www.euroncap.com

EUROPEAN NEW CAR ASSESSMENT PROGRAMME (Euro NCAP)

ASSESSMENT PROTOCOL – ADULT OCCUPANT PROTECTION

Version 8.0.1
August 2017

Version 8.0.1
August 2017

EUROPEAN NEW CAR ASSESSMENT PROGRAMME (Euro NCAP)

ASSESSMENT PROTOCOL – ADULT OCCUPANT PROTECTION

Table of Contents

Version 8.0.1
August 2017

EUROPEAN NEW CAR ASSESSMENT PROGRAMME (Euro NCAP)

ASSESSMENT PROTOCOL – ADULT OCCUPANT PROTECTION

1 INTRODUCTION

Euro NCAP's original assessment protocol was developed jointly by TRL and Vehicle Safety Consultants Ltd under contract to the UK Department of the Environment Transport and the Regions and International Testing, respectively. Subsequent versions of the protocol have been developed and released by the Euro NCAP Secretariat. Beginning with Version 5 important changes have been included that have been brought about by 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 Occupant 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 Adult Occupant Protection, in particular in the frontal offset deformable and full width impact tests, the side impact barrier test, the pole test and the whiplash tests.

DISCLAIMER: Euro NCAP has taken all reasonable care to ensure that the information published in this protocol is accurate and reflects the technical decisions taken by the organisation. In the unlikely event that this protocol contains a typographical error or any other inaccuracy, Euro NCAP reserves the right to make corrections and determine the assessment and subsequent result of the affected requirement(s).

2 METHOD OF ASSESSMENT

The starting point for the assessment of adult occupant protection is the dummy response data recorded in five different test configurations: frontal impact in offset and full overlap, side impact, pole impact and (low speed) rear impact. All criteria used are calculated according to Technical Bulletin 17. Initially, each relevant body area is given a score based on the measured dummy parameters. These scores can be adjusted after the test based on supplementary requirements. E.g. for frontal impact, consideration is given to whether the original score should be adjusted to reflect occupant kinematics or sensitivity to small changes in contact location, which might influence the protection of different sized occupants in different seating positions. The assessment also considers the structural performance of the car by taking account of such aspects as steering wheel displacement, pedal movement, foot well distortion and displacement of the A pillar. The adjustments (or modifiers) based on both inspection and geometrical considerations are applied to the body area assessments to which they are most relevant.

For frontal offset impact, the score for each body area is based on the driver data, unless part of the passenger fared less well. It is stated that the judgement relates primarily to the driver. For frontal full width, the score is based on driver and rear passenger. Side impact and pole impact results relate to the struck-side occupant only, while Whiplash results cover front and rear occupants. No attempt is made to rate the risk of life threatening injury any differently from the risk of disabling injury. Similarly, no attempt is made to rate the risk of the more serious but less frequent injury any differently from the risk of less serious but more frequent injury. Care has been taken to try to avoid encouraging manufacturers from concentrating their attention on areas which would provide little benefit in accidents.

From the information collected in the five test scenarios, individual test scores are computed for the frontal tests, side and pole impact and whiplash protection. The adjusted score for the different body regions is presented, in a visual format of coloured segments within a human body outline. This is presented for the driver and front/rear seat passenger in frontal impact, for the driver in side and pole impact and for all occupants in rear impact. Finally, for the complete area of adult occupant protection assessment, the scores for frontal, side, pole and whiplash are summed. The resulting Adult Occupant Protection Score is expressed as a percentage of the maximum achievable number of points.

In addition to the basic Euro NCAP assessment, additional information is recorded and may be reported. In future, some of these additional aspects may be added to the Euro NCAP assessment.

2.1 Points Calculation

From Phase 3, 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. In frontal, side, and pole impacts, the maximum score for each body region is four points; for rear impact protection, it is three points*. Where a value falls between the two limits, the score is calculated by linear interpolation.

2.1.1 Capping

For most tests that are part of the adult occupant protection assessment, capping limits are maintained for criteria related to critical body regions. Exceeding a capping limit generally indicates unacceptable high risk at injury or, in the case of the whiplash tests, an unacceptably high seat design parameter. In all cases, this leads to loss of all points related to the tests. Capping limits can be equal to or higher than the lower performance limit, depending on the test.

* Neck only – based on a combination of scores obtained in three individual test conditions.

3 OFFSET DEFORMABLE BARRIER FRONTAL IMPACT ASSESSMENT

3.1 Criteria and Limit Values

The basic assessment criteria used for frontal impact, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region. The lowest scoring body region of driver or passenger is used to determine the score. For the frontal offset deformable barrier impact, capping is applied on the critical body regions: head, neck and chest (see 2.1.1).

3.1.1 Head

3.1.1.1 Drivers with Steering Wheel Airbags and Passengers

If a steering wheel airbag is fitted the following criteria are used to assess the protection of the head for the driver. These criteria are always used for the passenger.

Note: HIC15 levels above 1000 have been recorded with airbags, where there is no hard contact and no established risk of internal head injury. A hard contact is assumed if the peak resultant head acceleration exceeds 80g or if there is other evidence of hard contact.

If there is no hard contact a score of 4 points is awarded. If there is hard contact, the following limits are used:

Higher performance limit		
HIC_{15}	500	
Resultant Acc. 3 msec exceedence	72g	
Lower performance and capping limit		
HIC_{15}	700	(20% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3 msec exceedence	80g	

3.1.1.2 Drivers with No Steering Wheel Airbag

If no steering wheel airbag is fitted, and the following requirements are met in the frontal impact test:

HIC_{15}	<700
Resultant Acc. 3 msec exceedence	<80g,

then 6.8 kg spherical headform test specified in ECE Regulation 12 [3] are carried out on the steering wheel. The tester attempts to choose the most aggressive sites to test and it is expected that

two tests will be required, one aimed at the hub and spoke junction and one at the rim and spoke junction. The assessment is then based on the following criteria:

Higher performance limit	
Resultant peak Acc.	80g
Resultant Acc. 3 msec exceedence	65g

Lower performance and capping limit	
HIC_{15}	700
Resultant peak Acc.	120g
Resultant Acc. 3 msec exceedence	80g

From the face form tests, a maximum of 2 points are awarded for performance better than the lower limits. For values worse than the lower performance limit, no points are awarded.

The results from the worst performing test are used for the assessment. This means that for cars, not equipped with a steering wheel airbag, the maximum score obtainable for the driver's head is 2 points.

3.1.2 Neck

Higher performance limit			
Shear	1.9kN @ 0 msec,	1.2kN @ 25 - 35msec,	1.1kN @ 45msec
Tension	2.7kN @ 0 msec,	2.3kN @ 35msec,	1.1kN @ 60msec
Extension	42Nm		

Lower performance and capping limit			
Shear	3.1kN @ 0msec,	1.5kN @ 25 - 35msec,	1.1kN @ 45msec*
Tension	3.3kN @ 0msec,	2.9kN @ 35msec,	1.1kN @ 60msec*
Extension	57Nm*	(Significant risk of injury [4])	

*(*EEVC Limits)*

Note: Neck Shear and Tension are assessed from cumulative exceedence plots, with the limits being functions of time. By interpolation, a plot of points against time is computed. The minimum point on this plot gives the score. Plots of the limits and colour rating boundaries are given in Appendix I.

3.1.3 Chest

Higher performance limit		
Compression	22mm	(5% risk of injury ≥ AIS3 [5])
Viscous Criterion	0.5m/sec	(5% risk of injury ≥ AIS4)

Lower performance and capping limit		
Compression	42mm	
Viscous Criterion	1.0m/sec	(25% risk of injury ≥ AIS4)

3.1.4 Knee, Femur and Pelvis

Higher performance limit		
Femur compression	3.8kN	(5% risk of pelvis injury [6])
Knee slider compressive displacement	6mm	
Lower performance limit		
Femur Compression	9.07kN @ 0msec,	
	7.56kN @ ≥ 10msec*	(Femur fracture limit [4])
Knee slider compressive displacement	15mm*	(Cruciate ligament failure limit [4,7])
		*(*EEVC Limit)*

Note: Femur compression is assessed from a cumulative exceedence plot, with the limits being functions of time. By interpolation, a plot of points against time is computed. The minimum point on this plot gives the score. Plots of the limits and colour rating boundaries are given in Appendix I.

The Lumbar forces and moments are measured for monitoring purpose only.

3.1.5 Lower Leg

Higher performance limit		
Tibia Index	0.4	
Tibia Compression	2kN	
Lower performance limit		
Tibia Index	1.3*	
Tibia Compression	8kN*	(10% risk of fracture [4,8])
		*(*EEVC Limits)*

3.1.6 Foot/Ankle

Higher performance limit		
Pedal rearward displacement	100mm	
Lower performance limit		
Pedal rearward displacement	200mm	

Notes:

1. *Pedal displacement is measured for all pedals with no load applied to them.*
2. *If any of the pedals are designed to completely release from their mountings during the impact, no account is taken of the pedal displacement provided that release occurred in the test and that the pedal retains no significant resistance to movement.*
3. *If a mechanism is present to move the pedal forwards in an impact, the resulting position of the pedal is used in the assessment.*
4. *The passenger's foot/ankle protection is not currently assessed.*

3.2 Modifiers

3.2.1 Driver

The score generated from driver dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or accidents of slightly different severity, can be expected to be worse than that indicated by the dummy readings or deformation data alone. There is no limit to the number of modifiers that can be applied. The concepts behind the modifiers are explained in Section 8.

3.2.1.1 Head

Unstable Contact on the Airbag

If during the forward movement of the head its centre of gravity moves further than the outside edge of the airbag, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head protection by the airbag is compromised, such as by detachment of the steering wheel from the column, or bottoming-out of the airbag by the dummy head, the modifier is also applied.

Note: Head bottoming-out is defined as follows: There is a definite rapid increase in the slope of one or more of the head acceleration traces, at a time when the dummy head is deep within the airbag. The acceleration spike associated with the bottoming out should last for more than 3ms.The acceleration spike associated with the bottoming out should generate a peak value more than 5 g above the likely level to have been reached if the spike had not occurred. This level will be established by smooth extrapolation of the curve between the start and end of the bottoming out spike.

