and per OEM. Therefore, Euro NCAP decided to define the Levels of Automation as Driving Modes and combine this with defined Operational Domains.

Three Driving Modes exist for Euro NCAP; Assistance, Automation and Autonomous, where the difference between the Automated Driving Mode and the Autonomous Driving Mode is subtle.

**Table 1.**  
**Euro NCAP Driving Modes**

DRIVING MODE	
Assisted	<ol style="list-style-type: none"><li>1. Driver retains full responsibility and shares control with the Vehicle</li><li>2. Vehicle &amp; Driver share Object and Event Detection and Response [OEDR]</li><li>3. Driver may not perform secondary tasks over and above those permitted during normal driving</li></ol>
Automated	<ol style="list-style-type: none"><li>1. Vehicle has full responsibility for control in Operational Design Domain [ODD] defined by the OEM</li><li>2. Vehicle performs OEDR</li><li>3. Driver may perform certain other non-driving tasks</li><li>4. Driver needs to be available for safe transition of control</li></ol>
Autonomous	<ol style="list-style-type: none"><li>1. Vehicle has full responsibility for control in Operational Design Domain [ODD] defined by the OEM</li><li>2. Vehicle performs OEDR</li><li>3. Driver is effectively a passenger</li><li>4. Driver has no ability to control [apart from switching to another mode]</li></ol>

In the Assisted Driving Mode, the driver is fully responsible but shares control with the vehicle. The Object and Event Detection and Response (OEDR) is performed by the both vehicle and driver, where the driver is not allowed to perform any secondary task over and above those permitted during normal driving. In short this means that the driver is driving and the vehicle provides support where it can.

The Automated Driving Mode gives full responsibility to the vehicle and the vehicle will have full control. As the driver is allowed to perform certain other non-driving tasks, the vehicle has to perform the OEDR, but the driver needs to remain available for a safe transition of control.

Vehicles function which take away the ability of the driver to take control of the vehicle are called Autonomous Driving modes. In this mode pedals and steering wheels may be retracted, which effectively will change the driver to a passenger in this specific driving mode.

These driving modes are combined with Operational Domains that are understandable by a consumer and moreover give Euro NCAP a defined range of assessment of different systems that the car manufacturers may offer to their costumers. The Operational Domains considered are: Parking, City, Inter-Urban and Highway. Combining Driving Modes and Operational Domains result in a matrix of possible systems, e.g. Assisted Highway systems or Automated City systems.

**Table 2.**  
**Euro NCAP Automated Driving Matrix**

<b>AUTOMATED DRIVING</b>	<b>Parking</b>	<b>City</b>	<b>Inter-Urban</b>	<b>Highway</b>
Assisted				
Automated				
Autonomous				

The Euro NCAP Working Group on Automated Driving is detailing the test and assessment procedures for each cell in the matrix for Euro NCAP to be able to comparatively provide consumer information on the different driver assist or automated systems offered by the car manufacturers.

### **HIGHWAY ASSIST SYSTEMS**

A first set of evaluations of Highway Assist systems was published with the goal to highlight the current level of performance and limitations of Highway Assist systems in the area of longitudinal, lateral and speed control. Highway Assist systems are supposed to support the driver in monotonous driving situations on motorways and adapt to the traffic conditions. The first publications investigated three different aspects of these assist systems; Human-Machine-Interaction (HMI), Adaptive Cruise Control (ACC) and Lane Centering (LC). For both ACC and LC, the Euro NCAP Working Group developed test scenarios where the limitations of the systems would be highlighted.

