CRASH TESTS TO ASSESS THE SECONDARY SAFETY OF A LARGE MPV

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ABSTRACT

Multi Purpose Vehicles (MPVs) have gained great popularity for many years. But up to now there are still lacks of published results showing the crash test performance of such vehicles. To assess the secondary safety of the large MPV Mercedes-Benz Viano, DEKRA conducted 3 crash tests according to the Euro NCAP test protocol: a 64-kph-40-%-ODB frontal crash, a 50-kph-MDB side impact and a 29-kph-pole side impact.

The tested model was a 2005 Viano 2.0 CDI Trend with a wheelbase of 3,200 mm and a kerb weight of 2,065 kg. The paper describes the tests and the tested vehicle with its relevant safety features. The test results are shown with special attention to the dummy loads and their assessment including modifiers according to the Euro NCAP protocol. The overall rating of the vehicle is 5 stars for adult occupant safety and 4 stars for child protection. With this background the articles gives also new information on what is state-of-the-art for secondary occupant safety in this vehicle class.

TEST VEHICLE

The crash tests were carried out on a new series Mercedes-Benz Viano, made in 2005, Fig. 1.

The manufacturer offers this six-seater vehicle in 3 versions. The compact variant has a length of 4,748 mm while the long- and extra-long variants have lengths of 4,993 mm and 5,223 mm respectively. The corresponding wheelbases are 3,200 mm for the compact- and long versions and 3,430 mm for the extra-long version. Depending upon the installed engine and equipment fitted, the kerb weight as determined in accordance with DIN 70020 lies within the range 2,020 - 2,195 kg while the gross vehicle mass lies between 2,770 and 2,940 kg.

The particularly popular model 2.0 CDI Trend was chosen for the crash tests, Fig. 2 - the actual vehicle being the long version with a wheelbase of 3,200 mm, an empty weight of 2,065 kg and a gross vehicle mass of 2,770 kg. The total weight of the vehicle when prepared for testing amounted to 2,290 kg for the frontal impact, 2,158 kg for the side-impact with a moving barrier and 2,222 kg for the side-impact on a vertical pole.

Figure 1. Variants of the Mercedes-Benz Viano

Figure 2. Test vehicle Mercedes-Benz Viano 2.0 CDI Trend

The safety equipment of the Mercedes-Benz Viano includes a body with high-strength passenger cell and a support structure capable of accepting very high loads, Fig. 3. This ensures the preservation of the survival space for the occupants in the event of a frontal collision, a side-collision, rear collision and a rollover. Energy-absorbing deformation zones, e.g. in the frontal area, contribute to a low level of loading being imposed upon the occupants.

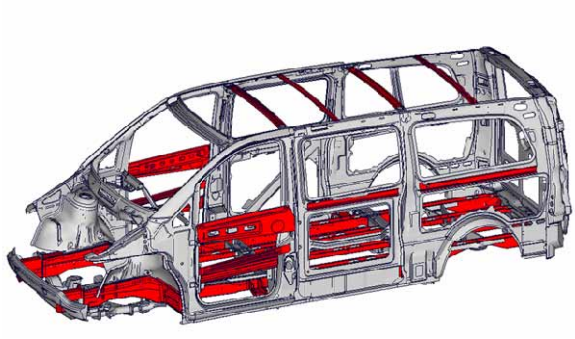

Figure 3. Structure of the body in white

All the seats are fitted with 3-point safety belts. The systems for the driver and the front-seat passenger include a belt tensioner and a belt-force limiter. Front airbags for the driver and the front-seat passenger are provided also in series production models, Fig. 4. Window airbags and thorax airbags can be provided for the driver and the front-seat passenger as optional fittings.

Seat Belt Reminders for the front seats form part of the series equipment for the Viano, too.

Figure 4. Airbags

TEST PROCEDURE

The tests were carried out in accordance with the requirements of the Euro NCAP Test Protocol, (August, 2005 Version) [1].

Frontal impact

In case of the frontal-impact test this takes place at 64.1 km/h with a frontal overlap of 40% with respect to the deformation element (ECE-R 94) on the fully rigid impact block, Fig. 5.