Hazardous Airbag Deployment

If, within the head zone, the airbag unfolds in a manner in which a flap develops, which sweeps across the face of an occupant vertically or horizontally the -1 point modifier for unstable airbag contact will be applied to the head score. If the airbag material deploys rearward, within the "head zone" at more than 90 m/s, the -1 point modifier will be applied to the head score. Further details are contained in Euro NCAP Technical Bulletin TB 001.

Incorrect Airbag Deployment

Any airbag(s) which does not deploy fully in the designed manner will attract a -1 point modifier applicable to each of the most relevant body part(s) for the affected occupant. For example, where a steering wheel mounted airbag is deemed to have deployed incorrectly, the penalty will be applied to the frontal impact driver's head (-1). Where, a passenger knee airbag fails to deploy correctly, the penalty will be applied to the frontal impact passenger left and right knee, femur and pelvis (-1).

Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual body part. For example, where a seat or door mounted side airbag, that is intended to provide protection to the head as well as the thorax, abdomen or pelvis deploys incorrectly, the penalty will be applied to two body regions, -1 to the head and -1 to the chest.

The modifier(s) will be applied to the scores of the impacts for which the airbag was intended to offer protection, regardless of the impact in which it deployed incorrectly. For example, the penalty will be applied to the side and pole impact scores if a side protection airbag deploys incorrectly during the frontal crash. Or, if a knee airbag deploys incorrectly in the full width impact, the modifier will be applied to the pelvic region of both the offset and full width tests. Where any frontal protection airbag deploys incorrectly, Euro NCAP will not accept knee mapping data for that occupant.

Unstable Contact on a Steering Wheel without an Air Bag

If, during the forward movement of the head, its centre of gravity moves radially outwards further than the outside edge of the steering wheel rim, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head contact on the steering wheel is unstable, such as detachment of the steering wheel from the column, the modifier is also applied.

Displacement of the Steering Column

The score is reduced for excessive rearward, lateral or upward static displacement of the top end of the steering column. Up to 90 percent of the EEVC limits, there is no penalty. Beyond 110 percent of the EEVC limits, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The EEVC recommended limits are: 100mm rearwards, 80mm upwards and 100mm lateral movement. The modifier used in the assessment is based on the worst of the rearward, lateral and upward penalties.

3.2.1.2 Chest

Displacement of the A Pillar

The score is reduced for excessive rearward displacement of the driver's front door pillar, at a height of 100mm below the lowest level of the side window aperture. Up to 100mm displacement there is no penalty. Above 200mm there is a penalty of two points. Between these limits, the penalty is generated by linear interpolation.

Integrity of the Passenger Compartment
Where the structural integrity of the passenger compartment is deemed to have been compromised, a penalty of one point is applied. The loss of structural integrity may be indicated by characteristics such as:

- Door latch or hinge failure, unless the door is adequately retained by the door frame.
- Buckling or other failure of the door resulting in severe loss of fore/aft compressive strength.
- Separation or near separation of the cross facia rail to A pillar joint.
- Severe loss of strength of the door aperture.

When this modifier is applied, Euro NCAP will not accept knee mapping data.

Steering Wheel Contact
Where there is obvious direct loading of the chest from the steering wheel, a one point penalty is applied.

Shoulder belt load (Driver and Front Passenger)
Where the shoulder belt load measured, exceeds 6kN a two point penalty is applied.

3.2.1.3 Knee, Femur & Pelvis

Variable Contact
The position of the dummy's knees is specified by the test protocol. Consequently, their point of contact on the facia is pre-determined. This is not the case with human drivers, who may have their knees in a variety of positions prior to impact. Different sized occupants and those seated in different positions may also have different knee contact locations on the facia and their knees may penetrate into the facia to a greater extent. In order to take some account of this, a larger area of potential knee contact is considered. If contact at other points, within this greater area, would be more aggressive penalties are applied.

The area considered extends vertically 50mm above and below the maximum height of the actual knee impact location [8]. Vertically upwards, consideration is given to the region up to 50mm above the maximum height of knee contact in the test. If the steering column has risen during the test it may be repositioned to its lowest setting if possible. Horizontally, for the outboard leg, it extends from the centre of the steering column to the end of the facia. For the inboard leg, it extends from the centre of the steering column the same distance inboard, unless knee contact would be prevented by some structure such as a centre console. Over the whole area, an additional penetration depth of 20mm is considered, beyond that identified as the maximum knee penetration in the test. The region considered for each knee is generated independently. Where, over these areas and this depth, femur loads greater that 3.8kN and/or knee slider displacements greater than 6mm would be expected, a one point penalty is applied to the relevant leg.

Concentrated Loading
The biomechanical tests which provided the injury tolerance data were carried out using a padded impactor which spread the load over the knee. Where there are structures in the knee impact area which could concentrate forces on part of the knee a one point penalty is applied to the relevant leg.

Where a manufacturer is able to show, by means of acceptable test data, that the Variable Contact and/or Concentrated Loading modifiers should not be applied, the penalties may be removed.

If the Concentrated load modifier is not applied to either of the driver's knees, the left and right knee zones (defined above) will both be split into two further areas, a 'column' area and the rest of the facia. The column area for each knee will extend 60mm from the centreline of the steering column and the remainder of the facia will form the other area for each knee. As a result, the one point penalty for Variable Contact will be divided into two with one half of a point being applied to the column area and one half of a point to the remainder of the facia for each knee.

3.2.1.4 Lower Leg

Upward Displacement of the Worst Performing Pedal
The score is reduced for excessive upward static displacement of the pedals. Up to 90 percent of the limit considered by EEVC, there is no penalty. Beyond 110 percent of the limit, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The limit agreed by EEVC was 80mm.

3.2.1.5 Foot & Ankle

Footwell Rupture
The score is reduced if there is significant rupture of the footwell area. This is usually due to separation of spot welded seams. A one point penalty is applied for footwell rupture. The footwell rupture may either pose a direct threat to the driver's feet or be sufficiently extensive to threaten the stability of footwell response. When this modifier is applied, Euro NCAP will not accept knee mapping data.

Pedal Blocking
Where the rearward displacement of a 'blocked' pedal exceeds 175mm relative to the pre-test measurement, a one point penalty is applied to the driver's foot and ankle assessment. A pedal is blocked when the forward movement of the intruded pedal under a load of 200N is <25mm. Between 50mm and 175mm of rearward displacement the penalty is calculated using a sliding scale between 0 to 1 points.

3.2.2 Passenger

The score generated from passenger dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or accidents of slightly different severity, can be expected to be worse than that indicated by the dummy readings alone. There is no limit to the number of modifiers that can be applied. The concepts behind the modifiers are explained in section 7. The modifiers applicable to the passenger are:

- *Unstable Contact on the airbag*
- *Hazardous airbag deployment*
- *Shoulder belt load*
- *Incorrect airbag deployment*
- *Knee, Femur & Pelvis, Variable Contact*
- *Knee, Femur & Pelvis, Concentrated loading*

The assessments airbag stability, head bottoming-out (where present) and the knee impact areas are the same as for driver. For the outboard knee, the lateral range of the knee impact area extends from the centre line of the passenger seat to the outboard end of the facia. For the inboard knee, the area extends the same distance inboard of the seat centre line, unless knee contact is prevented by the presence of some structure such as the centre console. The passenger knee zones and penalties will not be divided into two areas even if the concentrated load modifier is not applied.

3.2.3 Door Opening during the Impact

When a door opens in the test, a minus one-point modifier will be applied to the score for that test. The modifier will be applied to the frontal impact assessment for every door (including tailgates and moveable roofs) that opens. The number of door opening modifiers that can be applied to the vehicle score is not limited.

3.2.4 Door Opening Forces after the Impact

The force required to unlatch and open each side door to an angle of 45 degrees is measured after the impact. A record is also made of any doors which unlatch or open in the impact. Currently, this information is not used in the assessment but it may be referred to in the text of the published reports.

Door opening forces are categorised as follows:

Opens normally	Normal hand force is sufficient
Limited force	≤ 100N
Moderate force	> 100N to < 500N
Extreme hand force	≥ 500N
Tools had to be used	Tools necessary

3.3 Scoring & Visualisation

The protection provided for adults for each body region are presented visually, using coloured segments within body outlines. The colour used is based on the points awarded for that body region (rounded to three decimal places), as follows:

Green	'Good'	4.000	points
Yellow	'Adequate'	2.670 - 3.999	points
Orange	'Marginal'	1.330 - 2.669	points
Brown	'Weak'	0.001 - 1.329	points
Red	'Poor'	0.000	points

For frontal impact, the body regions are grouped together, with the score for the grouped body region being that of the worst performing region or limb. The grouped regions are: Head and Neck (4 points), Chest (4 points), Knee, Femur, Pelvis (i.e. left and right femur and knee slider) (4 points) and Leg and Foot (i.e. left and right lower leg and foot and ankle) (4 points). Results are shown separately for driver and passenger.

The contribution of the frontal impact test to the Adult Occupant Protection Score is calculated by summing the body scores for the relevant body regions, taking the lower of the driver and passenger scores for each region (16 points total). This score is halved with a total achievable score of 8 points.

4 FRONTAL FULL WIDTH IMPACT ASSESSMENT

4.1 Criteria and Limit Values

The basic assessment criteria used for the full width frontal impact test, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region. This does however not apply to the neck assessment for the rear passenger dummy. The scoring for the rear passenger neck is detailed in section 4.1.2.

The full width test is performed with a driver and rear passenger dummy as standard. The OEM is requested to provide data for the front passenger(s) from the same test set-up to demonstrate similar protection levels for all occupants seated in the front row. In cases where the OEM is not willing or able to provide this data, Euro NCAP may perform the full width test with an additional HIII-05F dummy in the front passenger seat.

Note: The front passenger data needs to be provided to the Euro NCAP Secretariat <u>at least one week before</u> the full width test is performed.

4.1.1 Head

4.1.1.1 Drivers with Steering Wheel Airbags and Passengers

If a steering wheel airbag is fitted the following criteria are used to assess the protection of the head for the driver. These criteria are always used for the passenger.

Note: HIC15 levels above 700 have been recorded with airbags, where there is no hard contact and no established risk of internal head injury. A hard contact is assumed, if the peak resultant head acceleration exceeds 80g, or if there is other evidence of hard contact.

