# INTEGRATING ROBUSTNESS IN EURO NCAP 2026 CRASH AVOIDANCE ASSESSMENT

**Adriano Palao[1], Richard Schram[1], Rikard Fredriksson[2], Mats Petersson[3], Stephan Ryrberg[3], Andreas Rigling[4], Ashley Patton[5]**

[1]Euro NCAP, Belgium

[2]Trafikverket, Sweden

[3]RISE, Sweden

[4]ADAC, Germany

[5]HORIBA MIRA, United Kingdom

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## ABSTRACT

This paper presents the introduction of robustness as a core element of the Euro NCAP 2026 Crash Avoidance assessment. The objective is to move beyond function performance under idealized test conditions and to incentivize systems that deliver consistent safety benefits under realistic operational variability. Robustness is implemented through a structured expansion of scenario parameters and the introduction of Robustness Layers reflecting real-world uncertainties. The paper describes the motivation, development process, implementation approach, and early observations from protocol development and research activities, and outlines future directions for the evolution of crash avoidance assessment.

Keywords: Euro NCAP, crash avoidance, robustness, consumer testing, active safety

## INTRODUCTION

Crash avoidance technologies have become an essential component of modern vehicle safety strategies, with the potential to mitigate or prevent a substantial proportion of serious and fatal road traffic crashes [1] [2]. Recent European accident statistics continue to show that road accidents remain a major issue, with approximately twenty thousand fatalities occurring annually across the European Union. Car drivers and occupants account for a large share of these fatalities, while vulnerable road users (VRU) including pedestrians, cyclists, powered two-wheelers (PTW), and new road users e.g., micromobility represent nearly half of all victims according to the most recent CARE accident database analyses. These figures highlight the importance of crash avoidance systems that perform reliably across a wide range of traffic situations and for all relevant target populations.

Since the introduction of Autonomous Emergency Braking assessment in 2014, Euro NCAP has progressively expanded its Crash Avoidance assessment. Over consecutive protocol cycles, the assessment has evolved from simple low-speed rear-end collision scenarios toward a broad range of longitudinal and lateral crash scenarios, including turn-across-path, crossing, reversing, and head-on conflicts, as well as steering-based interventions. In parallel, the scope of collision partners has been gradually extended beyond passenger vehicles to include pedestrians, cyclists, and powered two-wheelers. This expansion has always been motivated by the objective of accelerating the deployment of effective safety technologies while maintaining test repeatability and reproducibility.

As the number of assessed scenarios increased, Euro NCAP adopted grid-based and smart testing approaches to manage test burden and cost while preserving meaningful differentiation between systems. However, experience has shown that strong performance under tightly controlled, idealised test conditions does not necessarily translate into consistent real-world behaviour. Real traffic is characterised by variability in geometry, interaction timing, background complexity, and environmental conditions that are only partially captured by traditional track testing. Systems optimised for narrow test configurations may therefore achieve high assessment scores while exhibiting degraded performance under small, realistic variations.

Conscious of this limitation, Euro NCAP committed to move beyond single-point scenario optimisation and to focus on system robustness under realistic conditions. Going forward, the challenge will be introducing such variability in a manner that remains realistic, objective, and scalable within a consumer assessment framework.

This paper describes how robustness has been integrated for the first time in the Euro NCAP 2026 Crash Avoidance test and assessment procedures. Building on several years of Working Group development, data analysis, and test campaign experience, the 2026 assessment introduces variability through expanded scenario parameter ranges and dedicated Robustness Layers. The objective is to better align consumer testing with real-world crash conditions, incentivising system designs that deliver effective safety benefits in the widest possible operational coverage. Other areas in the Euro NCAP 2026 Rating have also followed the same objectives, such as Crash Protection, described in paper number 26-0211 [3].

## METHODS

### Euro NCAP 2026 Rating Scheme Structure

From January 2026, Euro NCAP vehicle safety assessments are organized under a revised Rating Scheme structured around four Stages of Safety, reflecting a holistic approach to vehicle safety across the full crash timeline. Each stage is scored independently on a 0 to 100 point scale and expressed as a percentage. Minimum performance thresholds apply at stage level and jointly determine the overall vehicle star rating.

The four Stages of Safety are:

- Safe Driving, addressing technologies and features that support safe vehicle operation and driver engagement;
- Crash Avoidance, evaluating systems designed to prevent or mitigate collisions through autonomous interventions e.g., AEB, ELK;
- Crash Protection, assessing the effectiveness of passive safety systems in reducing injury severity during a crash;
- Post-Crash Safety, focusing on emergency response facilitation and occupant rescue following a collision.

## Crash Avoidance Within the 2026 Rating Scheme

Within the 2026 Rating Scheme, Crash Avoidance constitutes a dedicated assessment stage, reflecting the increasing contribution of active safety systems to real-world casualty reduction. The stage covers a broad set of crash-prevention and mitigation technologies, including Autonomous Emergency Braking and Lane Support systems, and emphasizes both safety effectiveness and acceptability in everyday driving.

Crash Avoidance performance is assessed across three primary stage elements:

- Frontal Collisions, covering longitudinal, turning, and crossing conflict scenarios involving vehicles and vulnerable road users;
- Lane Departure Collisions, addressing intended and unintended lane departures, including crash prevention against vehicles in adjacent lanes through steering-based interventions;
- Low Speed Collisions, focusing on collision avoidance and damage mitigation in low-speed traffic environments, including start-from-stop scenarios, pedal misapplication, and cyclist dooring.

In addition to traditional outcome-based metrics, the 2026 protocols place greater emphasis on system behavior during normal driving that may result in driver acceptance issues, particularly for lane support systems, where smoothness and controllability of interventions contribute to the assessment. Further information on this aspect can be found in paper 26-200 [4]

## Scope of Robustness Implementation Across Stage Elements

The robustness framework described in this paper is implemented within the Crash Avoidance stage of the 2026 Rating Scheme and follows a differentiated implementation strategy across the three stage elements.

For the Frontal Collisions and Lane Departure Collisions stage elements, robustness is fully implemented. This includes both an expansion of scenario parameter ranges beyond nominal conditions – defined as Standard Range and Extended Range – and the application of structured Robustness Layers, organized into two clusters addressing (1) Decision & Control layers and (2) Perception layers.