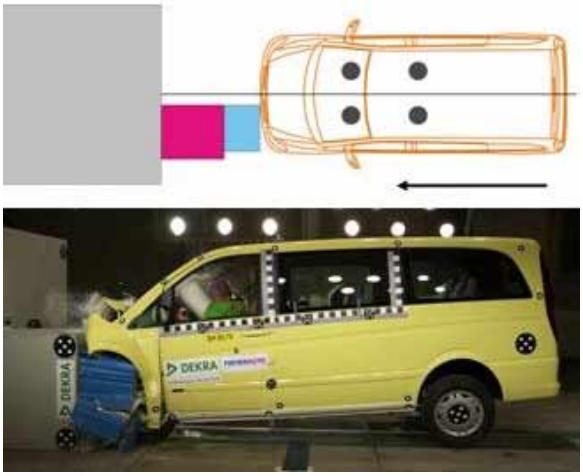

Figure 5. Frontal impact

In this test the vehicle was occupied by an adult dummy Hybrid III, 50th percentile male in both the driver seat and the front-passenger seat. Behind these in the second-row seats were two child dummies, Fig. 6. A P3 Dummy (a 3-year old child) was in the forward-facing seat (Römer Duo Plus) directly behind the driver. Behind the front-seat passenger was a P1 ½ Dummy (a child 1 ½ years old) in a rear-facing child seat (Römer Baby Safe Plus).

Figure 6. Child dummies P 3 and P 1 ½

To measure the deceleration of the vehicle a three-axial sensor was mounted in the lower area of the B-pillar of the vehicle. A further three-axial sensor was mounted on the seat-rails of the second row of seats. Other sensors measured the tensile force in the shoulder belts of the driver and front-seat passenger.

Six high-speed cameras recorded the sequence of motion in the crash test as observed in a horizontal direction from both the left- and the right-hand sides; two high-speed cameras were employed for downward observation recordings and one high-speed camera for upward observation from the filming pit.

Side-impact tests

Moving barrier impact

During the first side-impact test the moveable barrier (with a mass of 944 kg and a deformable front element in accordance with ECE-R 95) impacted the side of the stationary test vehicle at a speed of 50.3 km /h, Fig. 7. As required by the regulations, at the time of the impact the projection of the central vertical line of the barrier met the so-called "R-Point" of the vehicle. The test vehicle was occupied by an adult dummy on the driver side and two child-dummies in the second row of seats. As required by the testing procedure, on this occasion the P3 dummy was behind the front-seat passenger and the P1 ½ dummy behind the driver.

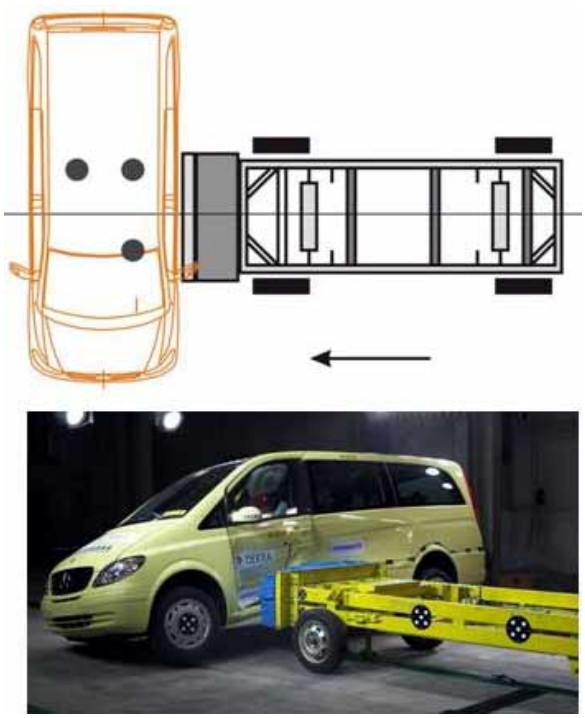

Figure 7. Side impact with moving barrier

As for the frontal-impact test, to measure the deceleration of the vehicle three-axial deceleration sonsors were mounted on the B-pillar and on the seat rails of the second row of seats.

Seven high-speed cameras recorded the sequence of motion during the test as seen from several sides in a horizontal direction. One high-speed camera was used to record what happened in a downward-looking direction.

Pole impact

Since the Mercedes-Benz Viano can be fitted with side airbags for the head as an optional feature, an additional test conforming to the conditions imposed by Euro NCAP was carried out. This involved a side-impact collision of the test vehicle against a rigidly mounted pole (with a diameter of 254 mm), Fig. 8. The impact speed was 29.1 km/h.