If there is no hard contact a score of 4 points is awarded. If there is hard contact, the following limits are used:

Higher performance limit	
HIC_{15}	500
Resultant Acc. 3 msec exceedence	72g
Lower performance and capping limit	
HIC_{15}	700
Resultant Acc. 3 msec exceedence	80g

4.1.1.2 Drivers with No Steering Wheel Airbag

If no steering wheel airbag is fitted, and the following requirements are met in the frontal impact test:

HIC_{15}	<700
Resultant Acc. 3 msec exceedence	<80g,

then 6.8 kg spherical headform test specified in ECE Regulation 12 [3] are carried out on the steering wheel. The tester attempts to choose the most aggressive sites to test and it is expected that two tests will be required, one aimed at the hub and spoke junction and one at the rim and spoke junction. The assessment is then based on the following criteria:

Higher performance limit

Resultant peak Acc.	80g
Resultant Acc. 3 msec exceedence	65g

Lower performance and capping limit

HIC_{15}	700
Resultant peak Acc.	120g
Resultant Acc. 3 msec exceedence	80g

From the face form tests, a maximum of 2 points are awarded for performance better than the lower limits. For values worse than the lower performance limit, no points are awarded.

The results from the worst performing test are used for the assessment. This means that for cars, not equipped with a steering wheel airbag, the maximum score obtainable for the driver's head is 2 points.

4.1.1.3 Rear Passenger

If there is no hard contact seen on the high speed film, the score is based on the 3ms resultant acceleration.

Higher performance limit

Resultant Acc. 3 msec exceedence	72g

Lower performance and capping limit

Resultant Acc. 3 msec exceedence	80g

If there is hard contact confirmed on the high speed film, the following limits are used:

Higher performance limit

HIC_{15}	500

Resultant Acc. 3 msec exceedence	72g

Lower performance and capping limit

HIC_{15}	700
Resultant Acc. 3 msec exceedence	80g

4.1.2 Neck

Higher performance limit

Shear	1.2kN
Tension	1.7kN
Extension	36Nm

Lower performance

Shear	1.95kN
Tension	2.62kN
Extension	49Nm

Capping limit (driver only)

Shear	2.7kN
Tension	2.9kN
Extension	57Nm

For the rear passenger dummy, the neck score is the sum of all three criteria, with the following maximum score per criterion:

Shear	1 point
Tension	1 point
Extension	2 points

4.1.3 Chest

Higher performance limit

Compression	18mm
Viscous Criterion	0.5m/sec

Lower performance and Capping limit

Compression	42mm
Viscous Criterion	1.0m/sec

4.1.4 Knee, Femur and Pelvis

The knee, femur, pelvis region is assessed by the femur compression:
Higher performance limit
Femur compression 2.6kN

Lower performance limit
Femur Compression 6.2kN

The knee slider displacement and the Lumbar forces and moments are measured for monitoring purpose only.

4.1.5 Lower Leg

The Lower Legs are measured for monitoring purpose only.

4.2 Modifiers

The score generated from dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or accidents of slightly different severity, can be expected to be worse than that indicated by the dummy readings or deformation data alone. There is no limit to the number of modifiers that can be applied.

4.2.1 Head

Unstable Contact on the Airbag (Driver and Rear Passenger)

If during the forward movement of the head its centre of gravity moves further than the outside edge of the airbag, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head protection by the airbag is compromised, such as by detachment of the steering wheel from the column, or bottoming-out of the airbag by the dummy head, the modifier is also applied.

> *Note: Head bottoming-out is defined as follows: There is a definite rapid increase in the slope of one or more of the head acceleration traces, at a time when the dummy head is deep within the airbag. The acceleration spike associated with the bottoming out should last for more than 3ms.The acceleration spike associated with the bottoming out should generate a peak value more than 5 g above the likely level to have been reached if the spike had not occurred. This level will be established by smooth extrapolation of the curve between the start and end of the bottoming out spike.*

Hazardous Airbag Deployment (Driver and Rear Passenger)

If, in the ODB test, the airbag was seen to unfold in a manner in which a flap develops, which sweeps across the face of an occupant vertically or horizontally the -1 point modifier for unstable airbag contact will be applied to the head score. Also, when the airbag material deployed rearward,

within the "head zone" at more than 90 m/s in the ODB test, the -1 point modifier will be applied to the head score. Further details are contained in Euro NCAP Technical Bulletin TB 001.

Incorrect Airbag Deployment (Driver and Rear Passenger)

Any airbag(s) which does not deploy fully in the designed manner will attract a -1 point modifier applicable to each of the most relevant body part(s) for the affected occupant. For example, where a steering wheel mounted airbag is deemed to have deployed incorrectly, the penalty will be applied to the frontal impact driver's head (-1). Where, a passenger knee airbag fails to deploy correctly, the penalty will be applied to the frontal impact passenger left and right knee, femur and pelvis (-1).

Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual body part. For example, where a seat or door mounted side airbag, that is intended to provide protection to the head as well as the thorax, abdomen or pelvis deploys incorrectly, the penalty will be applied to two body regions, -1 to the head and -1 to the chest.

The modifier(s) will be applied to the scores of the impacts for which the airbag was intended to offer protection, regardless of the impact in which it deployed incorrectly. For example, the penalty will be applied to the side and pole impact scores if a side protection airbag deploys incorrectly during the frontal crash. Or, if a knee airbag deploys incorrectly in the full width impact, the modifier will be applied to the pelvic region of both the offset and full width tests. Where any frontal protection airbag deploys incorrectly, Euro NCAP will not accept knee mapping data for that occupant.

Unstable Contact on a Steering Wheel without an Airbag (Driver)

If, during the forward movement of the head, its centre of gravity moves radially outwards further than the outside edge of the steering wheel rim, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head contact on the steering wheel is unstable, such as detachment of the steering wheel from the column, the modifier is also applied.

Displacement of the Steering Column (Driver)

The score is reduced for excessive rearward, lateral or upward static displacement of the top end of the steering column. Up to 90 percent of the EEVC limits, there is no penalty. Beyond 110 percent of the EEVC limits, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The EEVC recommended limits are: 100mm rearwards, 80mm upwards and 100mm lateral movement. The modifier used in the assessment is based on the worst of the rearward, lateral and upward penalties.

Exceeding forward excursion line (Rear Passenger)

The score is reduced for excessive forward excursion. Where the head of the Rear Passenger exceeds the 450mm or 550mm forward excursion line as defined in the full width test protocol, a 2 or 4 point modifier respectively is applied. The modifier can be removed when it is shown by means of numerical simulation or a sled test that the HIII-50M does not contact the front passenger seat when in the 50M seating position, or when the HIC_{15} value is below 700 in case of contact with the front passenger seat.

4.2.2 Chest

Steering Wheel Contact (Driver)

Where there is obvious direct loading of the chest from the steering wheel, a one point penalty is applied.

Shoulder belt load (Driver and Rear Passenger)

Where the shoulder belt load measured, exceeds 6kN a two point penalty is applied.

4.2.3 Knee, Femur & Pelvis

Submarining (Driver and Rear Passenger)

The score for the Knee, Femur & Pelvis is reduced by 4 points when submarining occurs. The modifier is applied when a 1kN drop in any of the two iliac forces measured is seen within 1 ms and when the submarining is confirmed on the high speed film.

4.2.4 Door Opening during the Impact

When a door opens in the test, a minus one-point modifier will be applied to the score for that test. The modifier will be applied to the frontal impact assessment for every door (including tailgates and moveable roofs) that opens. The number of door opening modifiers that can be applied to the vehicle score is not limited.

4.3 Scoring & Visualisation

The scores for the driver and rear passenger dummy are averaged. For the Full Width frontal impact, capping is applied on the critical body regions: head, neck (driver only) and chest.

To ensure similar levels of protection for all occupants, the total dummy score (excluding modifiers) of the front passenger (based on manufacturer provided data) may not be less than 90% of that of total score of the driver. The front passenger data needs to be provided to the Euro NCAP Secretariat before the full width test is performed. When this requirement is not met, the front row will be assessed using the worst performing body region of the driver and front passenger.

The protection provided for adults for each body region are presented visually, using coloured segments within body outlines. The colour used is based on the points awarded for that body region (rounded to three decimal places), as follows:

Green	'Good'	4.000	points
Yellow	'Adequate'	2.670 - 3.999	points
Orange	'Marginal'	1.330 - 2.669	points
Brown	'Weak'	0.001 - 1.329	points
Red	'Poor'	0.000	points

For frontal impact, the body regions are grouped together, with the score for the grouped body region being that of the worst performing region or limb. The grouped regions are: Head (4 points), Neck (4 points), Chest (4 points) and Knee, Femur & Pelvis (i.e. left and right femur) (4 points). Results are shown separately for driver and rear passenger.

The contribution of the frontal impact test to the Adult Occupant Protection Score is calculated by summing the body scores for the relevant body regions and calculating the average of the driver and rear passenger scores (total of 16 points each) and dividing it by two. The total achievable score for the Full Width test is 8 points.

5 SIDE BARRIER AND POLE IMPACT ASSESSMENT

5.1 Criteria and Limit Values

The basic assessment criteria used for both side barrier and pole impacts, with the upper and lower performance limits for each parameter, are summarised below. The assessments are divided into four individual body regions, the head, chest, abdomen and pelvis. The criteria and limits are equal for side barrier and pole test except for the head and chest. A maximum of four points are available for each body region. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region. There is no limit to the number of modifiers that can be applied. The concepts behind the modifiers are explained in section 8.

For both side and pole impacts, capping is applied on the head, chest, abdomen and pelvis. Where no head protection systems are present, the pole test will not be allowed and the points for that test are set to zero.

> *Note: The requirement is for the fitment of a head protection system, meaning that the manufacturer is free to use a solution other than an airbag. However, for technologies other than conventional curtain or head airbags, the manufacturer is requested to provide evidence that the system is effective, at least in principle, before a test can be allowed.*

5.1.1 Head

5.1.1.1 Side impact

Higher performance limit		
HIC_{15}	500	
Resultant Acc. 3 msec exceedence	72g	
Lower performance and capping limit		
HIC_{15}	700	(20% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3 msec exceedence	80g	

5.1.1.2 Pole impact

Capping limits	
HIC_{15}	<700
Peak Resultant Acc	<80g
No direct head contact with the pole	

5.1.2 Chest

The assessment is based on the worst performing individual rib lateral compression.