**Table 3.**  
**Automated Driving test vehicles with their Highway Assist system names**

<b>AUTOMATED DRIVING</b>		
	Audi A6	Adaptive Cruise Assist
	BMW 5-series	Active Driving Assistant Plus
	DS 7 Crossback	Connected Pilot
	Ford Focus	Co-Pilot360 (ACC,LC & SAS)
	Hyundai Nexo	Smart Cruise Control with Lane Following Assist
	Mercedes-Benz C-Class	Active Distance Assist DISTRONIC with Active Steering Assist
	Nissan Leaf	ProPILOT
	Tesla Model S	Autopilot
	Toyota Corolla	Toyota Safety Sense (ACC & LTA)
	Volvo V60	Pilot Assist

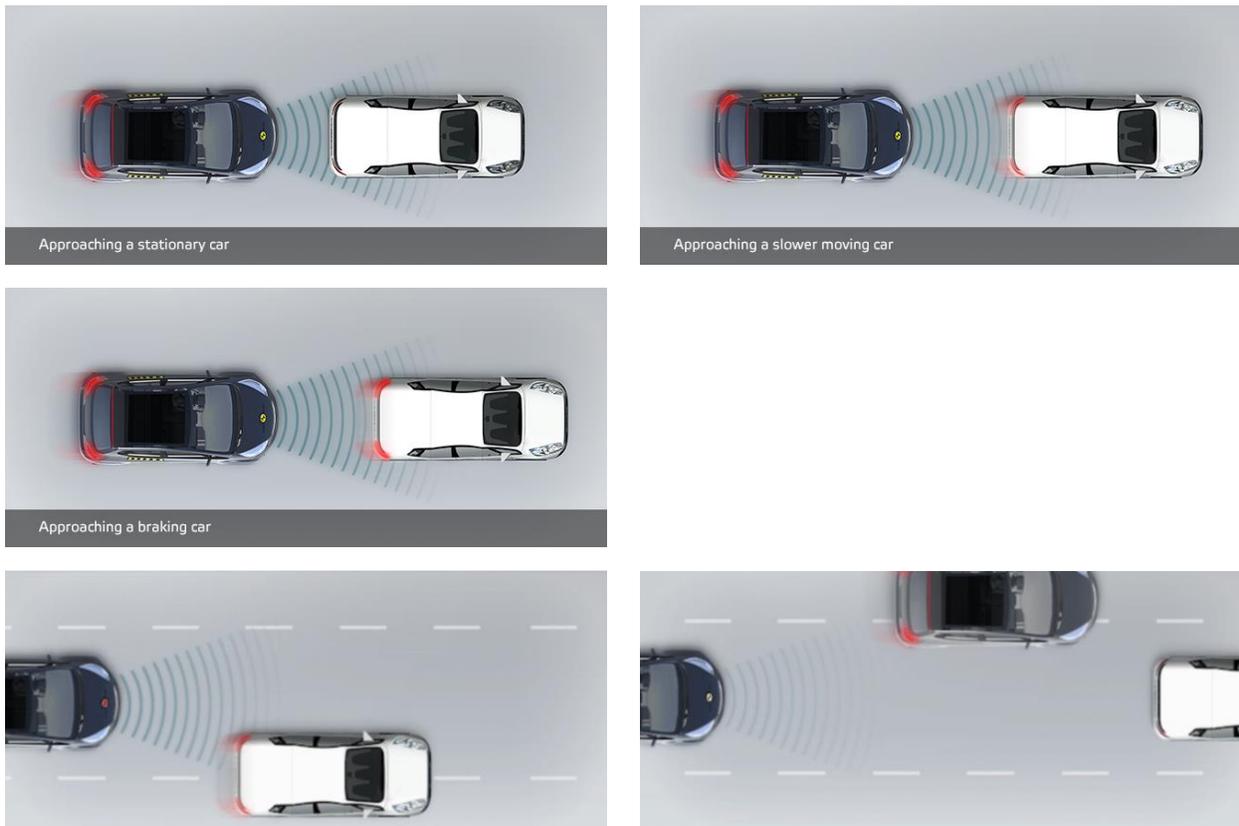
### Human-Machine-Interaction

In addition to physical testing, Euro NCAP reviewed the system names, official media from the car manufacturers as well as the vehicle handbooks to verify how the consumers are informed about these Highway Assist systems in the areas of marketing and technical details. For information purposes, additional features available in the different systems were published but not verified, like automatic speed adaptation. Finally, the vehicle response in case of no driver input (hands-off) was monitored.

