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EUROPEAN NEW CAR ASSESSMENT PROGRAMME
(Euro NCAP)

ASSESSMENT PROTOCOL – PEDESTRIAN PROTECTION

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1 INTRODUCTION

Important changes have been made to the Euro NCAP ratings resulting in the introduction of the overall rating scheme. Individual documents are released for the four main areas of assessment:

- Assessment Protocol – Adult Occupant Protection.
- Assessment Protocol – Child Occupant Protection.
- Assessment Protocol – Pedestrian Protection.
- Assessment Protocol – Safety Assist.

In addition to these four assessment protocols, a separate document is provided describing the method and criteria by which the overall safety rating is calculated on the basis of the car performance in each of the above areas of assessment.

The following protocol deals with the assessments made in the area of Pedestrian Protection, in particular in the adult and child head, the upper leg form, lower leg form impacts and AEB VRU.

2 METHOD OF ASSESSMENT

The assessment of pedestrian protection is made with the use of headform, upper legform, lower legform impact and AEB test data. In the legform areas, the bumper and front of the bonnet of the car will be marked with a grid and are assessed using the two legform impactors. Euro NCAP will test "worst case" grid points and manufacturers may nominate additional tests to be performed and the results will be included in the assessment.

In the headform impact area, a grid will be marked on the outer surface of the vehicle. The vehicle manufacturer is required to provide the Euro NCAP Secretariat with data detailing the protection offered by the vehicle at all grid locations. The data shall be provided to the Euro NCAP Secretariat before any test preparation begins. The predicted level of protection offered by the vehicle is verified by Euro NCAP by means of testing of a sample of randomly selected grid-points and the overall prediction is corrected accordingly.

For AEB testing, the vehicle manufacturer is also required to provide the Euro NCAP with data detailing the expected performance of the AEB VRU system for all four of the test scenarios. The expected performance will be used to as a reference to identify discrepancies between the expected results and the test results.

2.1 Points Calculation

For the legform impact areas, a sliding scale system of points scoring has been used to calculate points for each measured criterion. This involves two limits for each parameter, a more demanding limit (higher performance), below which a maximum score is obtained and a less demanding limit (lower performance), beyond which no points are scored. Where a value falls between the two limits, the score is calculated by linear interpolation. No capping is applied to any of the measurements. The maximum score for each grid point is one point for bumper and bonnet leading ledge tests. The total score will then be scaled to a maximum of six points for each impactor.

For the headform impact area, the protection predicted by the vehicle manufacturer will be compared to the outcome of the randomly selected test locations. The results at those test locations will be used to generate a correction factor, which will then be applied to the predicted score. Only data that results in a correction factor of between 0.750 and 1.250 are accepted. Where this is not the case, the cause will be investigated and the Secretariat will subsequently take a decision as to how to proceed. Where the data are accepted, the headform score will be based on the predicted data score with correction applied.

For AEB, a sliding scale based on the speed reduction is applied for test speeds up to 40 km/h/. Higher test speeds are assessed as pass/fail only.

PART I

PEDESTRIAN IMPACT ASSESSMENT

1 PEDESTRIAN IMPACT ASSESSMENT

1.1 Criteria and Limit Values

The assessment criteria used for the pedestrian impact tests, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual test, the lowest scoring parameter is used to determine the performance of that test, unless indicated otherwise.

1.1.1 Headform

The manufacturer must provide predicted data for all grid points. This data shall be expressed as a colour according to the corresponding colour boundaries for the predicted HIC_{15} performance below. Alternatively, HIC_{15} values may be provided.

Green	HIC_{15}	< 650
Yellow	$650 \le HIC_{15}$	< 1000
Orange	$1000 \le HIC_{15}$	< 1350
Brown	$1350 \le HIC_{15}$	< 1700
Red	$1700 \le HIC_{15}$	

The manufacturer is allowed to colour a limited number of grid points blue where the performance is unpredictable. These grid points will always be tested. The procedure is detailed in the Pedestrian Protection Test protocol.