Within each of these stage elements, the majority of the available score is attributed to performance in the Standard Range. As a general principle, approximately 80% of the total stage-element score is allocated to the Standard Range, while around 10% is attributed to the Extended Range and the remaining 10% to Robustness Layers.

In contrast, the Low Speed Collisions stage element incorporates robustness only partially for the 2026 rating cycle. In this stage element, robustness is limited to the expansion of scenario parameter ranges, while the application of Robustness Layers is currently planned for the next protocol phase from 2029 onwards.

## Overview of the Robustness Framework

The robustness concept introduced in the Euro NCAP 2026 Crash Avoidance assessment was developed to complement established scenario-based testing by systematically evaluating system performance under controlled variability. Rather than assessing crash avoidance functions solely at fixed, nominal parameter values, the 2026 framework expands the test envelope to capture performance consistency across realistic deviations representative of real-world operating conditions.

The objective is not to list all possible crash configurations, but to assess whether a system keeps consistent performance when exposed to variations around well-defined baseline scenarios. Robustness is therefore treated as a property of system behavior across a parameter space, rather than performance at a single operating point.

## Development Process and Evidence Basis

The robustness framework is the outcome of a three-year development effort within the Euro NCAP Crash Avoidance Working Group, involving test laboratories, vehicle manufacturers, and technical experts. The methodology was informed by several complementary evidence sources:

- analyses of European crash data, including statistics and in-depth accident databases from all Euro NCAP member countries;
- exploratory research by Euro NCAP laboratories, including cases of inconsistent system behavior under minor test deviations;
- review of academic literature on perception robustness and system generalization;
- feasibility studies and pilot testing conducted at multiple proving grounds.

Candidate scenario expansion and robustness elements were selected based on three primary criteria: relevance to real-world crash causation, ability to challenge current system designs, and feasibility of repeatable execution within a consumer testing environment. This resulted in the so-called "Crash Avoidance Mega-Matrix", which provides a structured representation of the combined scenario space across parameter ranges and robustness dimensions.