### Adaptive Cruise Control Tests

The ACC tests use the Autonomous Emergency Braking tests as a basis because these procedures are well known and represent the typical situations that ACC systems have to cope with on Highways. The speed ranges that are currently used for AEB were extended to cover the typical driving speeds on European Highways.

In addition to the stationary, slower moving and braking vehicles ahead, a so-called cut-in and cut-out scenario were added which were aimed to cover realistic driving situations and were knowingly ACC systems are responding well.



**Figure 3. Highway Assist test scenarios for Adaptive Cruise Control (Left top: Approaching a stationary car, Right top: Approaching a slower moving car, Middle left: Approaching a braking car, Left bottom: Other car cuts-in into your lane, Right Bottom: Car in front changes lane to avoid a stationary car)**

### Lane Centering

Steering Support systems were evaluated in two very simple tests where the level of steering support was evaluated by hands-off driving through an S-curve and a second test where the driver steered the car away from the middle of the lane to avoid a small obstacle to identify the interaction between car and driver.

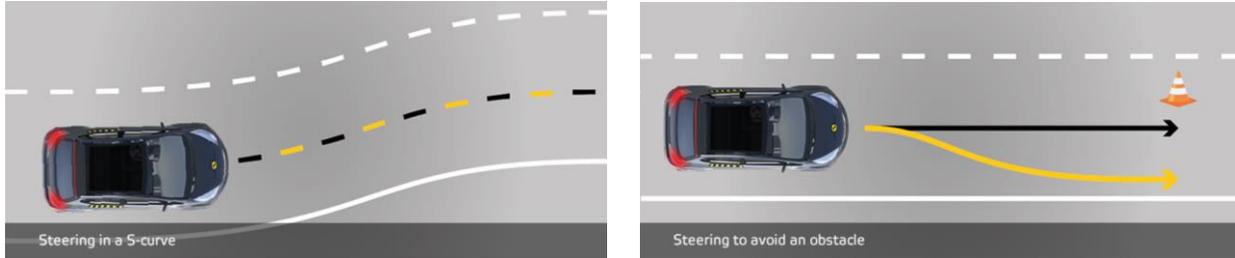


Figure 4. Highway Assist test scenarios for Lane Centering (Left: Steering in a S-curve, Right: Steering to avoid an obstacle)

## RESULTS

The main goal of the first series of tests was to highlight that all Highway Assist systems currently offered have a limited performance and they all need a vigilant driver to avoid the vehicle ending up in a critical situation. A vehicle which can comfortably, by ACC level braking, avoid all of the situation is not per se seen as a safe vehicle as the risk of overreliance is prominent. A balanced result where the role of the driver is clear, and where the vehicle merely provides support is what is expected of these systems. This paper will not go into the detailed test results of all vehicles separately but will provide the general observations and main conclusions from Euro NCAP's first Automated Driving publication.

Detailed results can be found on the Euro NCAP Automated Driving campaign website.[2]

### Human-Machine-Interaction

Often system names will instantly give the consumer the wrong idea about the system's capabilities as they do not clearly state whether the system is an assist system or not. Names like "Pilot" will give a false impression that the system is able to drive by itself, without the need of a driver. Of the ten systems verified, only three system names contained the word "Assist"; Adaptive Cruise Assist on the Audi A6, Active Driving Assistant Plus on the BMW 5-series and Pilot Assist on the Volvo V60. Hyundai, Mercedes and Toyota have non-specific for their Highway Assist systems and simply combine the separate functions. Four system names however, were perceived as misleading as they all contained the word "Pilot" without adding the word "Assist"; Connected Pilot in the DS 7 Crossback, Co-Pilot360 in the Ford Focus, ProPilot in the Nissan Leaf and Autopilot in the Tesla Model S.