1.1.2 Upper Legform

Higher performance limit

Bending Moment	285Nm
Sum of forces	5.0kN

Lower performance limit

Bending Moment	350Nm
Sum of forces	6.0kN

1.1.3 Legform

Higher performance limit

Tibia Bending Moment	282Nm
MCL Elongation	19mm
ACL/PCL Elongation	10mm

Lower performance limit

Tibia Bending Moment	340Nm
MCL Elongation	22mm
ACL/PCL Elongation	10mm

1.2 Modifiers

There are no modifiers applied.

1.3 Scoring & Visualisation

1.3.1 Scoring

A maximum of 24 points is available for the headform test zone. The total score for all grid points is calculated as a percentage of the maximum achievable score, which is then multiplied by 24 points. The bonnet leading edge and bumper test zone will be awarded a maximum of 6 points each. A total of 36 points are available in the pedestrian protection assessment.

1.3.1.1 Headform

Each of the grid points can be awarded up to one point, resulting in a maximum total amount of points equal to the number of grid points. For each predicted colour the following points are awarded to the grid point:

$HIC_{15} < 650$	*1.00 point*
$650 \leq HIC_{15} < 1000$	*0.75 points*
$1000 \leq HIC_{15} < 1350$	*0.50 points*
$1350 \leq HIC_{15} < 1700$	*0.25 points*
$1700 \leq HIC_{15}$	*0.00 points*

1.3.2 Headform Correction factor

The data provided by the manufacturer is scaled using a correction factor, which is calculated based on a number of verification tests performed. The verification points are randomly selected grid points, distributed in line with the predicted colour distribution.

The actual tested total score of the verification test points is divided by the predicted total score of these verification test points. This is called the correction factor, which can be lower or higher than 1.

$$Correction\ Factor = \frac{Actual\ tested\ score}{Predicted\ score}$$

The correction factor is multiplied to all the grid points (excluding defaulted and blue points). The final score for the vehicle can never exceed 100% regardless of the correction factor.

1.3.2.1 HIC tolerance

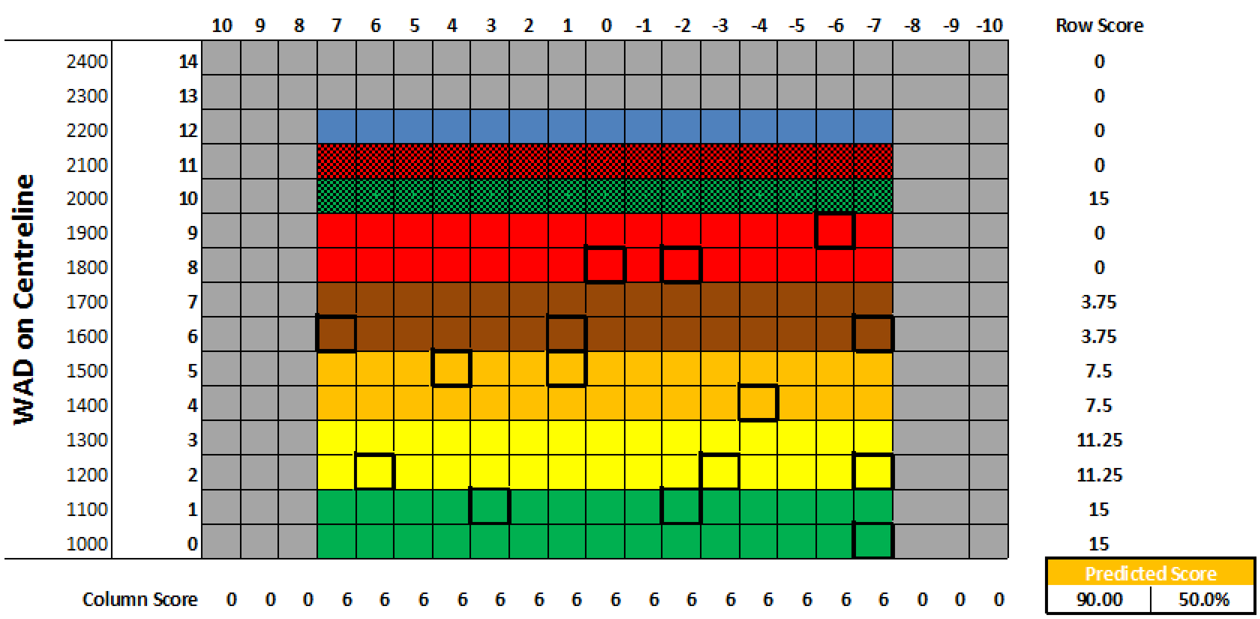
As test results can be variable between labs and in-house tests and/or simulations a 10% tolerance to the HIC value of the verification test is applied. The tolerance is applied in both directions, meaning that when a tested point scores better than predicted, but within tolerance, the predicted result is applied. The tolerance only applies to verify whether the predicted colour of the tested verification point is correct. When, including tolerance, the colour is not in line with the prediction, the true colour of the test point will be determined by comparing the actual measured HIC value with the colour band in section 1.3.1.1 without applying a tolerance to the HIC value.