MDB and Pole Higher performance limit		
Lateral Compression	28mm	(5% risk of AIS3, 67YO)
MDB Lower performance and capping limit		
Lateral Compression	50mm	(30% risk of AIS3, 45YO)
Pole Lower performance limit		
Lateral Compression	50mm	(30% risk of AIS3, 45YO)
Pole Capping limit		
Lateral Compression	55mm	(50% risk of AIS3, 45YO)

5.1.3 Abdomen

Higher performance limit		
Lateral Compression	47mm	(33% risk of AIS3, 67YO)
Lower performance and capping limit		
Lateral Compression	65mm	

5.1.4 Pelvis

Higher performance limit		
Pubic Symphysis Force	1.7kN	(5% risk of AIS3, 67YO)
Lower performance and capping limit		
Pubic Symphysis Force	2.8kN	(20% risk of AIS3, 45YO)

5.2 Modifiers

5.2.1 Shoulder

Where the shoulder lateral force (Y direction) component is 3.0kN or above, no points will be awarded for the chest assessment.

5.2.2 Chest & Abdomen

Where the viscous criterion (V*C) is 1.0m/s or above for the chest, abdomen or both, no points will be awarded for the relevant body region assessment.

5.2.3 Side Head Protection Device (Pole Impact Only)

Vehicles equipped with head protection side airbags, curtain, seat mounted or any other, will have the inflated energy absorbing areas evaluated by means of a geometric assessment. The airbags must provide protection for a range of occupant sizes in both the front and the rear on both sides of the vehicle. Where a vehicle does not offer sufficient protection, a penalty of -4 shall be applied to the overall pole impact score. Any vehicle that does not provide a head protection device covering the front and rear seat positions on both sides of the vehicle will also attract this modifier.

Where a vehicle is only equipped with separate head protecting devices for front and rear occupants, on both sides of the vehicle, and is considered as having limited space in the rear seats†, the penalty will be -2 points for each seat row (max -4 points).

5.2.3.1 Coverage areas

To ensure adequate head protection is offered, the head protection device coverage is assessed in the geometric area, or the Head Protection Device (HPD) assessment zone, where the occupant head would most likely impact side structures. If the vehicle is equipped with movable rear seats the seat shall be set to the most rearward position. If there is a third row of fixed seats, these will be included in the assessment unless they are per manufacturers' recommendation not suitable for adult occupation (handbook).

5.2.3.2 Application

Where the airbags differ between the left and right hand sides of the vehicle, the airbags on both sides of the vehicle will be evaluated and the assessment will be based upon worst performing side. All areas of the airbag, both front and rear, will be evaluated and the assessment will be based upon the worst performing part of any of the airbags.

---

† Vehicles will be considered as having limited rear space when the normal CRSs recommended by the manufacturer cannot be installed with the front seats in the test position. Where this is the case, the vehicle manufacturer should provide evidence showing that the CRS and/or child cannot be installed without interference from the vehicle.

5.2.3.3 Exclusions

The head protecting airbags should cover all glazed areas within the defined zone up to the edge of door daylight opening (FMVSS201) where it meets the roofline, B-pillar, C-pillar and door waistline. Seams in the airbag will not be penalised provided that the un-inflated area is no wider than 15mm. Any other areas where the airbag layers are connected will not be penalised provided that the surrounding areas are inflated and any un-inflated areas are no larger than 50mm in diameter or equivalent area or the sum of the major and minor axes of individual areas does not exceed 100mm. In the case that the un-inflated area would be larger than described above, the OEM shall provide data to demonstrate sufficient energy absorption is guaranteed.

Where a vehicle is fitted with a third row of foldable or removable seats, the third row (only) will be excluded from the assessment.

5.2.4 Incorrect Airbag Deployment

Any airbag(s) which does not deploy fully in the designed manner will attract a -1 point modifier applicable to each of the most relevant body part(s) for the affected occupant. For example, where a head curtain airbag is deemed to have deployed incorrectly, the penalty will be applied to the side impact driver's head (-1). Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual body part. For example, where a seat or door mounted side airbag fails to deploy correctly that is intended to provide protection to the head as well as the thorax, abdomen and pelvis, the penalty will be applied to two body regions, the head (-1) and the chest (-1). The two penalties would also be applicable to both the side and pole impacts, which are scaled down in the final vehicle rating.

The modifier will be applied even if the airbag was not intended to offer protection in that particular impact. For example, the penalty will be applied if a driver's knee airbag deploys incorrectly in a side or pole impact. In this case the modifier will be applied to both frontal impact driver knee, femur and pelvis body parts. Where a frontal protection airbag deploys incorrectly, knee-mapping is not permitted for the occupant whom the airbag was designed to protect.

5.2.5 Door Opening during the Impact

When a door opens in the test, a minus one-point modifier will be applied to the score for that test. The modifier will be applied to the side impact assessment score for every door (including tailgates and moveable roofs) that opens. The number of door opening modifiers that can be applied to the vehicle score is not limited.

5.2.6 Door Opening Forces after the Impact

A check is made to ensure that the doors on the non-struck side can be opened. The doors on the struck side are not opened.

5.3 Scoring & Visualisation

The protection provided for adults for each body region are presented visually, using coloured segments within body outlines. The colour used is based on the points awarded for that body region (rounded to three decimal places), as follows:

Green	'Good'	4.000	points
Yellow	'Adequate'	2.670 - 3.999	points
Orange	'Marginal'	1.330 - 2.669	points
Brown	'Weak'	0.001 - 1.329	points
Red	'Poor'	0.000	points

For the side barrier and pole impacts, all the individual regions are used. Results are shown separately for side barrier and pole impact.

The contribution of the side and pole impact tests to the Adult Occupant Protection Score is calculated by summing the body scores for the relevant body regions in each of the tests. The total score in side barrier and pole tests together is limited to 16 points. This is achieved by adding up the individual scores (after modifiers have been applied) for the side impact test (max. 16 points) and the pole test (max. 16 points) and dividing the result by two.

6 WHIPLASH SEAT ASSESSMENT

Whiplash is assessed for both the front seats and the rear outboard seats. Front seats are tested statically and dynamically according to Euro NCAP Whiplash Testing Protocol. Rear seats are assessed according to the Euro NCAP Rear Whiplash Protocol. The details of the front seat(s) that will be tested by Euro NCAP are contained in Section 3.2.5 of the Euro NCAP Vehicle Specification, Sponsorship, Testing and Re-testing Protocol.

6.1 Front Seat Whiplash Assessment

6.1.1 Criteria and Limit Values

The basic assessment criteria used for front whiplash protection assessment, with the upper and lower performance limits for each parameter, are summarised below.

6.1.1.1 Static Assessments

6.1.1.1.1 Head Restraint Geometry Assessment

The assessment is based on the worst performing parameter from either the height or backset:

Higher performance limit:
Height: 0mm below top height of HPM & HRMD
Backset: 40mm

Lower performance limit:
Height: 80mm below top height of HPM & HRMD
Backset: 100mm

The geometric assessment will be based on the average height and backset taken from at least 9 measurements obtained across all of the seats provided for assessment. A minimum of three drops per seat shall be performed to ensure consistent measurements are obtained on each individual seat. Where obvious outlying HRMD/HPM measurements occur, further installations shall be undertaken on that seat to ascertain whether differences are due to the individual installation or seat to seat variability. Where a seat has a non-reversible head restraint and qualifies for a geometric assessment in the deployed position, additional seats shall be provided by the vehicle manufacturer for measurement.

The geometry assessment has two points allocated to it ranging from plus one to minus one.

6.1.1.1.2 Worst Case Geometry‡

1/n points (where n = the number of front seats) will be available for each front seat scoring more than 0 points in the worst case geometry assessment. For seats where the occupant must adjust the head restraint, the worst case geometry shall be measured in the lowest and rearmost position regardless of whether or not the seat is equipped with an active head restraint. The assessment will be based on the average height and backset taken from at least 9 measurements in the down and back position obtained across all of the seats provided for assessment. A minimum of 3 drops per seat shall be performed to ensure consistent measurements are obtained on each individual seat. Alternatively, a means of ensuring that the head restraint is correctly positioned for different sized occupants without specific occupant action shall be offered. For these automatically adjusting head restraints, the worst case geometry assessment shall be measured in the position as obtained in Section 5.6 of the Euro NCAP Whiplash Testing Protocol. This credit will only be available to seats performing well dynamically, with a raw score greater than 4.50 points after capping and all modifiers have been applied.

For the dynamic test of self adjusting head restraints, the seat should be set in the position as obtained in Section 5.6. of the Euro NCAP Whiplash Testing Protocol and the corresponding head restraint height should be used irrespective of whether this is the mid height position of the head restraint itself.

The individual front seats are scored separately for this feature as cars have been encountered in which different provisions are made for the driver and front passenger seats and the system also allows for cars with three front seats. Where the manufacturer can provide evidence that the front seats are equivalent in terms of the worst case geometry assessment, the seats will be scored equally. Where this is not the case, the manufacturer will be asked to provide an additional seat for assessment.

6.1.1.2 Dynamic Assessments

A sliding scale system of points scoring shall be applied with two limits for each seat design parameter, a more demanding higher performance limit, below which a maximum score is obtained and a less demanding lower performance limit, beyond which no points are scored. Where a value falls between the two limits, the score is calculated by linear interpolation.

The maximum score for each parameter is 0.50 points, with a maximum of 3 points available per test. For each of the tests, the score for each of the seven parameters is calculated. The overall score for a single dynamic test is the sum of the scores for NIC, Nkm, Head rebound velocity, neck shear and neck tension, plus the maximum score from either T1 acceleration or head restraint contact time (T-HRC-start). The high severity pulse will be subject to an additional seatback deflection assessment where a three point penalty will be applied to seats with a rotation of 32.0° or greater. In the medium term, seat translation may also need to be controlled but, for the interim solution,

‡ Formerly referred to as “Ease of Adjustment”.

only rotational control of the seat back is specified. The relevant performance criteria for each pulse are detailed below.

6.1.1.2.1 Low Severity Pulse

Criterion*	Higher performance	Lower performance	Capping Limit
NIC	9.00	15.00	18.30
Nkm	0.12	0.35	0.50
Rebound velocity (m/s)	3.0	4.4	4.7
Upper Neck Shear Fx (N)	30	110	187
Upper Neck Tension Fz (N)	270	610	734
T1 acceleration (g)	9.40	12.00	14.10
T-HRC (s)	61	83	95

* All parameters calculated until T-HRC-end, except rebound velocity.