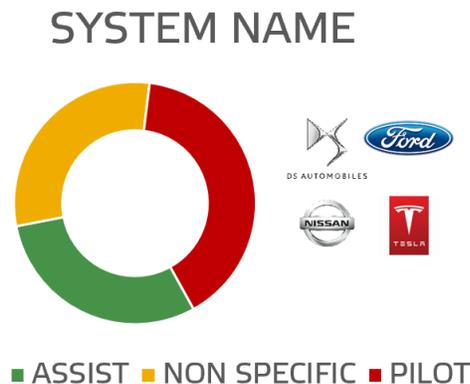


Figure 5. Highway Assist system name assessment

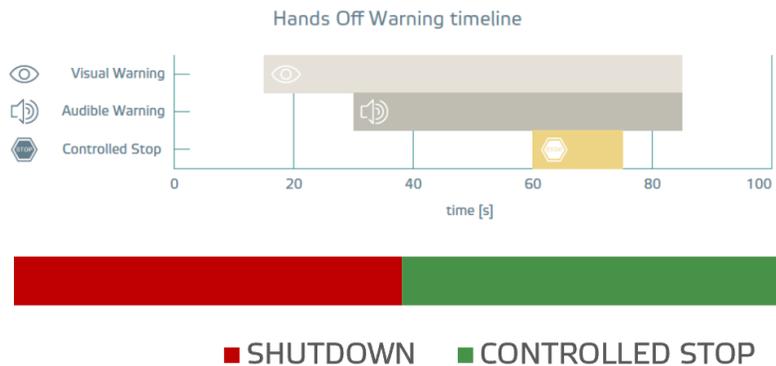
In general terms it was found that user manuals were extremely conservative and cautious regarding the role of the driver stating that the driver always has full responsibility. Contrary to this, marketing videos that were provided to Euro NCAP were seen as misleading for both the BMW and the Tesla where the drivers were shown to take their hands off the steering wheel and hand over control to the vehicle.

## OFFICIAL MEDIA



**Figure 6. Highway Assist system official media assessment**

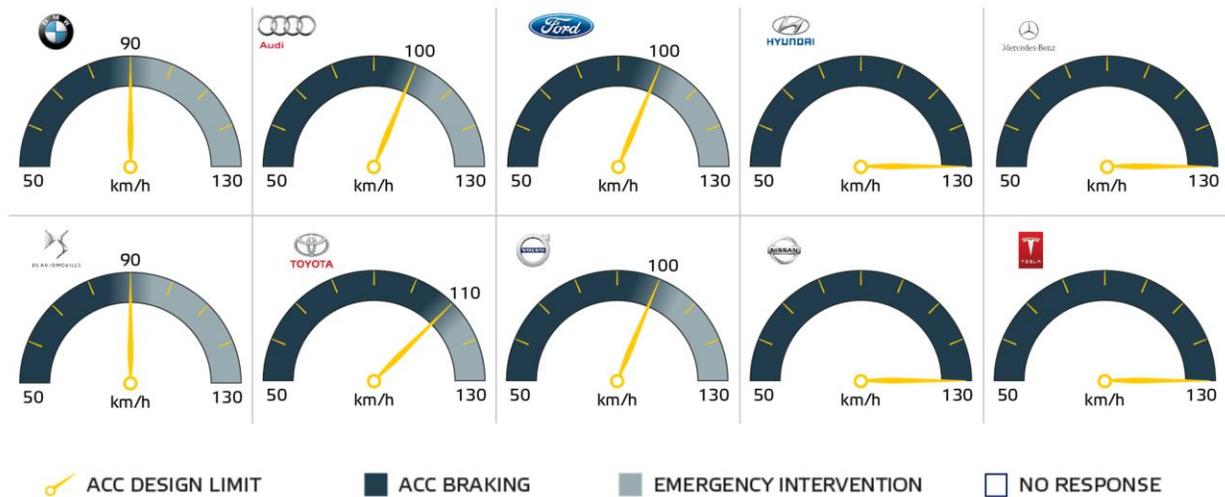
UNECE Regulation 79 requires all vehicles to have a monitor driver input on the steering wheel and warn the driver when the system detects that the driver is not in the loop. Two main strategies were applied by the vehicle manufacturers tested. In case the driver does not take back control after a certain warning sequence, half of the vehicles simply switched off their lane support and ACC, leaving the vehicle in principle uncontrolled. In case of sudden sickness or a driver falling asleep, this may have catastrophic results. The other half of the vehicles would bring the vehicle to a controlled stop within the lane, which was perceived as safer solution than simply cancelling the vehicle support functions.