***Figure 1: Working draft of the "Crash Avoidance Mega Matrix"***

| Crash Avoidance - Scenario overvi | | | | Robustness Scenarios | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | VUT | | | | Target | | | | | | Environment | | | |
| | | | | Longitudinal Speed [km/h] | Lateral Speed [m/s] | Impact location [%] | Driver input pre-crash | Type | Speed [km/h] | Acceleration [m/s^2] | Initial position offset | Trajectory/ Heading [°] | Appearance | AWC (Rain, Fog, Dirt/ice/moisture) | Illumination | Infrastructure / clutter | Obscuration / Obstruction |
| Frontal Collisions | Longitudinal | C2C | CCRs | – 50 (AEB)<br>– 80 (FCW) | - | -25 – -1, 0 – 24, 25 – 75, 76 – 100, 101 – 125 | Free steady state (Normal driving - no SR) | HGV | - | - | - | 0 – 20, 340–0 | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Railguard,<br>2) SUV aside of target | - |
| | | | CCRm | 30 – 130 | - | -25 – -1, 0 – 24, 25 – 75, 76 – 100, 101 – 125 | Free steady state (Normal driving - no SR) | Motorcycle, HGV | 20 – 70 | - | - | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Railguard,<br>2) SUV aside of target (moving) | - |
| | | | CCRb | 30 – 130 | - | -25 – -1, 0 – 24, 25 – 75, 76 – 100, 101 – 125 | Free steady state (Normal driving - no SR) | HGV | 30 – 130 | -6 – -2 | Headway :<br>0.50 – 0.80 [s]<br>0.85 – 3.00 [s] | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Railguard,<br>2) SUV aside of target | - |
| | | | CCFhos | 0, 81 – 100 | - | 25 – 75 | Free steady state (Normal driving - no SR) | Passenger car, Motorcyle | 30 – 80, 81 – 100 | - | - | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | | CCFhol | 30, 81 – 100 | - | 25 – 75 | Free steady state (Normal driving - no SR) | Passenger car, Motorcyle | 30 – 80, 81 – 100 | - | - | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | C2M | CMRs | – 50 (AEB)<br>– 80 (FCW) | - | 90 – 76, 75 – 25, 24 – 10 | Free steady state (Normal driving - no SR) | Motorcycle, Scooter | - | - | - | 0 – 20, 340–0 | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Railguard,<br>2) SUV aside of target<br>3) GVT in front of target | - |
| | | | CMRb | 30 – 130 | - | 90 – 76, 75 – 25, 24 – 10 | Free steady state (Normal driving - no SR) | Motorcycle, Scooter | 30 – 130 | -4 – -2 | Headway :<br>0.50 – 0.80 [s]<br>0.85 – 3.00 [s] | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Railguard,<br>2) SUV aside of target (moving) | - |
| | | C2P | CPLA | – 60 (AEB)<br>–80 (FCW) | - | 75 – 25, 24 – 10 | Free steady state (Normal driving - no SR) | Child | 5 – 8 | - | - | 180 (head-on) | e.g., Reflective; Dark clothing | ✓ | 2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | - | - |
| | | C2B | CBLA | 4, 25 – 60 (AEB)<br>–80 (FCW) | - | 75 – 25, 24 – 10 | Free steady state (Normal driving - no SR) | PSS | 10 – 14, 15 – 30 | - | - | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | Preceeding GVT in front of EBT (Moving) | - |
| | Turning | C2C | CCLTAP-OD | 0 – 20, 21 – 25 | - | 100 – 45 | No turning indicator | Passenger car, HGV | 30 – 60, 61 – 80 | - | +/- 0 – 0.5m lat. Offset | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | C2M | CMLTAP-OD | 10 – 20, 21 – 25 | - | 100 – 45, 46 – 0 | No turning indicator | Scooter | 30 – 60, 61 – 80 | - | +/- 0 – 0.5m lat. Offset | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | C2P | CPLTAP-SD<br>CPLTAP-OD<br>CPRTAP-SD<br>CPRTAP-OD | 20, 21 – 25 (Farside)<br>11 – 15 (Nearside) | - | 10 – 24, 25 – 75, 76 – 90 | No turning indicator | Child | 5, 6 – 8 | - | Pedestrian starts accelerating close(r) to VUT path | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare | Typical crossing scenery e.g., traffic sign, refuge, trash bin | - |
| | | C2B | CBL<br>CBL<br>CBF<br>CBR | 10 – 20, 21 – 25 (Farside)<br>10, 11 – 15 (Nearside) | - | 10 – 24, 25 – 75, 76 – 90 (OD)<br>0,100 [Front], 100 – 75 [Side] (SD) | No turning indicator | PSS | 10 – 15, 16 – 30 | - | Bicyclist starts accelerating close(r) to VUT path | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare | Typical crossing scenery e.g., traffic sign, refuge, trash bin | - |
| | Crossing | C2C | CCCscp | 0 – 60, 60 – 80 | - | 90 – 51, 50 – 25 (LD)<br>25 – 49, 50 – 75 (RD) | Free steady state (Normal driving - no SR) | Passenger car, HGV | 20 – 60, 61 – 80 | - | +/- 0 – 0.5m lat. Offset | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare | Typical crossing scenery e.g., traffic sign, stationary pedestrians on sidewalk, stationary (secondary) GVT on crossing road | - |
| | | C2M | CMCscp | 0 – 60, 60 – 80 | - | 90 – 100 [Front], 100 – 75 [Side] (LD)<br>0– 10 [Front], 100 – 75 [Side] (RD) | Free steady state (Normal driving - no SR) | Scooter | 20 – 60, 61 – 80 | - | +/- 0 – 0.5m lat. Offset | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare | Typical crossing scenery e.g., traffic sign, stationary pedestrians on sidewalk, stationary (secondary) GVT on crossing road | - |
| | | C2P | CPNA | 10 – 60 | - | 10 – 24, 25 – 75, 76 – 90 | Free steady state (Normal driving - no SR) | Child | 5, 6 – 8 | - | Pedestrian starts accelerating close(r) to VUT path | 250 – 290 | e.g., Reflective; Dark clothing | ✓ | 2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | Typical crossing scenery e.g., traffic sign, refuge, trash bin | Stationary pedestrian at the left side [1 - 1.5m] of the main crossing pedestrian |
| | | | CPFA | 10 – 60 | - | 90 – 51, 50 – 25, 24 – 10 | Free steady state (Normal driving - no SR) | Child | 5, 6 – 8 | - | - | 70 – 110 | e.g., Reflective; Dark clothing | ✓ | 2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Typical crossing scenery e.g., traffic sign, refuge, trash bin<br>2) Stationary SUV in adjacent lane | Stationary pedestrian at the right side [1 - 1.5m] of the main crossing pedestrian |
| | | | CPNCO | 10 – 60 | - | 25 – 49, 50 – 75 | Free steady state (Normal driving - no SR) | - | 5, 6 – 8 | - | Pedestrian starts accelerating close(r) to VUT path | 250 – 290 | e.g., Reflective; Dark clothing | ✓ | 2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Typical crossing scenery e.g., traffic sign, refuge, trash bin<br>2) Third obscuration vehicle: N2 Van/ Large SUV | Obstruction vehicle: N2 Van / Large SUV |
| | | C2B | CBNA | 10 – 60 | - | 25 – 49, 50 – 75 | Free steady state (Normal driving - no SR) | PSS | 10, 11 – 20 | - | Bicyclist starts accelerating close(r) to VUT path | 250 – 290 | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Typical crossing scenery e.g., traffic sign, refuge, trash bin<br>2) Replacing small obscuration vehicle for a N2 Van/ Large SUV | Stationary pedestrian at the left side [1 - 1.5m] of the crossing bicyclist |
| | | | CBFA | 10 – 60 | - | 90 – 51, 50 – 25, 24 – 10 | Free steady state (Normal driving - no SR) | PSS | 10, 11 – 20 | - | - | 70 – 110 | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Typical crossing scenery e.g., traffic sign, refuge, trash bin<br>2) Stationary SUV in adjacent lane | Stationary pedestrian at the right side [1 - 1.5m] of the crossing bicyclist |
| | | | CBNAO | 10 – 60 | - | 25 – 49, 50 – 75 | Free steady state (Normal driving - no SR) | PSS | 10, 11 – 20 | - | 1) Bicyclist starts accelerating close(r) to VUT path<br>2) Bicyclist path | 250 – 290 | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare OR Night time + glare of vehicle in adjacent lane (JNCAP) | 1) Typical crossing scenery e.g., traffic sign, refuge, trash bin<br>2) Replacing small obscuration vehicle for a N2 Van/ Large SUV | Updated CBNAO |
| Lane departure collisions | LKA & LDW | Single Vehicle | Driver Acceptance | 60 – 140 | 0.2 – 0.6 | - | - | - | - | - | - | - | S-Bend | - | - | - | - |
| | ELK | | Road Edge | 50–69, 70– 90 | 0.2 – 0.6 | - | - | - | - | - | - | - | Diverse road edges all other types of lane lines beyond road edge, including degraded lines, curvatures, color | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | C2C | Overtaking | 50 – 140 | 0.2 – 0.7 | 0 – 25, 26 – 50 | - | - | 60 – 150 | - | +/- 0 – 0.25m | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | | Oncoming | 50 – 100 | 0.2 – 0.6 | 100 –90, 89–50 | - | - | 50 – 100 | - | +/- 0 – 0.25m | - | e.g., Dark color | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | C2M | Overtaking | 50 – 140 | 0.2 – 0.7 | 0 – 25, 26 – 50 | - | Scooter | 60 – 150 | - | +/- 0 – 0.25m | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| | | | Oncoming | 50 – 100 | 0.2 – 0.6 | 120 –100 | - | Scooter | 50 – 100 | - | +/- 0 – 0.25m | - | e.g., Reflective; Dark clothing | ✓ | 1) Night time<br>2) Low sun glare | - | - |
| Low Speed Collisions | Crossing | C2C | CCCSCP-LD<br>CCCSCP-RD | 0 – 10 | - | 90 – 51, 50 – 25 (LD)<br>25 – 49, 50 – 75 (RD) | - | - | 20 – 80, 81 – 90 | - | - | - | - | - | - | - | - |
| | | C2M | CMCSCP-LD<br>CMCSCP-RD | 0 – 10 | - | 90 – 100 [Front], 100 – 75 [Side] (LD)<br>0– 10 [Front], 100 – 75 [Side] (RD) | - | - | 20 – 80, 81 – 90 | - | - | - | - | - | - | - | - |
| | | C2P | CPNA | 0 – 10 | - | 25 – 50 | - | - | 5, 6 – 8 | - | - | - | - | - | - | - | - |
| | | C2B | CBNAO | 0 – 10 | - | 25 – 50 | - | - | 10 – 15, 16 – 20 | - | - | - | - | - | - | - | - |
| | Turning | C2M | CMLTAP-OD | 0 – 10 | - | 100 – 45, 46 – 0 | - | Passenger Car | 20 – 80, 81 – 90 | - | - | - | - | - | - | - | - |
| | Manoeuvring | C2P | CPMRA<br>CPMRC | 0 – 8 | - | 10 – 24, 25 – 75, 76 – 90 | - | - | 0,5, 6 – 8 | - | - | - | - | - | - | - | - |
| | | | CPMFC | Pedal application at:<br>1) Max. Creeping speed<br>2) [1]s. after releasing brake pedal | - | 25 – 75 | - | - | 0 | - | - | - | - | - | - | - | - |
| | Dooring | C2B | CBDA | - | - | - | - | - | 10 – 15, 16 – 20 | - | - | - | - | - | - | - | Rear gap:<br>0.5 – 1.4,1.5 – 2.0 m ±0.05m |