Prediction	***HIC_{15} range***	***Accepted HIC_{15} range***
Green	$HIC_{15} < 650$	$HIC_{15} < 722.22$
Yellow	$650 \leq HIC_{15} < 1000$	$590.91 \leq HIC_{15} < 1111.11$
Orange	$1000 \leq HIC_{15} < 1350$	$909.09 \leq HIC_{15} < 1500.00$
Brown	$1350 \leq HIC_{15} < 1700$	$1227.27 \leq HIC_{15} < 1888.89$
Red	$1700 \leq HIC_{15}$	$1545.45 \leq HIC_{15}$

1.3.2.2 Example:

Headform testing:

Manufacturer X has provided the following prediction to Euro NCAP with a total score of 90 points (excluding blue) out of the possible 195:



The prediction consists of the following:

15 Default Green x 1.00 = 15.00
30 Green x 1.00 = 30.00
30 Yellow x 0.75 = 22.50
30 Orange x 0.50 = 15.00
30 Brown x 0.25 = 7.50
30 Red x 0.00 = 0.00
15 Default Red x 0.00 = 0.00
15 Blue

195 grid points 90.00 points

15 verification points were chosen for testing:

	Verification											Score
1-10	GRID-point	R2|C-7	R2|C-3	R1|C-2	R4|C-4	R5|C1	R5|C4	R8|C-2	R6|C-7	R2|C6	R1|C3	
	Prediction											6
	Test result (HIC)	750	600	500	1200	1492	850	2000	1400	1112	660	
	Test result (pts)	0.75	0.75	1	0.5	0.5	0.75	0	0.25	0.5	1	6
11-20	GRID-point	R8|C0	R6|C7	R0|C-7	R9|C-6	R6|C1						
	Prediction											1.50
	Test result (HIC)	2000	1822	700	1544	1450						
	Test result (pts)	0	0.25	1	0.25	0.25						1.75
											Correction factor	1.033

$$Correction\ Factor = \frac{Actual\ tested\ score}{Predicted\ score} = \frac{6.00 + 1.75}{6.00 + 1.50} = 1.033$$

8 Blue zones were tested containing 15 blue points:

	Blue points									Score
Blue	Blue Zone	1	2	3	4	5	6	7	8	
	GRID-point	12,7 12,6	12,5 12,4	12,3 12,2	12,1 12,0	12,-1 12,-2	12,-3 12,-4	12,-5 12,-6	12,-7	
	Test result (HIC)	1000	650	1700	1500	1700	1699	1350	1349	
	Test result (pts)	0.5	0.75	0	0.25	0	0.25	0.25	0.5	4.5

The final score will be:

150 Predicted 75.00 x 1.033 = 77.475
15 Default Green 15.000
15 Default Red 0.000
15 Blue 4.500

195 grid points 96.975 points

The score in terms of percentage of the maximum achievable score is 96.975/195 = 49.730%

The final headform score is 49.730% x 24 = **11.935 points**

1.3.2.3 Upper Legform

Each of the grid points can be awarded up to one point resulting in a maximum total of points equal to the number of grid points. A linear sliding scale is applied between the relevant limits of each parameter. The upper legform performance for each grid point is based upon the worst performing parameter.

The total score for the upper legform area will be calculated out of six by scaling the sum of grid points score by the relevant number of grid points.