**Figure 7. Highway Assist system Hands Off Warnings**

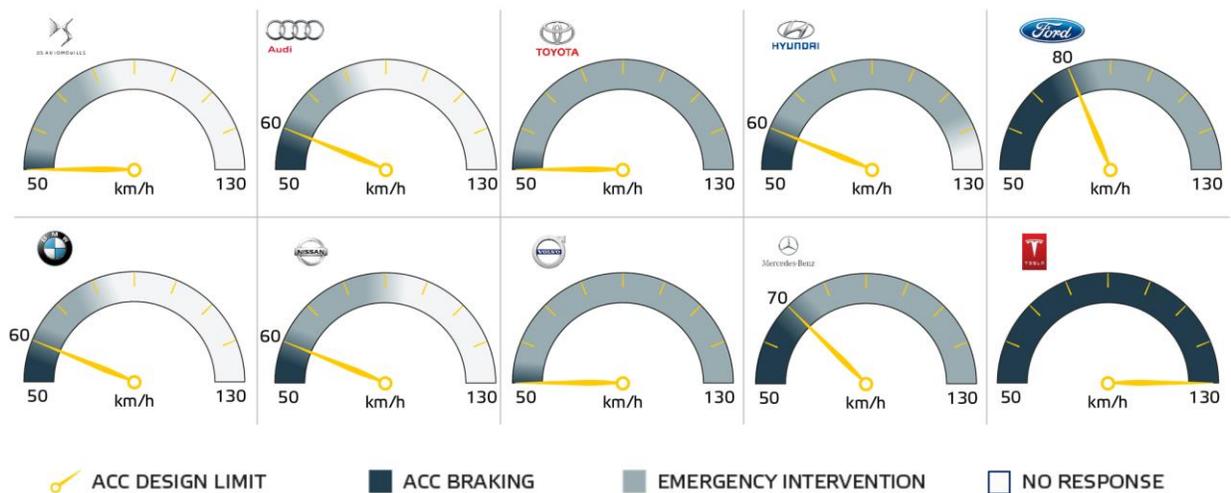
## Adaptive Cruise Control Tests

The performance in the ACC test scenarios revealed the strategies implemented by the different manufacturers, but also clearly shows that these systems are designed to work best in the slower moving scenarios.



**Figure 8. Results of the Approaching a slower moving car scenario**

In the stationary car in front scenario, most systems were very conservative and provide ACC level braking only upto 60 km/h to safely avoid the collision. DS, BMW, Audi and Nissan provided emergency support (FCW and/or AEB) only upto a speed of 80 to 90 km/h, where Toyota, Volvo, Hyundai, Mercedes, Ford provided emergency support over the whole speed range. Tesla however provided ACC level braking over the full speed range in this scenario which may lead to a consumer perceiving the system as full automation, with a high risk of the driver over relying on the system. Assist systems offering such a high level are expected to have a direct driver monitoring system to ensure the driver is in the loop but this was not the case for this vehicle.



**Figure 9. Results of the Approaching a stationary car scenario**

In the most challenging scenarios, the cut-in and cut-out of a vehicle in front, all vehicles highlighted limitations showing that a driver is always needed to respond to the situation before the vehicle does to avoid a collision.

### Lane Centering

The steering tests showed that all manufacturers apart from one, apply the same strategy where the driver keeps control of the lateral control and where the vehicle offers lane centering. This strategy is what one would expect from an assist system to avoid the driver thinking he is not required which can ultimately result in overreliance.

Tesla's Autopilot is not designed to work together with the driver and will not allow any driver input. As soon as the test driver steered around the obstacle in the lane, the system disengaged and stopped the steering support.