6.1.1.2.2 Medium Severity Pulse

Criterion*	Higher performance	Lower performance	Capping Limit
NIC	11.00	24.00	27.00
Nkm	0.15	0.55	0.69
Rebound velocity (m/s)	3.2	4.8	5.2
Upper Neck Shear Fx (N)	30	190	290
Upper Neck Tension Fz (N)	360	750	900
T1 acceleration* (g)	9.30	13.10	15.55
T-HRC	57	82	92

* All parameters calculated until THRC-end, except rebound velocity.

6.1.1.2.3 High Severity Pulse

Criterion*	Higher performance	Lower performance	Capping Limit
NIC	13.00	23.00	25.50
Nkm	0.22	0.47	0.78
Rebound velocity (m/s)	4.1	5.5	6.0
Upper Neck Shear Fx (N)	30	210	364
Upper Neck Tension Fz (N)	470	770	1024
T1 acceleration* (g)	12.50	15.90	17.80
T-HRC	53	80	92
Seatback Deflection assessment	32.0°		

* All parameters calculated until THRC-end, except rebound velocity.

6.1.2 Front Whiplash Modifiers

6.1.2.1 Seatback Dynamic Deflection

The high severity pulse will be subject to an additional seatback deflection assessment where a three point penalty will be applied to the overall score where seats have a rotation of 32.0° or greater.

6.1.2.2 Dummy Artefact Loading

A two point negative modifier would be applied as a means of penalising any seat that, by design, places unfavourable loading on other body areas (e.g. preventing realistic ramping up) or exploits a dummy artefact.

6.2 Rear Seat Whiplash Assessment

The assessment criteria used for rear seat whiplash protection assessment, with the points scored for each parameter, are summarised below. Only outboard seating positions are assessed. Manufacturers will be asked to provide theoretical design data for R point position and torso angle of the two outboard seating positions. If these are the same to within the following tolerances,

R point position (vertical and horizontal): ±2.5mm
Torso angle: ±0.5°,

the two outboard seating positions will be considered symmetrical and only one position needs to be measured. Otherwise, the two outboard seating positions will be separately assessed. However, even in the case that manufacturer data indicates symmetry, the laboratory may assess the seating positions separately if they have reason to believe that the seats are not symmetrical.

6.2.1 Prerequisite

For a seating row to score points in the rear whiplash assessment, any centre seating position in that row needs to comply with the requirements of UN-ECE Regulation 17-08. This may be achieved by use of a separate head restraint or otherwise but, in any case, all vehicles in the model range must be equipped as standard with what is needed to ensure compliance. Manufacturers will be asked for evidence (approval, technical service report) that the rear centre seat complies with the requirements of UN-ECE Regulation 17-08. For example, a vehicle with 3 seating rows having a restraint as standard in row 2 but not standard in row 3 can score points for row 2 only.

Cars which have no rear centre seating position (4 seaters for example) will automatically fulfil this prerequisite.

6.2.2 Criteria and Limit Values

A maximum of four points is awarded for each seating position based on the Effective Height measurements, backset (ΔCP X) and non-use position. One and a half points are awarded if the height requirements are met. If the height requirements are met, an additional one point is awarded if the backset requirement is met in the mid head restraint position; a further half point is awarded if the backset is met in the worst-case position; and an additional point can be scored if the requirements for non-use position are met.

6.2.2.1 Effective Height requirements

The seating position shall be deemed to have met the height requirements of this protocol if either paragraph 6.2.2.1.1 or 6.2.2.1.2 is met.

6.2.2.1.1 The requirements of this paragraph are met if the effective height of the head restraint meets the requirements of both the following:

- The effective height of the restraint is, in its lowest position, no less than 720mm
- The effective height of the restraint is, in its highest position, no less than 770mm§.

6.2.2.1.2 If the interior surface of the vehicle roofline, including the headliner or backlight, physically prevents a head restraint located in the rear outboard designated seating position from attaining the height required by paragraph **6.2.2.1.1** of this protocol, the gap between the head restraint and interior surface of the roofline, including the headliner or the backlight when measured as described below, shall not exceed 50mm when the head restraint is adjusted to its highest position intended for occupant use:

- If adjustable, adjust the head restraint to its maximum height and measure the clearance between the top of the head restraint or the seat back at all seat back angles for intended use and the interior surface of the roofline or the rear backlight, by attempting to pass a 50 ± 0.5mm sphere between them.

6.2.2.2 Backset Requirements

Using the torso angle, the calculated limit value of backset $(\Delta CP\ X)_{LIMIT}$ is determined using the following formula:

$$(\Delta \boldsymbol{CP\ X})_{\boldsymbol{LIMIT}} = \mathbf{7.128} \cdot \boldsymbol{Torso\ angle} + \mathbf{153}$$

This limit value is applied in both mid and worst case position.

§ Euro NCAP will monitor legislative requirements and may revise this figure in future years.

6.2.2.3 Non-Use Position Assessment

6.2.2.3.1 Automatic Return Head Restraints

The head restraint needs to automatically go to the use-position from the non-use position at ignition on or when the engine is started.

6.2.2.3.2 60° Rotation Evaluation

The difference in head restraint angle needs to be larger than 60° between the in-use and non-use position. Rearward rotation or retraction of the head restraint to set the non-use position is not compliant with the requirements of this section.

6.2.2.3.3 10° Torso Line Change

The difference in torso angle between the in-use and non-use position needs to be larger than 10°.

6.2.2.3.4 Discomfort Metric

The lower edge of the head restraint (H_{LE}) shall be not more than 460 mm, but not less than 250 mm from the R-Point and the thickness (S) shall not be less than 40 mm.

6.3 Scoring

6.3.1 Front Whiplash Score

6.3.1.1 Raw Score

The protocol allows for a maximum score of 11 points as a result of carrying out the three severities of whiplash test, assuming no negative modifiers have been applied. This score is known as the raw score and its components are explained below.

Each severity of whiplash test pulse results in a maximum of 3 points being awarded based on the measured criteria. Half a point is awarded for each of NIC, Nkm, Head rebound velocity, F_x and F_y. A further half point is awarded on the basis of the best score from either T1 acceleration or head restraint contact time (T-HRC).

If any of NIC, Nkm, Head rebound velocity, neck shear or tension exceed the capping limit, no score is given for that pulse. Additionally, if both T1 and head restraint contact time exceed the lower performance limit and either one also exceeds the relevant capping limit, no score is given for the pulse. The sum of the scores from the dynamic tests is then subject to the application of the modifiers.

	Points available
Static assessments	
HR geometry	*-1 to +1 points*
Worst case geometry	*1 point*
Dynamic assessments	
Low severity pulse	*3 points*
Medium severity pulse	*3 points*
High severity pulse	*3 points*
Modifiers	
Seatback deflection	*-3 points*
Dummy artefact loading	*-2 points*
Maximum points	***11 points***

6.3.1.2 Scaled Front Whiplash Score

The raw score is scaled to a maximum of 1.5 points by dividing it by 11. Scaled scores less than zero are set to zero points.

6.3.2 Rear Whiplash Score

6.3.2.1 Raw Score

Seat rows having a rear centre seating position meeting the prerequisites of 6.2.1 can score points for geometry and non-use position according to the following paragraphs.

The rear whiplash score for each seat is the sum of its geometry assessment score and its non-use position assessment score. The rear whiplash score is the sum of the scores for the two rear outboard seats (double the score for one seat in the case of symmetric seating positions).

For a vehicle with a third row the scores of the second and third row are added and scaled to a maximum of 1 point. Vehicles with no subsequent seating positions after the front row are excluded from the assessment.

6.3.2.1.1 Geometry Assessment Score

Parameter		**Score** (per seating position)
Effective Height		**1.5**
$(\Delta CP\ X)^*_{mid}$	**<= $(\Delta CP\ X)_{LIMIT}$**	**1**
	> $(\Delta CP\ X)_{LIMIT}$	**0**
$(\Delta CP\ X)^*_{wc}$	**<= $(\Delta CP\ X)_{LIMIT}$**	**0.5**
	> $(\Delta CP\ X)_{LIMIT}$	**0**

** Points can be scored for backset only if the Effective Height requirements are met.*

6.3.2.1.2 Non-Use Position Score

As a prerequisite for scoring for the Non-Use Position, the height and backset assessment needs to score more than 0 points.

If the head restraint is always in a use position, and scores more than 0 points for geometry, the seating position scores 1 point. Seating positions with a non-use position compliant with one of the procedures described in 6.2.2.3 and which score more than 0 points for geometry also score 1 point. If no points are scored for geometry, no points can be scored for use/non-use positions.

6.3.2.2 Scaled Rear Whiplash Score

The raw score is scaled to half a point by multiplication by dividing it by 4n where n is the number of rear outboard seating positions.

6.4 Visualisation

The front and rear whiplash scores are presented separately is using a coloured head and neck graphic. The colours used are based on the front seat and rear seat scores respectively, rounded to three decimal places.

6.4.1 Front Whiplash Visualisation

For whiplash, the protection provided for the neck of a front seat adult occupant is presented visually using a coloured head and neck graphic. The colour used is based on the scaled points (rounded to three decimal places), as follows:

Green	'Good'	1.000 - 1.500 points
Orange	'Marginal'	0.500 – 0.999 points
Red	'Poor'	0.000 - 0.499 points

6.4.2 Rear Whiplash Visualisation

The protection provided for the neck of the rear seat occupant is presented visually using a coloured head and neck graphic. The colour used is based on the scaled points (rounded to three decimal places), as follows:

Green	'Good'	0.375 – 0.500 points
Orange	'Marginal'	0.188 – 0.374 points
Red	'Poor'	0.000 – 0.187 points

7 ASSESSMENT OF AEB CITY SYSTEMS

7.1 Introduction

For the assessment of AEB City systems, the AEB function is assessed using a stationary Global Vehicle Target in a speed range of 10-50km/h combined with an overlap range of -50%-50%.

7.2 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.

Car-to-Car Rear Stationary (CCRs) – a collision in which a vehicle travels forwards towards another stationary vehicle and the frontal structure of the vehicle strikes the rear structure of the other.

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

Global Vehicle Target (GVT) – means the vehicle target used in this protocol as specified in Annex A of the AEB test protocol.

Vrel_test – means the relative speed between the VUT and the GVT by subtracting the velocity of the GVT from that of the VUT at the start of test.