**Dual Expansion of the Test Envelope**

Robustness is implemented in the 2026 protocols through a dual expansion of the assessment envelope, combining parameter range expansion with the introduction of Robustness Layers.

## Expansion of Scenario Parameter Ranges

For each assessed crash avoidance scenario, the allowable parameter space is expanded beyond previous nominal values. This includes, where applicable, variations in own vehicle and/or target speed, impact location, lateral offset, and related parameters. These expanded ranges reflect the natural variability observed in real traffic interactions and reduce the incentive for system optimization toward narrowly defined test points. The expansion has been organized in two clusters: Standard Range, representing the foundational level of performance requirements; and Extended Range, representing more challenging situations, such as higher speeds and/or small overlap.

One example illustrating this expansion is the Car-to-Car Rear Braking (CCRb) scenario. Previously, CCRb included only a single speed combination at one impact location under two following distances and two lead vehicle decelerations, resulting in four test cases. The updated CCRb assessment includes eleven speed combinations and seven impact locations as part of the Standard and Extended Range definitions. These can further be populated with multiple Robustness Layers, including variations in time headway and lead vehicle deceleration profiles.

*Figure 02: CCRb scenario showing Standard and Extended Range test cases*

| CCRb | GVT speed | Function | Impact Location | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 125% | 100% | 75% | 50% | 25% | 0% | -25% |
| 30 km/h | 30 km/h | AEB | ░ | ▓ | ▓ | ▓ | ▓ | ▓ | ░ |
| 40 km/h | 40 km/h | AEB | ░ | ▓ | ▓ | ▓ | ▓ | ▓ | ░ |
| 50 km/h | 50 km/h | AEB | ░ | ▓ | ▓ | ▓ | ▓ | ▓ | ░ |
| 60 km/h | 60 km/h | AEB | ░ | ▓ | ▓ | ▓ | ▓ | ▓ | ░ |
| 70 km/h | 70 km/h | AEB | ░ | ▓ | ▓ | ▓ | ▓ | ▓ | ░ |
| 80 km/h | 80 km/h | AEB | ░ | ▓ | ▓ | ▓ | ▓ | ▓ | ░ |
| 90 km/h | 90 km/h | AEB | ░ | ░ | ░ | ░ | ░ | ░ | ░ |
| 100 km/h | 100 km/h | AEB | ░ | ░ | ░ | ░ | ░ | ░ | ░ |
| 110 km/h | 110 km/h | AEB | ░ | ░ | ░ | ░ | ░ | ░ | ░ |
| 120 km/h | 120 km/h | AEB | ░ | ░ | ░ | ░ | ░ | ░ | ░ |
| 130 km/h | 130 km/h | AEB | ░ | ░ | ░ | ░ | ░ | ░ | ░ |

| | |
|---|---|
| ▓ | Standard Range |
| ░ | Extended Range |

Although scenario expansion represents a substantial increase in the overall assessment envelope, its implementation remains within predefined bounds and controlled cases. This ensures that, across vehicles, test outcomes reflect comparable system performance rather than random variation.

## Introduction of Robustness Layers

In addition to the expansion of scenario parameter ranges, the 2026 Crash Avoidance protocols introduce a set of structured Robustness Layers that add controlled variability to otherwise standardised test configurations. These layers are intended to probe the stability and predictability of system behaviour when exposed to realistic deviations from nominal conditions, without fundamentally altering the underlying crash scenario.

Robustness Layers are organised into two clusters: Decision & Control layers and Perception layers. Their implementation follows different assessment and verification approaches, reflecting both technical feasibility and the nature of the performance aspects being evaluated.

For Decision & Control Robustness Layers, Vehicle Manufacturers are required to provide performance predictions for the applicable scenarios, using virtual testing, self-claimed performance, or other approved prediction methods. Euro NCAP then verifies these predictions through randomly selected verification tests conducted within the Standard Range. For each scenario, a single robustness layer is randomly selected and applied consistently across the verification tests for that scenario. Performance with the robustness layer present must be equal to or better than the predicted outcome, assessed against the closest applicable Standard Range grid cell. If a verification test with the robustness layer results in a performance downgrade relative to the prediction, the layer is considered failed for that scenario and subsequent verification tests are conducted without the layer present.

The eligibility of Robustness Layers for scoring is subject to minimum baseline performance requirements. In particular, robustness scoring is only applied to scenarios that achieve at least 50 % of the total available score in the Standard Range, ensuring that robustness does not compensate for insufficient baseline system capability. The same fundamental outcome metrics used in baseline assessments – such as collision avoidance, impact speed reduction, and warning timing – are retained under robustness conditions, preserving consistency across the assessment framework.

Perception Robustness Layers are primarily assessed through Vehicle Manufacturer in-house evidence rather than systematic track testing. For these layers, manufacturers must demonstrate function availability and/or performance under the presence of relevant environmental, infrastructural, or target-related variations using real-world data. This evidence is reported in accordance with Technical Bulletin CA 003, which defines the required documentation of datasets, methodologies, and environmental coverage used to support the claimed performance. Some degree of performance degradation under challenging perception conditions is acceptable; however, the function is expected to remain available and operational.