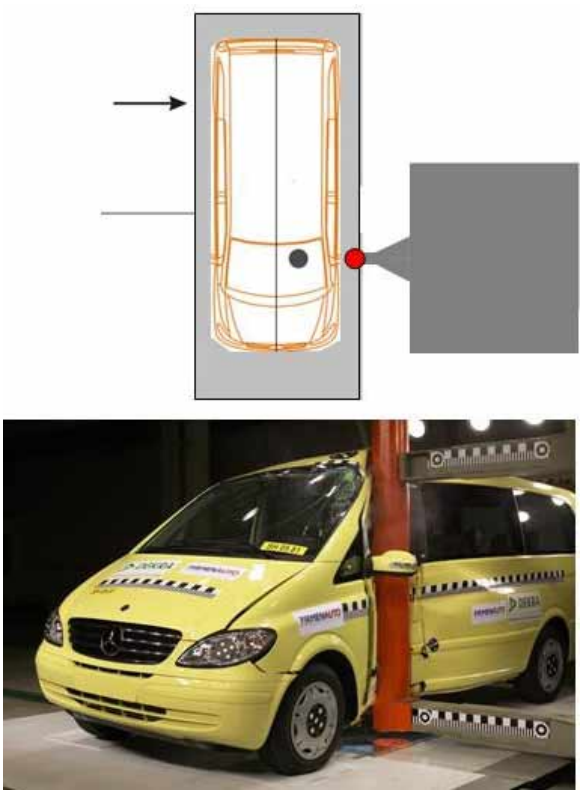

Figure 8. Impact with vertical pole

In the test vehicle the driver was represented by a EuroSid 2 (ES2) Dummy. As required by the conditions prescribed by Euro NCAP the vehicle impacted in such a manner that in the absence of an airbag the pole would have come into direct contact with the head of the driver in the projected direction of its centre of gravity.

In this test also, the measurement of the deceleration of the vehicle was made by three-axial deceleration sensors mounted on the B-pillars and the seat-rails of the second row of seats.

Five high-speed cameras were used to document the movement sequence as seen from several sides in a horizontal direction, one high-speed camera was used for the downward looking recording and another high-speed camera for the upward-looking recording made from the filming pit.

TEST RESULTS

Frontal impact

Fig. 9 shows the test vehicle after the frontal impact. Both front airbags and the belt tensioners for the driver and the front-seat passenger were activated in the manner expected in the event of such a crash. As a result of the deformation caused by the crash the overall length of the left side of the vehicle was reduced by 643 mm while the right-hand side increased in length by 52 mm. In a corresponding manner, the wheelbase on the left-hand side was reduced by 305 mm while on the right-hand side it was increased by 175 mm.

Figure 9. Test vehicle after frontal impact

The A-columns were displaced to only a very slight extent. The survival space for the occupants remained almost entirely intact. Table 1 contains the values for the displacement of the steering wheel, the brake-, clutch- and accelerator pedals in the horizontal- (x), sideways- (y) and vertical (z) directions. No rupture developed in the area of the underbody and splashboard. The bonnet crumpled and did not penetrate into the compartment. During the collision the doors remained closed. After the test the doors could be opened by hand without using tools.

Table 1.
Displacement of steering wheel and pedals

	Steering wheel	Accele-ration pedal	Brake pedal	Clutch pedal
Displacement x [mm]	13	24	59	48
Displacement y [mm]	10	42	2	40
Displacement z [mm]	1	17	42	31

The loads experienced by the dummies in the driver and front passenger seats (both H III) are given in Table 2.

Table 2.
Driver and passenger dummy loads (H III)

Body region	Dummy measured Value	Driver	Pass-enger
	$a_{res, max}$ [g] $a_{res, 3 ms}$ [g] HIC_{36} [-]	51.59 51.01 386	50.0 49.41 396
Neck	F_{shear} [kN] $F_{tension}$ [kN] $M_{retro\ flexio}$ [Nm]	0.26 1.08 7.58	0.27 0.89 8.98
Chest	Compression [mm] VC [m/s]	**33.60** 0.16	**32.73** 0.12
Knee left	Displacement [mm]	0.86	0.67
Knee right	Displacement [mm]	0.90	0.71
Femur left	$F_{compressive}$ [kN]	3.18	2.13
Femur right	$F_{compressive}$ [kN]	2.78	1.62
Lower-leg left	$F_{compressive}$ [kN] Upper Tibia Index Lower Tibia Index	0.74 0.35 0.26	1.19 0.39 0.23
Lower-leg right	$F_{compressive}$ [kN] Upper Tibia Index Lower Tibia Index	0.42 0.29 0.29	1.38 0.28 0.26

With the exception of the chest compression all the measured loads on the dummies lie below the limiting values which are graded by Euro NCAP as the higher performance limits. Therefore, in this instance the best possible (highest) evaluation points (4.00) were awarded for the protection afforded to the two body areas of head and neck as well for the knee, femur and pelvis. The total points for the driver and the front seat passenger thus amounts to 8.00 each.