Example:
For a vehicle that has 9 grid points and tests are performed to points U0, U-2 & U-4 with the following results:

Test result U0	**Score**	**Total**
Femur upper bending moment = 281.40Nm	1.000	
Femur middle bending moment = 342.60Nm	0.114 =>	**0.114**
Femur lower bending moment = 324.10Nm	0.398	
Femur sum of forces = 5.26kN	0.740	

Test result U-2	**Score**	**Total**
Femur upper bending moment = 395.81Nm	0.000	**0.000**
Femur middle bending moment = 467.69Nm	0.000	
Femur lower bending moment = 435.69Nm	0.000	
Femur sum of forces = 6.80kN	0.000	

Test result U-4	**Score**	**Total**
Femur upper bending moment = 152.00Nm	1.000	**1.000**
Femur middle bending moment = 208.00Nm	1.000	
Femur lower bending moment = 245.00Nm	1.000	
Femur sum of forces = 4.89kN	1.000	

Grid points that have not been tested will be awarded the worst result from one of the adjacent points. Given that U-1 and U-3 have not been tested, both will be awarded the result from the adjacent point U-2. Symmetry will also be applied to all grid points on the opposite side of the vehicle (U+1 to U+4).

U+4	U+3	U+2	U+1	U0	U-1	U-2	U-3	U-4
1.000	0.0	0.0	0.0	0.114	0.0	0.0	0.0	1.000

The score for each individual grid point is then summed, this produces a score in terms of the maximum achievable percentage of 2.114/9 = 23.488%

The final upper legform score is 23.488% x 6 = **1.409 points**

1.3.2.4 Legform

Each of the grid points can be awarded up to one point resulting in a maximum total of points equal to the number of grid points. A linear sliding scale is applied between the relevant limits of each parameter. The one point per grid point is divided into two independent assessment areas of equal weight:

1. Tibia injury assessment based on the worst performing of tibia moments T1, T2, T3, T4 (0.500 point).

2. Knee injury assessment based upon MCL elongation, as long as ACL/PCL elongation is smaller than the threshold (0.500 point).

The total score for the legform area will be calculated out of six by scaling down the sum of grid points scores by the relevant number of grid points.

Example:

For a vehicle that has 11 grid points and tests are performed to points L1, L+3 & L+5 with the following results:

Test result L+1	**Score**	**Total**
Tibia bending moment = 280.00Nm	0.500	0.500
ACL or PCL elongation = 10.00mm	Fail	} 0.000
MCL elongation = 15.00mm	0.500	
		= 0.500

Test result L+3	**Score**	**Total**
Tibia bending moment = 320.00Nm	0.172	0.172
ACL or PCL elongation = 9.50mm	Pass	} 0.250
MCL elongation = 20.50mm	0.250	
		= 0.422

Test result L+5	**Score**	**Total**
Tibia bending moment = 340.00Nm	0.000	0.000
ACL or PCL elongation = 10.00mm	Fail	0.000
MCL elongation = 19.00mm	0.000	
		= 0.000

Grid points that have not been tested will be awarded the worst result from one of the adjacent points. Given that L0, L+2 & L+4 have not been tested, L0 will be awarded the score from L+1, L+2 will be awarded the score from L+3 and L+4 will be awarded the score from L+5. Symmetry will also be applied to the other side of the vehicle.

L+5	L+4	L+3	L+2	L+1	L0	L-1	L-2	L-3	L-4	L-5
0.0	0.0	0.422	0.422	0.500	0.500	0.500	0.422	0.422	0.0	0.0

The score for each individual grid point is then summed, this produces a score in terms of the maximum achievable percentage of 3.188/11 = 28.981%
The final upper legform score is 28.981% x 6 = **1.739 points**

1.3.3 Visualisation of results

1.3.3.1 Headform results

The protection provided by each grid location is illustrated by a coloured area, on an outline of the front of the car. Where no grid is used in the assessment and the fallback scenario is adopted, the same 5 colour boundaries and HIC650 – HIC 1700 values will be applied. The headform performance boundaries are detailed below.