***Table 1: Decision & Control Robustness Layers***

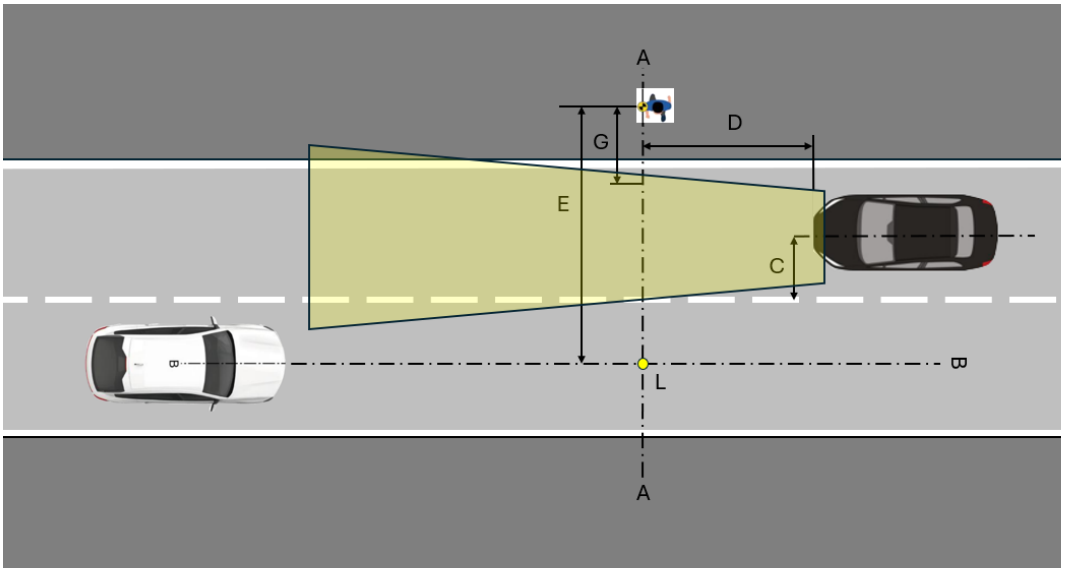
| **Robustness Layers (Decision & Control)** | | **Description** | **Verification Test** | **Performance prediction source** |
|---|---|---|---|---|
| **Type** | **Layer** | | | |
| VUT | Driver input pre-crash | Normal driving without steering robot and/or speed control function | Yes | OEM information on system overriding conditions |
| Target | Speed | Small variance in the nominal target speed | Yes | Virtual Testing or Self-claimed |
| | Acceleration | Small variance in the nominal target acceleration | Yes | |
| | Initial position offset | Small variance in the nominal target initial position | Yes | |
| | Trajectory/ Heading | Small variance in the nominal target heading | Yes | |

*Table 2: Perception Robustness Layers*

| **Robustness Layers (Perception)** | | **Description** | **Verification Test** | **Performance prediction source** |
|---|---|---|---|---|
| **Type** | **Layer** | | | |
| Target | Type | Different collision partner type (e.g.,<br>Car: Vehicle Cat.: N1, N2, N3<br>PTW: Vehicle Cat.: L1, Bicyclist: Powered Standing Scooter) | No | Field Data** |
| | Appearance | Same collision partner type but with different appearance (e.g., color, accessories, shape) | | |
| Environment | Adverse weather conditions | Functionality available under the presence of Rain, Fog, Dirt/ice/moisture | | |
| | Illumination (Night time) | Performance in darkness (1 lux) for all daytime-only scenarios. Target shall be equipped with realistic lighting. | Verification test may be conducted under request of Euro NCAP Secretariat | |
| | Illumination (Sun glare) | Functionality available under the presence of glare caused by Low sun (all scenarios during daytime condition) | No | |
| | Illumination (Headlamp glare) | Performance under the presence of glare caused by headlamps of a stationary vehicle on adjacent lane (all standard nighttime scenarios) | Verification test may be conducted under request of Euro NCAP Secretariat | |
| | Infrastructure / clutter | Performance in environments cluttered with objects such as urban furniture or secondary road users (without fully obscuring the main target) | | |
| | Obscuration / Obstruction | Variance in the layout of nominal obstructions | | |

While most Perception Robustness Layers are not routinely verified on the test track, certain layers – such as infrastructure and background clutter or obstruction and obscuration effects – are technically feasible to assess under controlled and repeatable conditions. In such cases, small and well-defined variations may be introduced, for example through modified layouts of obscuring vehicles in crossing scenarios or the inclusion of road furniture partially obscuring vulnerable road users. For the 2026 rating cycle, Euro NCAP continues to rely primarily on Vehicle Manufacturer evidence for these layers, but reserves the right to request targeted track verification where deemed necessary to ensure consistency between declared and observed system behaviour.

*Figure 3: Test setup to verify performance in CPFA scenario against Illuminatio Headlamp glare Robustness Layer*



## Test Execution and Repeatability Considerations

Introducing variability into consumer testing requires stricter control of test execution and validation processes. For the 2026 protocols, Decision & Control Robustness Layers are defined using precise boundary conditions and tolerances to ensure repeatability across vehicles and test laboratories.

While many of the Perception Robustness Layers are not assessed directly on the test track, but rather through vehicle manufacturer in-house data demonstrating system performance under the presence of these layers (for example, illumination effects such as sun glare), certain perception-related aspects are technically feasible to assess under controlled track conditions. These include, in particular, infrastructure and background clutter as well as obscuration or obstruction effects, where small and well-defined variations can be introduced while preserving test repeatability.

Examples include variations in the layout and positioning of obscuring vehicles in crossing scenarios, such as Car-to-Pedestrian Nearside Obstructed (CPNCO), or the inclusion of road furniture and other static elements that partially obscure pedestrians or cyclists in crossing configurations. These controlled modifications allow the influence of visual complexity on system perception to be evaluated without introducing uncontrolled environmental variability.

For the 2026 rating cycle, Euro NCAP will rely primarily on vehicle manufacturer evidence for these perception Robustness Layers. However, Euro NCAP reserves the right to verify system performance on the test track where feasible and deemed necessary, ensuring consistency between declared and observed behaviour. This approach maintains flexibility in assessment while preserving the objectivity and robustness required within a consumer testing framework.

## RESULTS

### General Observations Across Crash Avoidance Stage Elements

During the research phase of the introduction of robustness across a number of baseline Crash Avoidance scenarios, performance effects were observed outside of the nominal test conditions. In general, systems that performed well under baseline scenarios continued to do so when exposed to moderate parameter expansion, but performance degradation became evident once scenarios transitioned into more time-critical configurations or when additional variability was introduced through Robustness Layers.