In Table 2, the loads experienced by the lower legs of the dummies were also below the relevant higher performance limits. In addition, the evaluation of the protection afforded to the occupants in respect of the accelerator pedal displacement on the driver's side was taken into account. Since here, too, no critical values were recorded, the level of occupant protection provided for the body regions of lower leg, feet and ankles was assessed as being the best possible and justifying a points rating of 4.00 each for the driver and the front-seat passenger.

In the case of the chest compression of the driver dummy (33.6 mm) and the passenger dummy (32.73 mm), the Higher Performance Limit of 22 mm was exceeded. In that situation the evaluation points for this body region have to be determined by reference to an appropriate so-called sliding scale. For example, as shown in Fig. 10, the driver dummy receives 2.34 points while his front-seat passenger receives 2.47.

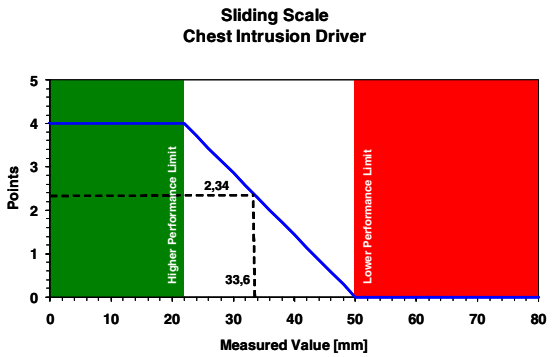

Fig. 10. Assessment of the protection level relating to compression of the driver's chest

This means that the total points scored for protection of all regions of the body of the occupants as assessed by Euro NCAP amounted to 14.34 for the driver and 14.47 for the front-seat passenger compared with a corresponding possible maximum of 16.00.

In the further evaluation procedure specified by Euro NCAP, account was taken of the so-called modifiers. These can lead to a subsequent reduction of the evaluation points initially awarded.

Deductions are made in respect of the head if an unstable airbag contact or an airbag burst is detected by the high-speed cameras. This was not the case in the tests carried out. Consequently the awarded maximal point total of 4.0 actually represents the end-result for occupant protection afforded to the driver and the front-seat passenger.

Where the chest area is concerned, an unstable behaviour of the vehicle structure or contact with the steering wheel and displacement of the A-pillars can lead to a doubled modifier-deduction. Similarly, instabilities in the foot area - for example, a rupture in the floor plate - can lead to a modifier-deduction. None of these situations developed in the tests that were carried out. This means that once again no modifier deduction was necessary. As far as the feet were concerned the awarded maximal point score of 4.00 – as was the case for the driver chest area with a point score of 2.34 and the front-seat passenger of 2.47 – also represent the final result for the overall evaluation of the degree of safety available to the occupants of the vehicle.

A particularly critical view was taken of knee area problems in a collision situation. Medical personnel treating accident victims have reported that in real-life crash situations involving transporters of up to 3.5 t gross vehicle mass, injuries to the lower extremities - characterised by fractures adjacent to the knee-joint as well as direct knee injuries - present a significant problem [2].

The evaluation procedure prescribed by Euro NCAP provides that account be taken of concentrated loads or varied contact conditions involving the knee area of the driver and front-seat passenger in collision situations since these can result in aggravated risks of injury. This means that - although the measured values experienced by the dummies do not reflect a corresponding objective degree of risk - associated modifier-deductions come into play. To be able to assess this factor it is necessary to carry out a detailed analysis of the structure of the vehicle in the knee-impact area, including areas underneath the external panelling. The relevant knee-impact areas for the passenger are illustrated in Fig. 12. The corresponding area for the front-seat passenger is shown in Fig. 11.

As can also be demonstrated by the supplementary sled tests carried out by the manufacturers it is the case that in terms of frontal impact collision situations the structures in the knee-impact area for the driver and the front-seat passenger of the Viano are designed in an exemplary manner for this class of vehicle. Amongst other features, special knee-protection cushions are integrated into the structure supporting the dashboard in order to keep the bio-mechanical loading within acceptable limits in the event of a knee impact.

Figure 11. Front-seat passenger knee-impact areas

Figure 12 Knee support in the driver-knee impact area –visible only after dismantling the panelling

The detailed analysis revealed that no additional risk of injury can be identified for either the outer (right) knee of the front-seat passenger or the outer (left) knee of the driver as well. This confirms the very low level of risk of injury established by the final result of the measured values provided by the dummies.