Green	$HIC_{15} < 650$
Yellow	$650 \leq HIC_{15} < 1000$
Orange	$1000 \leq HIC_{15} < 1350$
Brown	$1350 \leq HIC_{15} < 1700$
Red	$1700 \leq HIC_{15}$

1.3.3.2 Legform & upper legform results

The protection provided by each grid location is illustrated by a coloured point on an outline of the front of the car. The colour used is based on the points awarded for that test site (rounded to three decimal places), as follows:

Green	*grid point score = 1.000*
Yellow	*0.750 <= grid point score < 1.000*
Orange	*0.500 <= grid point score < 0.750*
Brown	*0.250 <= grid point score < 0.500*
Red	*0.000 <= grid point score < 0.250*

2 REFERENCES

1 Prasad, P. and H. Mertz. *The position of the US delegation to the ISO Working Group 6 on the use of HIC in the automotive environment.* SAE Paper 851246. 1985

2 Mertz, H., P. Prasad and G. Nusholtz. *Head Injury Risk Assessment for forehead impacts.* SAE paper 960099 (also ISO WG6 document N447)

3 EEVC WG17 Report, 'Improved Test Methods to Evaluate Pedestrian Protection Afforded by Passenger Cars', September 2002.

PART II

PEDESTRIAN AEB ASSESSMENT

1 ASSESSMENT OF AEB VULNERABLE ROAD USER SYSTEMS

1.1 Introduction

AEB Vulnerable Road User (VRU) systems are AEB systems that are designed to brake autonomously for pedestrian and/or cyclists crossing the path of the vehicle. For the assessment of AEB VRU systems, two areas of assessment are considered; the Autonomous Emergency Braking function and the Human Machine Interface. The AEB function is assessed in three different types of scenarios.
At this stage the HMI operation is assessed in a general way as scientific evidence regarding quality of warning is lacking. The current emphasis in the assessment of AEB VRU lies with the AEB function as typically there is not enough time for the driver to react to the unavoidable collision.

1.2 Definitions

Throughout this protocol the following terms are used:

Autonomous emergency braking (AEB) – braking that is applied automatically by the vehicle in response to the detection of a likely collision to reduce the vehicle speed and potentially avoid the collision.

Forward Collision Warning (FCW) – an audiovisual warning that is provided automatically by the vehicle in response to the detection of a likely collision to alert the driver.

Car-to-VRU Farside Adult (CVFA) – a collision in which a vehicle travels forwards towards an adult pedestrian crossing it's path running from the farside and the frontal structure of the vehicle strikes the pedestrian at 50% of the vehicle's width when no braking action is applied.

Car-to-VRU Nearside Adult (CVNA-25) – a collision in which a vehicle travels forwards towards an adult pedestrian crossing it's path walking from the nearside and the frontal structure of the vehicle strikes the pedestrian at 25% of the vehicles width when no braking action is applied.

Car-to-VRU Nearside Adult (CVNA-75) – a collision in which a vehicle travels forwards towards an adult pedestrian crossing it's path walking from the nearside and the frontal structure of the vehicle strikes the pedestrian at 75% of the vehicles width when no braking action is applied.

Car-to-VRU Nearside Child (CVNC) – a collision in which a vehicle travels forwards towards a child pedestrian crossing it's path running from behind and obstruction from the nearside and the frontal structure of the vehicle strikes the pedestrian at 50% of the vehicle's width when no braking action is applied.

Vehicle under test (VUT) – means the vehicle tested according to this protocol with a pre-crash collision mitigation or avoidance system on board

Euro NCAP Pedestrian Target (EPT) – means the pedestrian target used in this protocol as specified in Annex A of the AEB VRU test protocol

Vimpact – means the speed at which the profiled box around the VUT coincides with the square box around the EPT

1.3 Criteria and Scoring

To be eligible for scoring points in AEB VRU, the AEB system must operate (i.e. warn or brake) from speeds of 10 km/h in the CVNA-75 scenario In addition, the system must be able to detect pedestrians walking as slow as 3 km/h and reduce speed in the CVNA-75 scenario at 20 km/h. The system may also not automatically switch off at a speed below 60 km/h.
The total score is also conditional to the subsystem test score, see section 0.

1.3.1 Human Machine Interface (HMI)

To be eligible for scoring points for HMI, the AEB and FCW function (if applicable) needs to be default ON at the start of every journey.
When the prerequisites mentioned above are met, points can be achieved for the following:

- **Deactivating AEB and FCW system (if applicable) 2 points**

  De-activation of the AEB and FCW (if applicable) system should not be possible with a single push on a button.

