THE LIMITATIONS OF CURRENT ADAS TESTING SCENARIOS

White Paper

Sep 2019

A version of this paper has been published as a series by Society of Automotive Engineers (SAE) International

THE LIMITATIONS OF CURRENT ADAS TESTING SCENARIOS

IDENTIFYING CORNER CASES AND THE NEED FOR ADDITIONAL SENSOR TECHNOLOGY

By rewarding improved vehicle performance, testing organizations such as Euro NCAP play a critical role in spurring automakers to develop enhanced safety features. With car-buyers ranking safety among their top priorities,[1] automakers strive to achieve higher ratings and perhaps earn a "Five Star Rating" (NHTSA), "Top Safety Pick" (IIHS), or "Best in Class" (Euro NCAP) award. Of course, safety ratings are based on how the vehicle performs at a testing facility within strictly defined parameters, which often do not capture the broad range of contexts encountered in real world driving. By examining two examples of vehicle testing protocols, this paper identifies a range of common scenarios that exist outside of current testing parameters, and which current camera/radar systems would struggle to address. These uncaptured scenarios, or "corner cases," represent a great opportunity for improving roadway safety.

We will first consider Euro NCAP's testing protocol for Lane Support Systems (LSS), which include ADAS features such as Emergency Lane Keep (ELK), Lane Keep Assist (LKA), and Lane Departure Warning (LDW). These features aim to improve vehicle safety by either alerting the driver or changing the trajectory of the vehicle when it begins to drift out of its lane. This protocol is instructive for our purposes because Euro NCAP has already announced that it will implement more demanding guidelines in its assessment of Lane Support Systems, to give more weight to Emergency Lane Keep performance over basic Lane Keep Assist.[2] As opposed to LKA, ELK requires the system to identify which vehicle crossings of lane lines or road edges are dangerous as opposed to benign. Instances when an ELK system would be expected to intervene include cases where the vehicle is running off the road, heading into oncoming traffic, or cutting in front of a passing vehicle. The ability to identify these critical cases will decrease the number of unnecessary responses generated by less-advanced LKA systems, which can be so annoying that drivers sometimes disable the feature entirely.[3] Lane Support therefore provides a good example in which testing organizations are signaling that future test protocols will aim to capture increasing levels of system performance in an expanding range of conditions.

An examination of the current testing parameters of Lane Support features will allow us to identify the corner cases that future vehicle systems and test protocols will need to address. Current LSS testing criteria include:

- Tests conducted in daylight conditions only, in homogenous ambient illumination of at least 2000 lux (lx)
- Test conducted on straight roadways only
- No irregularities, such as large dips or cracks, manhole covers, or reflective studs can be within 3.0 m to either side of the center of the test lane and 30 m ahead of the test vehicle from the point of test completion
- Horizontal visibility at ground level greater than 1 km
- No strong shadows in the test area other than those caused by the targets
- Vehicle must not drive towards or away from direct sunlight
- Test vehicle velocity of 72 km/h (45 mph)

- Target vehicle velocity to 72 or 80 km/h (50 mph)
- Test vehicle shall travel in “an initial straight line path followed by a fixed radius as specified for the test scenarios, followed again by a straight line.”

Certainly, it is challenging to develop test guidelines that represent a real-world environment while also designing in uniformity and repeatability. Although we recognize that comparing vehicle performance requires testing scenarios and conditions to be regulated at levels of precise granularity, it is nonetheless informative to consider the conditions that these specific testing protocols are not designed to capture (or perhaps even designed not to capture). Even more, we can consider how the systems around which the current testing protocols are designed would perform in these corner-cases, thereby demonstrating the need for alternative sensor modalities to enable ADAS feature functionality in expanded domains.

Scenarios that are not captured by the current LSS test protocol and that would not be adequately addressed by camera/radar-based systems could involve:

- Shadows across the roadway
- Lighting conditions outside of the defined parameters
- Irregularities in the roadway
- Increased test vehicle speeds/detection range requirements
- Curved roadways or irregular route geometries (roundabouts, junctions, merges)
- Roadways with unclear or unmarked lane lines or road edges
- Test targets with minimal visual contrast with their surroundings/backgrounds.

Examining a second protocol from Euro NCAP will further demonstrate the existence of corner cases that will require additional sensors to address.

As with LSS, Euro NCAP’s test protocol for measuring Automatic Emergency Braking (AEB) systems’ ability to detect and avoid pedestrians and bicyclists carefully defines the scenarios it intends to capture.[4] These scenarios include permutations of collisions involving adult and child targets either crossing the vehicle’s path or travelling in its same direction. According to Euro NCAP, the testing parameters are designed to represent “main roads in urban situations with velocity 30-60 km/h, where main users are motorized vehicles and where bicycles and pedestrians are permitted.”[5] Examples of the prescribed conditions include:

- Specifications for pedestrian and bicyclist targets[6]
- A regular and level test track with 1 km visibility and no lane markings
- Daytime trials performed in homogenous ambient illumination of at least 2000 lux (lx)
- No strong shadows in the test area other than those caused by the targets
- Vehicle must not drive towards or away from direct sunlight
- No overhead signs, bridges, or gantries