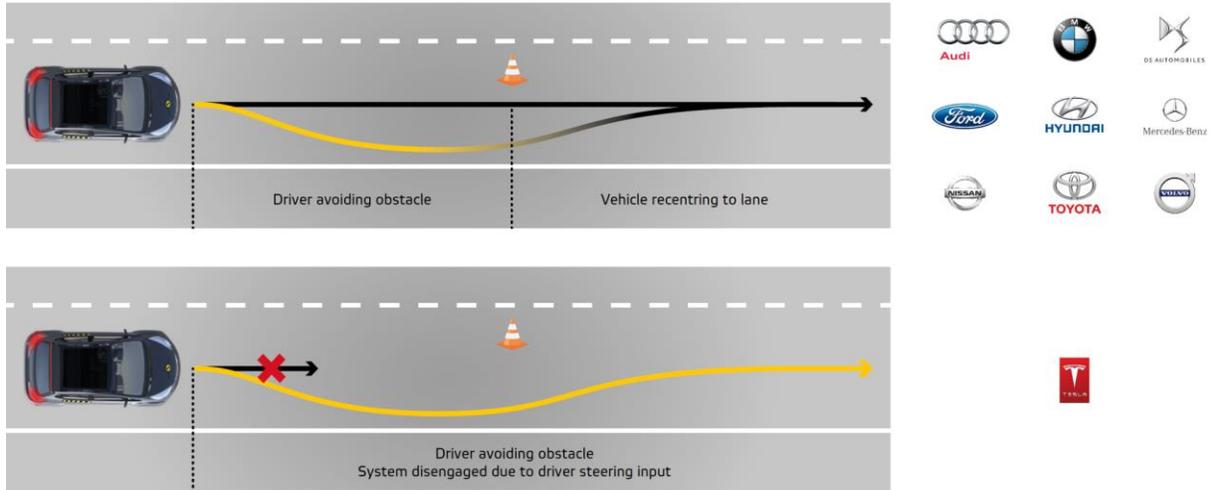


Figure 10. Results of the Steering to avoid an obstacle scenario

### Summary of results

In general terms all vehicles, apart from Tesla, behaved very similar with different levels of steering support and ACC performance. Overall, both BMW and DS were judged to be too conservative, where a consumer may not see the added value of the support function. On the other extreme, Tesla was seen as providing too much support for a Highway Assist system which results in the risk of a driver over relying on the system. The Highway Assist systems of the other seven manufacturers provided different levels of support but were all seen as balanced systems where the driver will clearly understand its role while the function is engaged.



Figure 11. Overall Highway Assist system results

## **DISCUSSION**

The different scenarios for testing the ACC performance are extended AEB scenarios but there is only an intuitive link to accident data or potential risk at crashes at the moment. More research is needed on the relevance of certain scenarios within the ODD of the systems assessed.

Clear and objective criteria need to be developed that can quantify and/or assess over-reliance so that car manufacturers can take this into account while developing these systems. Over the next years, when more automation is expected to penetrate the market, requirements need to be reviewed and updated to incentivise better, safer and more intuitive assist systems that support the driver in normal driving conditions.

## **CONCLUSION**

With the first round of evaluating Assisted Driving technologies, Euro NCAP is entering a whole new area of safety and safety assessments where public expectations are high, although understanding may be low. Euro NCAP is striving to promote automated driving technologies while at the same time raise awareness of their safety benefits and moreover their limitations.

For future assessments a clear and understandable definition to classify different driving modes so that consumers will have no problems understanding the capabilities of these systems and what the role of the driver is once the system is engaged. By combining these Driving Modes with well-defined Operational Domains, a solid foundation is available for Euro NCAP to develop specific test and assessment procedures for different levels of automation.

## **REFERENCES**

- [1] Society of Automotive Engineers, 2014 - Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems J3016
- [2] Euro NCAP Automated Driving campaign website, [www.euroncap.com/en/vehicle-safety/safety-campaigns/2018-automated-driving-tests](http://www.euroncap.com/en/vehicle-safety/safety-campaigns/2018-automated-driving-tests)