Vimpact – means the speed at which the VUT hits the GVT.

Vrel_impact – means the relative speed at which the VUT hits the GVT by subtracting the velocity of the GVT from Vimpact at the time of collision.

7.3 Criteria and Scoring

AEB City points are awarded only when the following preconditions are met:

- Whiplash score for the front seat is at least 1.0 points or "Good" (from section 6.3.1).
- The AEB system needs to be default ON at the start of every journey and de-activation of the AEB system should not be possible with a single push on a button.
- Full avoidance needs to be achieved for test speeds up to and including 20 km/h for all overlap situations, which is verified by one randomly selected testpoint.

7.3.1 Assessment Criteria

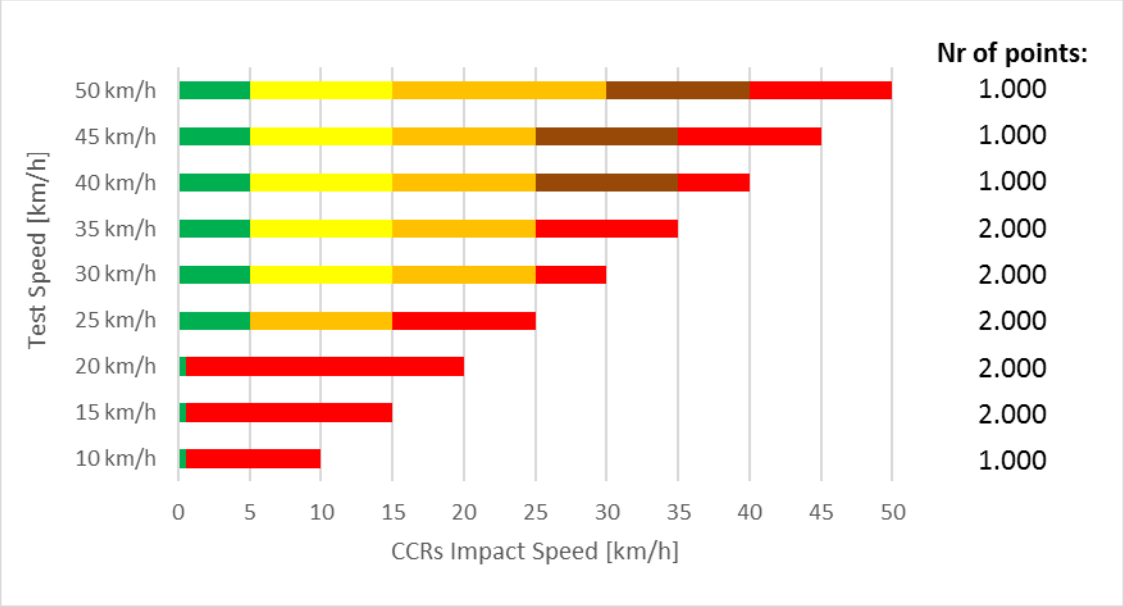
For the AEB function tests, the assessment criteria used is the relative impact speed Vrel_impact.

7.3.2 Scoring

A maximum of 4 points is available for AEB City. The total score for all five grid points per test speed is calculated as a percentage of the maximum achievable score per test speed, which is then multiplied by the points available for this test speed. It should be noted that the 100% overlap score is double counted.

The total amount of points is subsequently scaled from a maximum 14 points down to 4 points available for AEB City.

The points available and the colour distribution for the different test speeds for CCRs are detailed in the graph below:



For each predicted colour the following scaling is applied to the grid point:

Green	*1.000*
Yellow	*0.750*
Orange	*0.500*
Brown	*0.250*
Red	*0.000*

7.3.3 AEB City 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 vehicle sponsor will fund 10 verification tests. The vehicle manufacturer has the option of sponsoring up to 10 additional verification tests for AEB City.
The verification points are randomly selected grid points, distributed in line with the predicted colour distribution (excluding red points).

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. The final score for the vehicle can never exceed 100% (4 points) regardless of the correction factor.

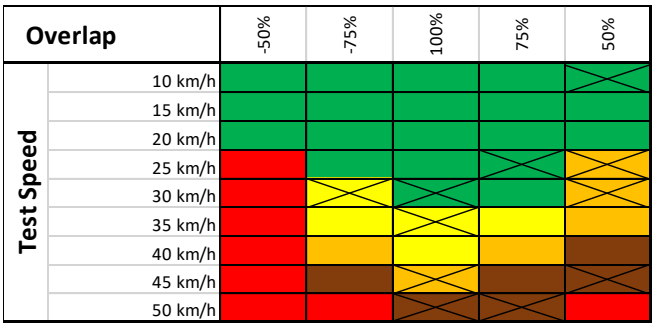
7.3.4 Impact speed tolerance

As test results can be variable between labs and in-house tests and/or simulations a 2 km/h tolerance to the impact speeds 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 impact speed with the colour band in section 7.3.2 without applying a tolerance to the impact speed. As an example the accepted impact speed ranges for the 45km/h tests are as follows:

Prediction	***Impact speed range [km/h]***	***Accepted range [km/h]***
Green	$0 \leq v_{impact} < 5$	$0 \leq v_{impact} < 7$
Yellow	$5 \leq v_{impact} < 15$	$3 \leq v_{impact} < 17$
Orange	$15 \leq v_{impact} < 25$	$13 \leq v_{impact} < 27$
Brown	$25 \leq v_{impact} < 35$	$23 \leq v_{impact} < 37$
Red	$35 \leq v_{impact}$	*excluded*

7.3.5 Scoring Example

Manufacturer X has provided the following prediction to Euro NCAP, where the predicted score is 2.845 points:



PREDICTION						
CCRs	Green	Yellow	Orange	Brown	Red	Points
10 km/h	6				0	1.000
15 km/h	6				0	2.000
20 km/h	6				0	2.000
25 km/h	4		1		1	1.500
30 km/h	3	1	1		1	1.417
35 km/h	0	4	1		1	1.167
40 km/h	0	2	2	1	1	0.458
45 km/h	0	0	2	3	1	0.292
50 km/h	0	0	0	3	3	0.125
Predicted AEB City score						**2.845**

Where the predicted AEB City score is calculated by scaling the total amount of points from a maximum of 14.000 points to a maximum score of 4.000.

The randomly chosen verification points and test results are:

VERIFICATION				
Testpoint	Prediction	Points	Impact Speed	Points
50,75		0.250	27.58	0.500
35,100		0.750	3.01	0.750
30,100		1.000	6.99	1.000
30,-75		0.750	10.20	0.750
45,50		0.250	36.25	0.250
25,75		1.000	0.00	1.000
50,100		0.250	29.85	0.250
25,50		0.500	8.00	0.500
45,100		0.500	27.58	0.250
30,50		0.500	12.85	0.750
Total		**5.750**		**6.000**

$$Correction\ Factor = \frac{Actual\ tested\ score}{Predicted\ score} = \frac{6.000}{5.750} = 1.043$$

a) The FINAL AEB City score is: 2.845 x 1.043= 2.968 points

8 CONCEPTS BEHIND THE ASSESSMENTS

8.1 Frontal Impact

8.1.1 Head

CONCEPT*: The driver's head should be predictably restrained by the airbag, and should remain protected by the airbag during the dummy's forward movement. There should be no bottoming out of the airbag.*

CONCEPT: *Hazardous airbag deployment*
The deployment mode of the airbag should not pose a risk of facial injury to occupants of any size.

CONCEPT: *Incorrect airbag deployment*
All airbags that deploy during an impact should do so fully and in the designed manner so as to provide the maximum amount of protection to occupants available. It is expected that, where required, all airbags should deploy in a robust manner regardless of the impact scenario.

CONCEPT*: Geometric control of steering wheel movement is needed to ensure that the airbag launch platform remains as close as possible to the design position, to protect a full range of occupant sizes.*

8.1.2 Neck

CONCEPT: *Neck injuries are frequent, but relatively little is known about appropriate injury criteria. The neck criteria recommended by EEVC are used to identify poorly designed restraint systems. It is not expected that many cars will fail these requirements.*

In addition to the EEVC recommended limits, additional ones have been added, at the request of the car manufacturers. It is assumed that good restraint systems will have no problems meeting these criteria.

8.1.3 Chest

CONCEPT*: Rib compression is used as the main guide to injury risk. It is expected that the Viscous Criterion will only identify cars with poorly performing restraint systems.*

The injury risk data is relevant for seat belt only loading rather than combined seat belt and airbag loading. No change is made in the event of combined seat belt and airbag restraint. This avoids value judgements about the extent of airbag restraint on the chest and is in line with the EEVC recommendation.

CONCEPT: *There is an interrelationship between chest loading, as measured by the above dummy criteria, and intrusion. To ensure that a good balance is struck, a geometric criterion on waist level intrusion, as measured by door pillar movement at waist level, is used.*

CONCEPT: *When the passenger compartment becomes unstable, any additional load can result in unpredictable excessive further collapse of the passenger compartment. When the passenger compartment becomes unstable the repeatability of the car's response in the test becomes poor and confidence in the car's performance is reduced.*

CONCEPT: *The chest performance criteria are developed for loads applied by a seat belt. The more concentrated loading from a "stiff" steering wheel exposes the chest to direct loading injury.*

8.1.4 Abdomen

Protection of the abdomen is important, but no criteria or assessment techniques are available at present.

8.1.5 Knee, Femur & Pelvis

CONCEPT*: Transmitting loads through the knee joint from the upper part of the tibia to the femur can lead to cruciate ligament failure.*

Zero knee slider displacement is both desirable and possible. The higher performance limit allows for some possible movement due to forces transmitted axially up the tibia.

CONCEPT: *The knee impact area should have uniformly good properties over a wide area of potential impact sites. This is to account for people sitting with their knees in different positions and slight variations in impact angle. The characteristics of the area should not change markedly if knee penetration is slightly greater than that observed with the 50 percentile dummy in this test. This takes into account the protection of different sized occupants or occupants in different seating positions.*

CONCEPT*: Loading on the knee should be well distributed and avoid concentration that could result in localised damage to the knee.*

The injury tolerance work that supports the legislative femur criterion was conducted with padded impactors that spread the load over the knee.

8.1.6 Lower Leg

CONCEPT: *Loads resulting in fracture of the tibia produce bending moments and forces measurable at the upper and lower ends of the tibia. These measurements on the tibia relate to risk of tibia fracture.*

At the request of the car manufacturers, further limits were added to those proposed for lower leg protection. These limits can be expected to help protect the ankle joint.