These findings confirm that peak performance under idealised test conditions does not necessarily imply consistent system behaviour across realistic variations, and that robustness is a relevant discriminator between systems optimised for specific test points and those designed for broader real-world applicability.

### Frontal Collisions

#### Effect of Scenario Parameter Expansion

When considering scenario parameter expansion alone (i.e. Standard Range and Extended Range), most systems demonstrated stable performance until scenarios became significantly more time-critical. Performance degradation was primarily observed in configurations involving reduced time-to-collision, such as more extreme impact locations in crossing scenarios (e.g. near-side obscured pedestrian configurations with an impact scheduled at 25% of the vehicle width).

Research conducted by Euro NCAP revealed that these effects were particularly evident when the required sensing and decision time was shortened, highlighting sensitivity to late object detection and delayed intervention timing rather than system availability. More details about the performance impact of parameter variation and Robustness Layers in pedestrian crossing scenarios can be found in the paper 026-256 [5]

#### Effect of Robustness Layers

The introduction of Robustness Layers also revealed performance degradation beyond parameter expansion alone. In general, Decision & Control Robustness Layers more frequently resulted in greater performance impact than Perception Robustness Layers, particularly when variations affected target speed, target trajectory/heading, or target initial positioning [5].

However, Euro NCAP research demonstrated that certain perception-related variations could also be critical for some vehicles, even when applied to otherwise simple baseline scenarios . Examples included:

- changes in object layout in straightforward crossing scenarios (e.g. parked vehicle on the nearside in Car-to-Bicyclist Farside scenario);
- the introduction of minor roadside clutter, such as traffic cones along the vehicle’s path;
- partial obscuration of pedestrians by static objects or vehicles.

In these cases, some systems exhibited large reductions in intervention performance, despite maintaining high scores under baseline configurations. The research also showed that small variations in target orientation or a changed layout configuration could result in disproportionately large performance changes for certain vehicles.

A consolidated qualitative overview of the robustness research results is provided in *Table 3*. It should be noted that this work represents early robustness research, and that not all configurations investigated during this phase were ultimately implemented in the 2026 protocols, following feasibility, repeatability, and relevance considerations.

***Table 3: Qualitative overview of robustness research variations and observed performance impact***

| **Scenario** | **Variation** | **Variation type** | **Performance degradation across runs** | | | |
|---|---|---|---|---|---|---|
| | | | 🟩 | Impacted 0% of runs | | |
| | | | 🟨 | Impacted <50% of runs | | |
| | | | 🟧 | Impacted >50% of runs | | |
| | | | 🟥 | Impacted 100% of runs | | |
| | | | **Veh A** | **Veh B** | **Veh C** | **Veh D** |
| **CPFA Baseline** | Baseline CPFA (as per VRU protocol) | Baseline | 🟩 | 🟩 | 🟩 | 🟩 |
| **CPFA Speedbump (full)** | Speed bump full overlap | Perception – road/infrastructure | 🟩 | 🟩 | 🟨 | 🟧 |
| **CPFA Speedbump (half)** | Speed bump half overlap | Perception – road/infrastructure | 🟩 | 🟩 | 🟨 | 🟩 |
| **CPFA Parked Car Nearside** | Parked car nearside (no obstruction vehicle) | Perception – clutter/vehicle presence | 🟩 | 🟩 | 🟨 | 🟩 |
| **CPFA Roadside Object** | Roadside object placed near pedestrian approach path | Perception – clutter | 🟩 | 🟩 | 🟨 | 🟨 |
| **CPFA Roadside Cones** | Cones / misleading road marking layout | Perception – clutter/layout | 🟥 | 🟩 | 🟩 | 🟩 |
| **CPFA Stopped Car Opposite Direction** | Stopped vehicle in opposite direction | Perception – clutter/other traffic | 🟨 | 🟩 | 🟥 | 🟩 |
| **CPFA High-vis jacket** | Pedestrian clothing changed to high-visibility | Perception – target appearance | 🟨 | 🟩 | 🟨 | 🟩 |
| **CPFA Dark dress** | Pedestrian clothing changed to a dark dress | Perception – target appearance | 🟨 | 🟨 | 🟨 | 🟩 |
| **CPFA Stopped legs** | Pedestrian posture/gait modified ("stopped legs") | Perception/behaviour | 🟨 | 🟩 | 🟨 | 🟩 |
| **CPFA Couple** | Two pedestrians ("family/couple") | Perception – target composition | 🟩 | 🟨 | 🟥 | 🟨 |
| **CPFA Jogging on** | Pedestrian "jogging on the | Perception/behaviour | 🟨 | 🟩 | 🟨 | 🟩 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **the spot** | spot" configuration | | 🟨 | 🟩 | 🟨 | 🟩 |
| **CPFA Static cyclist obscuration** | Cyclist placed to partially obscure pedestrian | Perception – obstruction | 🟧 | 🟧 | 🟥 | 🟧 |
| **CPFA Sine wave steer (low amp)** | Low amplitude sine-wave steering input (≈0.2 m path offset) | Decision & Control – steer input | 🟧 | 🟩 | 🟧 | 🟩 |
| **CPFA Sine wave steer (medium amp)** | Medium amplitude sine-wave steering input (≈0.4 m path offset) | Decision & Control – steer input | 🟧 | 🟨 | 🟧 | 🟨 |
| **CCRS 100% overlap baseline** | CCRS baseline (100% overlap) | Baseline | 🟩 | 🟩 | 🟩 | 🟩 |
| **CCRS Road & Infrastructure (set)** | Speed bump full + half + parked car nearside + roadside object + cones | Perception – road/infrastructure & clutter | 🟩 | 🟩 | 🟩 | 🟩 |
| **CCRS Objects (set)** | Static cyclist on left + jogger on the spot | Perception – objects | 🟩 | 🟨 | 🟩 | 🟩 |
| **CCRS 180° GVT** | Target (GVT) rotated 180° towards VUT | Perception – target orientation | 🟩 | 🟥 | 🟩 | 🟩 |
| **CCRS 45° GVT** | GVT rotated 45° (incl. point-of-rotation differences ISO vs NCAP) | Perception – target orientation/geometry | 🟧 | 🟥 | 🟥 | 🟨 |
| **CCRS 135° GVT** | GVT rotated 135° (incl. point-of-rotation differences) | Perception – target orientation/geometry | 🟨 | 🟥 | 🟥 | 🟨 |
| **CCRS Sine wave steer (low & med)** | Sine-wave steer inputs (low & medium) | Decision & Control – steer input | 🟨 | 🟨 | 🟩 | 🟩 |

Overall, these findings provided clear evidence that Robustness Layers can expose sensitivities in both perception and control variations that are not captured by expanded parameter ranges alone. Further research was later conducted to understand the implications of the Robustness Layers in the perception capabilities of vehicle sensors, see paper 26-169 [6].