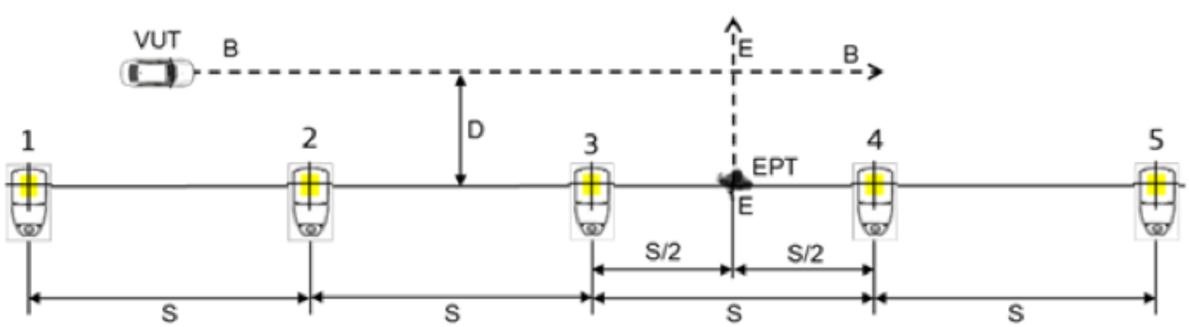
---

1. https://aceee.org/blog/2018/06/car-buyers-rank-fuel-economy-top
2. Euro NCAP, “2025 Roadmap,” pg 12.
3. Grover, Colin and Matthew Avery, “Emergency Lane Keeping (ELK) System Test Development,” Thatcham Research.
4. https://cdn.euroncap.com/media/32279/euro-ncap-aeb-vru-test-protocol-v202.pdf
5. Euro NCAP, pg 25
6. https://www.acea.be/uploads/publications/Articulated_Pedestrian_Target_Specifications_version_1.0.pdf

- Free space around the test vehicle ranging from 4 m to 17 m, depending on the testing scenario
- 1.0 m of free space surrounding the test target and 30 m of free space behind the target along the test vehicle path
- Surrounding visible areas "shall comprise of a wholly plain man made or natural environment (e.g. further test surface, plain colored fencing or hoardings, natural vegetation or sky, etc.) and must not comprise any highly reflective surfaces or contain any vehicle-like silhouettes that may give rise to abnormal sensor measurements"
- Vehicle and target paths are straight and either aligned in the same forward-facing direction or crossing at a 90-degree angle
- At the given speeds, Euro NCAP's AEB Pedestrian trials require a maximum perception range of 50 m
- At the given speeds, Euro NCAP's AEB Bicyclist trials require a maximum perception range of 67 m.

In addition, the guidelines for testing under low lighting conditions are outlined in an appendix which, at seventeen pages in length, composes roughly half of the overall protocol document. The parameters described in this section are extensive and detailed. They include:

- Levels of allowable background illuminance (<1 lux)
- Levels of allowable road area illuminance (between 5 lux and 22.5 lx)
- The type and positioning of street lamps in the test area
- The position of the test target in relation to the street lighting (2 lamps down road from the test target and 3 lamps in front of the test target)
- The average illuminance of the test vehicle path (between 16 lx and 22 lx)
- The average illuminance of the test target path (at least 5 lx)
- Free space between the lamp poles/mounts and test vehicle path (at least 4 m)
- Light measurement parameters, tools, and documentation methods.



D: Lateral distance between the centre of the light field and the VUT path

EE: Axis of centreline of pedestrian dummy

BB: Axis of centreline of Vehicle under Test

VUT: Vehicle under Test

EPT: Euro NCAP Pedestrian Target

S: Distance between streetlight

Example diagram of Euro NCAP's guidelines for AEB pedestrian tests conducted in low ambient light.[7]

Scenarios that are not captured by the current AEB Pedestrian and Bicyclist test protocol and that would not be adequately addressed by camera/radar-based systems could involve:

- Shadows across the roadway
- Lighting conditions outside of the defined parameters
- Vehicles, persons, or objects within the currently prescribed free space around the test target or test vehicle
- Overhead signs, bridges, or gantries
- Test targets with minimal visual contrast with their surroundings/backgrounds
- Increased detection range requirements/test vehicle speeds
- Targets that do not match the shapes of current pedestrian and bicycle targets (animals, tire debris, mattresses, etc)
- Diagonal paths of approach to the collision point
- Rural roadways.

Taken collectively, we see that these outlying scenarios are quite a bit more inclusive of real-world driving conditions than the ones outlined in the sterilized and limited test protocol.

In order to address these scenarios, vehicle sensors must not be confounded by shadows, irregular lane markings, low ambient light, cluttered or low contrast scenes, overhead objects, irregular object shapes, or curved roads. Systems that utilize cameras as a front-line sensor for object detection and then call on radar to provide objects' distances from the vehicle likely suffer in the above conditions. Cameras can be fooled by shadows, are prone to optical illusions, struggle to detect objects that blend with their backgrounds, and lack adequate range in low light conditions. Radar (even next-generation hi-resolution radar) lacks the resolution to distinguish objects at required ranges. Simply adding more cameras and radar will not fix these problems. Therefore, as Euro NCAP expands its testing guidelines to include broader and more realistic roadway scenarios, vehicles with lidar sensors providing robust range and resolution performance will earn the highest ratings.

7. Euro NCAP, pg. 31

Velodyne Lidar®

Leading Lidar Technology™

VelodyneLidar.com