- **FCW system 1 point**

  When at test speeds over 40 km/h detects a critical situation that can possibly lead to a crash with a vulnerable road user, a loud and clear audiovisual warning is issued to alert the driver of the oncoming collision. The warning needs to be issued at least 1.2 seconds TTC (assessed at 45 km/h in the CVNA-75 scenario), to leave sufficient time for the driver to react to the warning.

- **Not switching off at low ambient lighting conditions 1 point**

  The system may not switch off at low ambient lighting conditions (<1000lux).

1.3.2 Autonomous Emergency Braking (AEB)

For the AEB system tests, the assessment criteria used is the impact speed. For test speeds up to 40 km/h, the available points per test speed are awarded based on the relative speed reduction achieved. Where there is no full avoidance a linear interpolation is applied to calculate the score for every single test speed.

$$Score_{\,test\ speed} = ((Vtest - Vimpact)/Vtest) \times points_{test\ speed}$$

For test speeds above 40km/h points are available on a pass/fail basis. For each of these test speeds points are awarded when a speed reduction of at least 20 km/h is achieved related to actual test speed.

The points available for the different test speeds are detailed in the table below:

Test speed	CVFA	CVNA-25	CVNA-75	CVNC
20 km/h	1.000	1.000	1.000	1.000
25 km/h	2.000	2.000	2.000	2.000
30 km/h	2.000	2.000	2.000	2.000
35 km/h	3.000	3.000	3.000	3.000
40 km/h	3.000	3.000	3.000	3.000
45 km/h	3.000	3.000	3.000	3.000
50 km/h	2.000	2.000	2.000	2.000
55 km/h	1.000	1.000	1.000	1.000
60 km/h	1.000	1.000	1.000	1.000
Total	**18.000**	**18.000**	**18.000**	**18.000**

1.4 Scoring and Visualisation

The scoring is based on normalized scores of the AEB function.

1.4.1 AEB score

For each scenario (CVFA, CVNA-25, CVNA-75 and CVNC) normalised scores are calculated for AEB. The total AEB score is calculated by averaging the scenario scores. This results in one percentage for the AEB performance.

1.4.2 HMI score

The HMI score is the normalised score of the points achieved under section 1.3.1.

1.4.3 Total AEB Vulnerable Road User score

The total score in points is the weighted sum of the AEB score and HMI score as shown below.

$$AEB\ VRU\ total\ score = (AEB\ score\ x\ 5) + (HMI\ score\ x\ 1)$$

AEB VRU scoring is conditional to the total points achieved in subsystem tests, i.e. the sum of pedestrian Headform, Upper Legform & Lower Legform scores:

- If the subsystem total test score is lower than 22 points, no points are available for AEB VRU, regardless whether the system is fitted and would achieve a good score.

☞ **Example:**
AEB function test results in CVFA scenario

Vtest	$points_{test\ speed}$	Vimpact	$Score_{test\ speed}$
20 km/h	1.000	0 km/h	1.000
25 km/h	2.000	0 km/h	2.000
30 km/h	2.000	0 km/h	2.000
35 km/h	3.000	0 km/h	3.000
40 km/h	3.000	20 km/h	1.500
45 km/h	3.000	25 km/h	3.000
50 km/h	2.000	30 km/h	2.000
55 km/h	1.000	40 km/h	0.000
60 km/h	1.000	Not tested	0.000
Total	**18.000**		**14.500**
Normalised score			**80.6%**

AEB function (assumed normalized scores for this example)
- Normalized score in CVNA-25 scenario: **76.7%**
- Normalized score in CVNA-75 scenario: **100.0%**
- Normalized score in CVNC scenario: **45.3%**

AEB score = 75.7%

HMI score:
Prerequisites met.
- De-activation of the AEB and FCW (if applicable) system not be possible with a single push on a button. **2 points**
- No FCW at speeds over 40 km/h **0 points**
- System switches off at low ambient lighting conditions **0 points**

HMI score = 50.0%

AEB VRU total score = 5.0 x 75.7% + 1.0 x 50.0%
= **4.285 points**