### Lane Departure Collisions

Early robustness investigations for Lane Departure Collisions indicated generally stable system behaviour under moderate scenario variations. Most systems demonstrated consistent lane-keeping or lane-departure mitigation performance when exposed to small deviations in vehicle trajectory or lane geometry.

The most significant performance degradation was observed when varying the impact location of the target vehicle in Emergency Lane Keeping (ELK) oncoming and overtaking scenarios, particularly for oncoming configurations. In these cases, moving the impact location effectively required the system to detect and classify the target vehicle at a greater distance and earlier point in time, increasing reliance on long-range perception and prediction.

To mitigate unintended over-sensitivity and preserve scenario criticality, the variability in impact location was bounded such that the time-to-collision at lane crossing remained below a threshold of 3 seconds. This ensured that interventions were still triggered under sufficiently critical conditions, while avoiding unrealistic early detection requirements.

The influence of perception Robustness Layers in Lane Departure Collisions—such as variations in lane markings, target appearance, or night-time operation—could not be systematically quantified during the development phase. Experience from official Euro NCAP testing from 2026 onwards is therefore expected to provide further evidence regarding system sensitivity in these areas.

### Low Speed Collisions

For Low Speed Collisions, the application of scenario parameter expansion alone already revealed meaningful performance effects. In particular, start-from-stop (SfS) car-to-car and car-to-motorcyclist turning and crossing scenarios became challenging when target speeds were increased and available sensing and reaction time was reduced.

Similarly, in cyclist dooring scenarios, certain parameter combinations were identified as edge cases. These included configurations where:

- the rear-corner radar used to detect a passing cyclist was partially obscured by a nearby parked vehicle positioned closer to the vehicle under test; and/or
- the scenario became highly time-critical, requiring very low system latency to trigger a warning or door-locking mechanism in time.

Limited exploratory testing of robustness-related variations was conducted for Euro NCAP in the Low Speed Collisions domain, notably in start-from-stop car-to-car crossing scenarios. Variations included changes in the initial distance to the collision point and modifications of target acceleration profiles. While the tested vehicle performed well under these conditions, the results were not considered representative of broader fleet performance.

Perception Robustness Layers—such as variations in scenery or reduced illumination—are expected to influence system behaviour in Low Speed Collisions based on accident data and system design considerations. However, these layers were postponed to the planned 2029 protocol update to allow for a gradual introduction of the robustness approach.

## DISCUSSION

### Observations from current systems

The results presented in this paper illustrate that current crash avoidance systems can exhibit different behaviour when exposed to small, structured variations around nominal test conditions. While strong performance under baseline scenarios remains important, robustness testing shows that this alone is insufficient to characterise how systems behave across the diversity of real-world traffic interactions.

The observed performance degradation under Robustness Layers does not necessarily indicate a lack of safety functionality. Some level of degradation is to be expected as scenarios become more demanding. However, the results demonstrate that unpredictable or inconsistent system behaviour – where minor and realistic variations result in disproportionate changes in intervention outcome – remains a key concern. From a consumer perspective, such unpredictability undermines trust and may reduce the effectiveness of advanced driver assistance systems in everyday use.

The robustness concept therefore shifts the assessment focus away from isolated peak performance and towards consistency of behaviour across a defined operational envelope. This distinction is critical for consumer information, as real-world safety benefit depends not only on whether a system can perform well in idealised conditions, but on whether it does so reliably across the variability inherent in real traffic.

### Robustness as a necessary evolution for safety assessment

Euro NCAP's role has always been to provide consumers with meaningful, independent information on vehicle safety performance, and to incentivise manufacturers to develop systems that deliver real-world benefits. The findings presented here support that idealised, fixed-point testing alone is no longer sufficient to fulfil this role for crash avoidance technologies.

Evidence collected during protocol development confirmed that systems can be optimised to perform well within a narrowly defined assessment envelope, without necessarily delivering equivalent robustness outside of it. Such optimisation runs counter to the societal benefit expected from advanced safety systems and risks overstating real-world effectiveness if not addressed explicitly in consumer ratings.

By introducing robustness, Euro NCAP acknowledges and incorporates real-world uncertainty into the assessment process. The objective is not to penalise systems for every performance limitation, but to ensure that ratings reflect how systems behave when confronted with realistic variations that consumers are likely to encounter.

### Interpretation of decision & control and perception layers

The robustness research highlighted trends indicating that variations affecting decision-making and control logic frequently led to performance degradation, while certain perception-related variations were critical for specific vehicles. However, it is still early to draw strong conclusions about the relative importance of perception versus decision and control layers.

From a consumer testing perspective, distinguishing whether degradation originates from perception, system tuning, arbitration logic, or other internal design choices is of limited value. Modern driver assistance systems are increasingly complex, with tightly coupled components and, in the future, the anticipated introduction of non-deterministic AI not only in perception but also in decision and control. In such systems, attributing performance outcomes to individual modules may become increasingly difficult and less meaningful.

Euro NCAP therefore remains sensor-agnostic and scenario-based, focusing on observable system behaviour rather than internal implementation. Over the coming years, large-scale testing under the 2026 protocols – with more than 120 vehicles assessed in 2025 alone – should provide the statistical basis needed to better understand performance trends across the fleet, should such analysis be deemed beneficial.

### Rationale for step-wise implementation and feasibility considerations

The phased introduction of robustness between 2026 and 2029 reflects a deliberate balance between ambition, feasibility, and repeatability. While early research explored a broad range of robustness variations, only a subset could be implemented in the 2026 protocols in a manner consistent with the requirements of consumer testing: controlled execution, repeatability across laboratories, and proportional test burden.

Introducing robustness inevitably increases assessment complexity. Without careful design, this could lead to excessive testing requirements, reduced reproducibility, or ambiguity in result interpretation. The 2026 implementation therefore prioritises robustness elements that can be applied in a structured and controlled manner, while allowing experience to be gained before further expansion.