CONCEPT: *Pedal blocking*
There should be no blocking of any foot operated pedals which have displaced rearward after the impact; blocked pedals represent a greater hazard to the lower limbs of the driver than non-blocked pedals.

8.1.7 Foot and Ankle

CONCEPT: *Expert opinion suggests that a Tibia Index of less than 0.2 would be necessary to prevent ankle joint failure. Until a biofidelic ankle and foot become available, the assessment will be based on intrusion. Intrusion is highly correlated with the risk of injury.*

CONCEPT*: Rupture of the footwell exposes the occupant to additional dangers. Objects outside the passenger compartment may enter, parts of the occupant may contact items outside the passenger compartment, there is a risk from exposed edges and the structure may become unstable.*

8.2 Side and Pole Impact

CONCEPT: *Incorrect airbag deployment*
All airbags that deploy during an impact should do so fully and in the designed manner so as to provide the maximum amount of protection to occupants available. It is expected that, where required, all airbags should deploy in a robust manner regardless of the impact scenario.

CONCEPT: *Seat position in side impact*
Effective side impact protection needs to consider all sizes of occupants. This concept is included in the EU Directive. Currently, side impact tests are conducted with the seat in the design position. In future, consideration may be given to the level of protection in other seating positions.

8.3 Door Opening (Front, Side, Pole Impact)

CONCEPT: *The intention is to ensure that the structural integrity is maintained. The underlying principle is to minimise the risks of occupant ejection occurring.*

The 'door opening' modifier will be applied if any of the following have occurred:

- the latch has fully released or shows significant partial release, either by release of its components from one another, or effective separation of one part of the latch from its supporting structure
- the latch has moved away from the fully latched condition
- if any hinge has released either from the door or bodyshell or due to internal hinge failure
- if there is a loss of structure between the hinges and latches
- if door or hinges fail whilst the door opening tests are being conducted post impact, as loading from an occupant could have a similar effect.
- if there was any potential risk of occupant ejection and/or partial ejection/entrapment from openings such as sliding doors or moveable roofs. Dynamic opening during the impact of any apertures, such as roofs, will also be considered even if the openings have closed post test.
- if both side doors latch together with no b-pillar or other form of restraint, the modifier may apply to both the front and rear doors.

8.4 Whiplash

8.4.1 Geometry Assessment

CONCEPT: *This is used to encourage front seats to have optimum geometry in terms of both height and backset.*

8.4.2 Worst Case Geometry

CONCEPT: *The head restraint should be ideally placed for optimal dynamic performance without occupants of different size taking any action other than simply adjusting the seat to suit their leg length. This implies that the head restraint should either be fixed, automatically adjust to the optimal position or should be an adjustable restraint that provides optimum position even in its fully down (worst case) position.*

8.4.3 Seatback Dynamic Deflection

CONCEPT: *The seat distortion should be controlled so that a front occupant is not liable to ejection from behind the seat belt in a rear impact and the risk of interaction between the front and rear occupants is minimised.*

8.4.4 Dummy Artefact Loading

CONCEPT: *A two point negative modifier will be applied to any seat that, by design, places unfavourable loading on other parts of the body as a result of the head restraint mechanism. This modifier shall also penalise any design feature aimed at exploiting any dummy artefact. This is seen as a clear incentive to avoid such design, and an essential feature to safeguard Euro NCAP's position for future designs.*

9 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 ECE Regulation 12 Revision 3 - Uniform Provisions Concerning the Approval of Vehicles With Regard To the Protection of the Driver against the Steering Mechanism in the Event of Impact. 1994.

4 Mertz, H. *Anthropomorphic test devices.* Accidental Injury - Biomechanics and Prevention, Chapter 4. Ed. Alan Nahum and John Melvin. Pub. Springer-Verlag 1993.

5 Mertz, H., J. Horsch, G. Horn and R Lowne. *Hybrid III sternal deflection associated with thoracic injury severities on occupants restrained with force-limiting shoulder belts.* SAE paper 910812. 1991.

6 Wall, J., R. Lowne and J. Harris. *The determination of tolerable loadings for car occupants in impacts.* Proc 6th ESV Conference. 1976

7 Viano, D., C. Culver, R. Haut, J. Melvin, M. Bender, R. Culver and R. Levine. *Bolster impacts to the knee and tibia of human cadavers and an anthropomorphic dummy.* SAE Paper 780896, Proc 22nd Stapp conference.

8 EEVC WG. *The Validation of the EEVC Frontal Impact Test Procedure.* Proc 15th ESV Conference, Melbourne, 1996.

9 Schneider, L.W., Vogel, M. and Bosio, C.A. Locations of driver knees relative to knee bolster design. The University of Michigan Transportation Research Institute, Ann Arbor, Michigan. UMTRI-88-40. September 1988.

10 Lowne, R. and E. Janssen. *Thorax injury probability estimation using production prototype EUROSID.* ISO/TC22/SC12/WG6 document N302.