This phased approach also provides industry with a clear and predictable roadmap. Manufacturers are incentivised to improve system consistency without being confronted with an unmanageable increase in test complexity, while Euro NCAP retains the flexibility to refine and extend the framework based on accumulated evidence.

### Robustness, regulation, and the future of safety assessment

Euro NCAP has historically assessed crash avoidance performance over a much broader envelope than regulatory requirements, and the introduction of robustness continues this trend beyond GSR2 homologation mandates. At the moment, robustness lies largely outside the scope of regulation, which remains predominantly rules-based and focused on minimum performance thresholds. In this respect, Euro NCAP currently complements regulation by addressing aspects of system behaviour that are critical for real-world safety.

Looking ahead, both consumer testing organisations and regulators face a common challenge. As vehicle systems increasingly incorporate adaptive and non-deterministic AI, fixed-point, rules-based testing may become insufficient to characterise safety performance. Performance may vary over time, across environments, or as a result of continuous learning and updates.

In this context, robustness represents an intermediate step towards more comprehensive assessment methodologies. For future protocol cycles, including 2029 and beyond, Euro NCAP aims to evolve from isolated test points towards parameter-range-based assessment, where declared performance envelopes – such as speed ranges, impact locations, or heading angles – are evaluated across large combinatorial spaces. These spaces can then be further enriched through the addition of environmental variability, such as illumination or weather effects, while ensuring that resulting scenarios remain realistic and representative of real-world crash causation.

Such an evolution is complex and future assessments will likely require increased use of complementary methods, including real-world testing, simulation and synthetic environments. In this context, there is an opportunity to learn from the validation methods developed by the autonomous driving community and to apply relevant insights to both consumer testing and regulatory assessment.

### Outlook

The introduction of robustness in the Euro NCAP 2026 Crash Avoidance assessment marks a fundamental shift in how active safety performance is evaluated and communicated. While the current implementation represents only a first step, it establishes a clear direction towards assessing consistency and reliability under real-world variability.

Ultimately, robustness is not an end in itself, but a means to ensure that consumer ratings continue to reflect meaningful safety performance as vehicle systems evolve. The experience gained during the 2026–2028 rating cycles will be instrumental in shaping future assessment methods capable of addressing increasing system complexity while maintaining transparency, credibility, and consumer relevance.

## LIMITATIONS

The robustness framework introduced in the Euro NCAP 2026 Crash Avoidance assessment does not aim to exhaustively cover all possible real-world crash configurations. The assessment remains scenario-based and bounded by predefined parameter ranges and robustness layers. While these variations are selected to be representative of relevant real-world variability, they inevitably capture only a subset of operational complexity. Robustness should therefore be understood as an indicator of performance consistency within a defined envelope, rather than a guarantee of behaviour under all conditions.

The selection and implementation of robustness layers are constrained by feasibility and repeatability requirements inherent to consumer testing. Not all variations explored during early research phases could be translated into formal protocol requirements for 2026. Certain perception-related factors cannot yet be assessed reliably and at scale through physical testing alone, and complementary evidence from vehicle manufacturer in-house data or alternative methods may be required.

Early robustness research was exploratory and qualitative, and broader conclusions regarding fleet-wide performance trends will depend on experience gained from large-scale testing under the 2026 protocols. The robustness framework also increases assessment complexity and test burden, and trade-offs remain between assessment depth, repeatability, and practical feasibility.

In addition, in the 2026 assessment, robustness layers represent a limited proportion of the total available score within the relevant Crash Avoidance stage elements. With robustness layers accounting for approximately 10 % of the stage-element score, it remains possible for a vehicle to achieve moderate to good overall rating through strong performance in baseline scenarios while exhibiting limited robustness under variability. This is a recognised outcome of the stepwise implementation strategy adopted for 2026. Future protocol cycles are expected to increase the relative weight attributed to robustness, further strengthening the incentive for consistent system performance across a broader operating envelope.

Finally, the assessment of certain Perception robustness layers relies to a significant extent on vehicle manufacturer in-house evidence. While Euro NCAP remains impartial and results-driven, this reliance implies that the programme is not fully independent for these aspects of the assessment. Euro NCAP is aware of this limitation and considers it a transitional measure driven by current technical and feasibility constraints. Ongoing work is aimed at identifying alternative or complementary assessment approaches that reduce dependency on manufacturer-provided data over time, while preserving assessment credibility, transparency, and rigor.

## CONCLUSIONS

This paper presented the rationale, development, and initial implementation of a robustness framework within the Euro NCAP 2026 Crash Avoidance assessment. The framework was introduced to address a fundamental limitation of traditional scenario-based testing: strong performance under nominal, idealised conditions does not necessarily imply consistent behaviour under realistic variability.

Early robustness research demonstrated that small and structured variations around baseline scenarios can lead to substantial changes in system behaviour for some vehicles. These findings confirmed that idealised testing alone is no longer sufficient to characterise the real-world effectiveness of modern crash avoidance systems, and that robustness is a meaningful discriminator for consumer information.

The robustness concept introduced in 2026 shifts the assessment focus from isolated peak performance towards consistency across a defined operational envelope. Rather than attempting to enumerate all possible crash configurations, the framework evaluates whether systems maintain reliable behaviour when exposed to controlled and representative variations. This approach aligns with Euro NCAP's consumer-oriented mission, recognising that some performance degradation is acceptable, but unpredictability is not.

The phased implementation strategy adopted for 2026 reflects a deliberate balance between ambition, feasibility, and repeatability. While early research explored a wide range of robustness variations, only those that could be applied in a controlled and reproducible manner were introduced in the first protocol cycle. Experience gained from large-scale testing under the 2026 protocols will be critical in informing future expansions.

Looking ahead, robustness represents an important step towards more comprehensive assessment methods capable of addressing increasing system complexity, including adaptive and non-deterministic AI-based technologies. Future protocol cycles, including the planned 2029 update, are expected to further evolve the framework towards parameter-range-based assessment and expanded use of complementary methods, such as simulation, while maintaining the transparency and credibility required for consumer ratings.

In summary, the introduction of robustness in the Euro NCAP 2026 Crash Avoidance assessment establishes a new foundation for evaluating active safety performance under real-world uncertainty. While not exhaustive, it provides a more realistic and informative basis for consumer decision-making and sets a clear direction for the future evolution of crash avoidance testing.

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