APPENDIX I

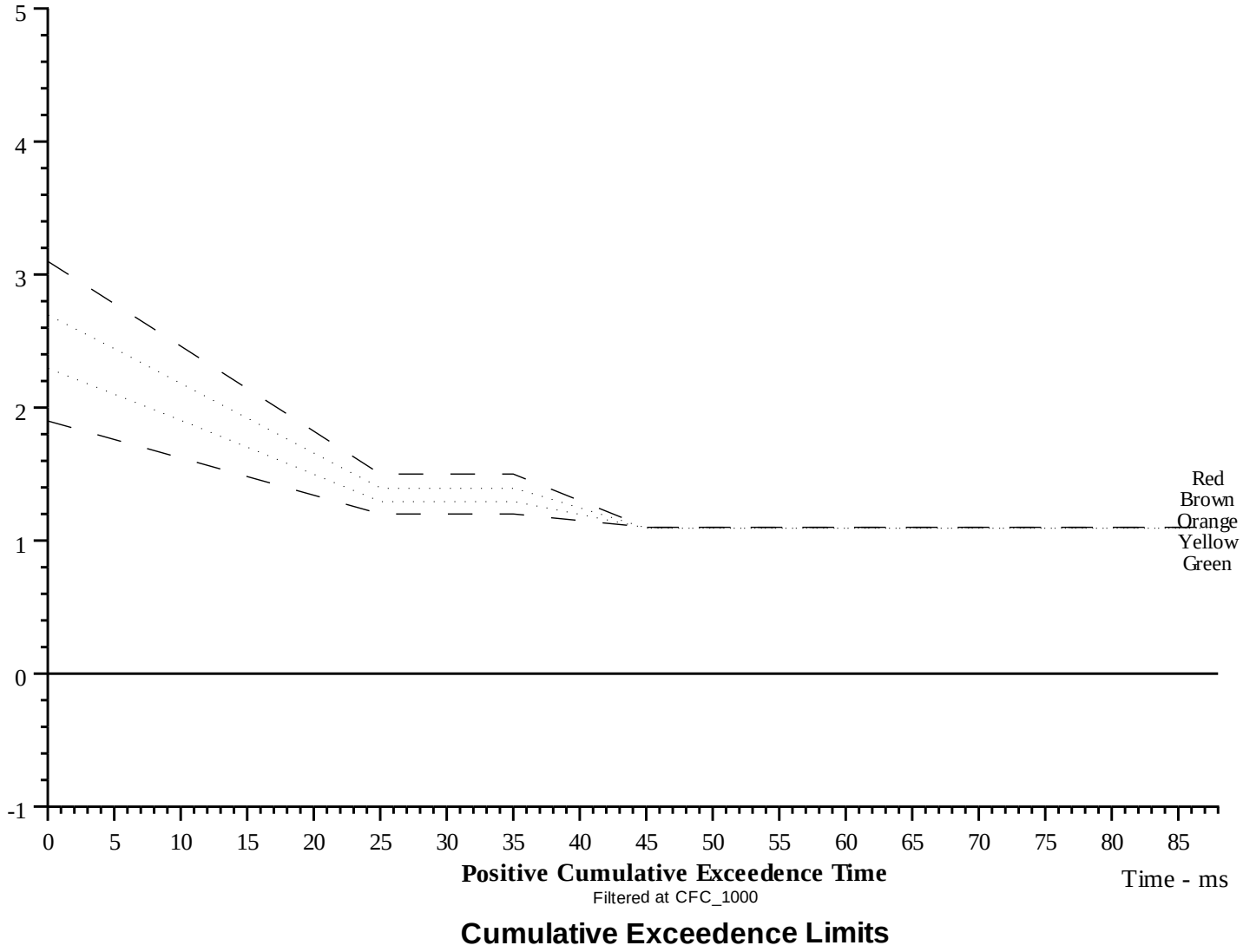
GRAPHICAL LIMITS FOR CUMULATIVE EXCEEDENCE PARAMETERS

1 Upper Neck Shear FX - Positive

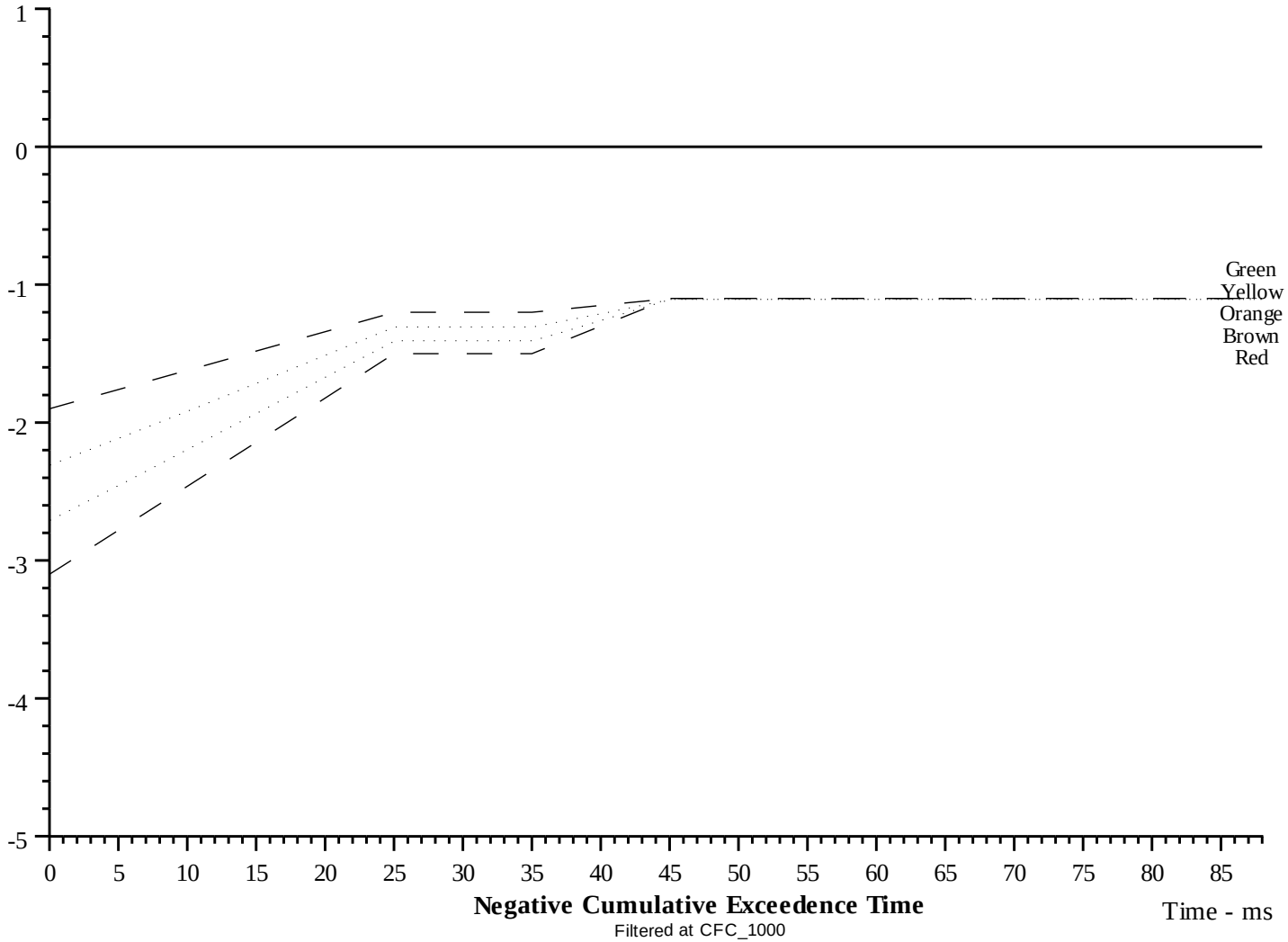
2 Upper Neck Shear FX - Negative

3 Upper Neck Tension FZ

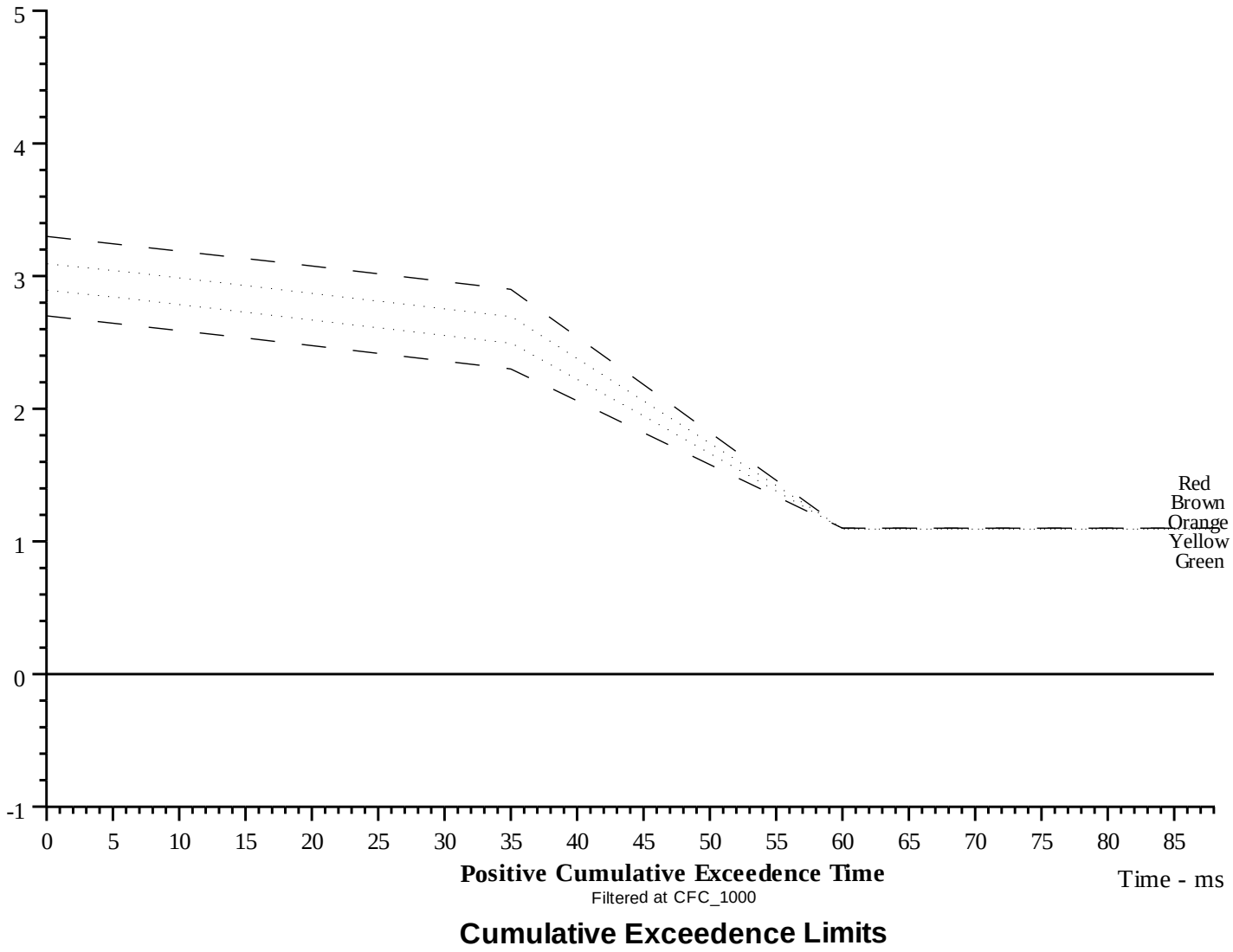
4 Femur Compression



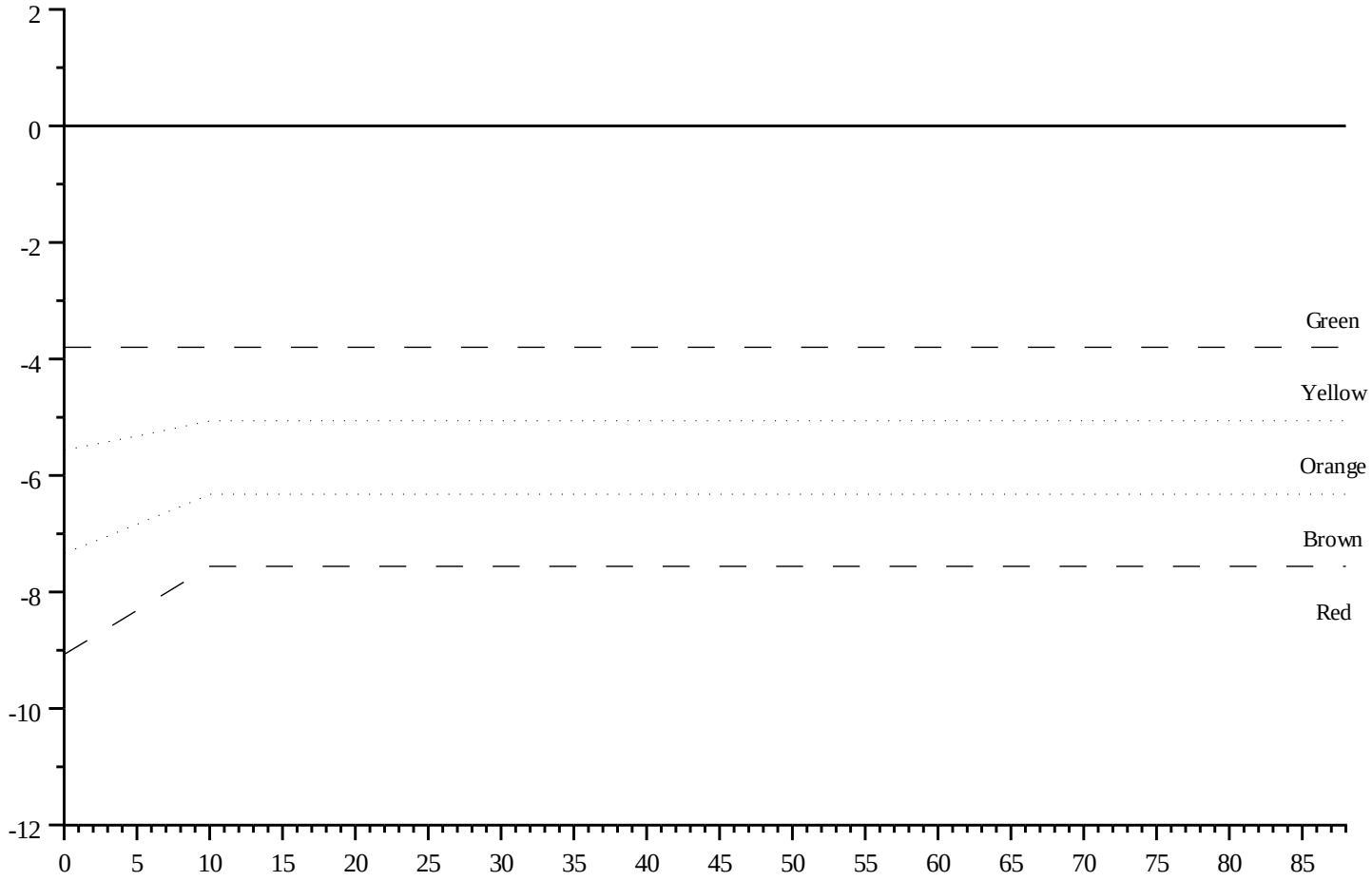
Cumulative Exceedence Limits



Cumulative Exceedence Limits



Cumulative Exceedence Limits



Cumulative Exceedence Limits