However, as far as the inner (right) knee of the driver and the inner (left) knee of the front-seat passenger are concerned, the possibility cannot be excluded that in, for example, an oblique frontal impact collision the flexibility of the knee-impact area could limited by the massive support structure lying behind it. Consequently, this lead to a devaluation by one point each.

After rounding off the measured value, the total end-result value for the safety evaluation of the front-seat occupants of the Mercedes-Benz Viano involved in a frontal collision and determined by the Euro NCAP procedure amounted to 13 points, i.e. 81% of the maximal possible value of 16 points. The associated occupant safety-levels in terms of the individual body regions of the driver and the front-seat passenger are displayed by the coloured manikins appearing in Fig. 13.

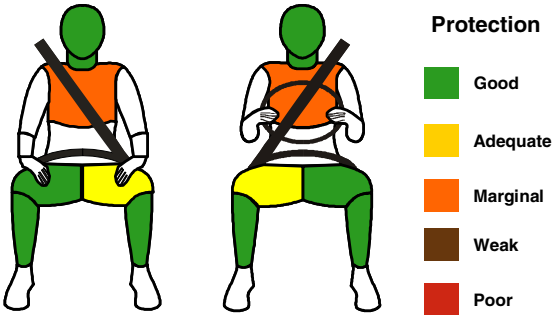

Figure 13. Front impact protection for driver and passenger related to the body regions

Table 3 provides the measured loads experienced by the child dummies during a frontal-impact test.

Table 3.
Child dummy loads frontal impact

Body region	Measured value	Dummy P3	Dummy P 1 ½
Head	$a_{res,\ max}$ [g]	45.80	34.75
	$a_{res,\ 3\ ms}$ [g]	41.86	**33.44**
	$a_{z,\ 3\ ms}$ [g]	-	**21.29**
	Forward displacement [mm]	400	-
Chest	$a_{res,\ 3\ ms}$ [g]	35.83	28.59
	$a_{z,\ 3ms}$ [g]	21.22	21.37

The occupant safety level for children in child restraint systems is evaluated in accordance with the Euro NCAP procedure, too. This involves the measured values for dummies together with supplementary criteria for the head and chest. Up to 4 points can be awarded for each of the two body regions, making a possible total of 8.0. In addition, an evaluation of the child restraint system is carried out and based upon the labelling and the degree of secure fixing in the vehicle. This carries a maximal total of 6.0 points.

In terms of occupant safety level, a points total of 4.0 was awarded for each of the head and chest regions of a 3-year old child strapped in a forward-facing Römer Duo Plus child seat. A further 6.0 points were awarded for the child seat itself so that the total

number of points awarded matched the best-possible evaluation result of 14.0 points.

On the one hand the dummy measurements, which were all below the relevant higher performance limits, were decisive for this. Furthermore, it was important that the dummy was neither partially not completely thrown out of the child seat and similarly that there was no direct hard contact between the head of the dummy and parts within the inner compartment of the vehicle.

The evaluation of a 1 ½ year old child in a Römer Baby Safe Plus awarded 1.87 points (out of a maximum of 4.0) for the head region because in this case the measured deceleration values were above the relevant higher performance limits. However, the P1 ½ Dummy was also neither partially nor wholly thrown out of the child seat and similarly there was also no hard contact between the head and features within the inner compartment of the vehicle.

With regard to the occupant safety level relating to the chest region, the measured values made on the P 1½ dummy again allowed the maximal number of points to be awarded (4.0). This produced a total of 5.87 points (73% of the maximal 8.0 points). In this case, the securing system was awarded a maximal 8.0 points. Consequently, the overall total of points awarded in respect of the occupant safety level relating to the 1 ½-year old child strapped in the Römer Duo Plus child seat amounted to 11.87 (85% of the possible maximal award of 14.0).

Side impacts

<u>Moving-barrier impact</u>

The condition of the exterior body of the test vehicle following the side-impact collision is shown in Fig. 14.

In the sill area the depth of deformation amounted to 110 mm with respect to the original contour of the vehicle. The most extensive depths of deformation were at a height of 150 mm above the sill level and amounted here to 250 mm.

After the collision, the driver door was jammed. The front-seat passenger door could be easily opened by hand without using any tools. As was to be expected, the collision caused the thorax side air bag and the head air bag to be activated.

Figure 14. Test vehicle after side impact with moving barrier

Table 4 provides the measured loads experienced by the driver dummies (ES2)

Table 4.
Driver dummy loads (ES-2 barrier impact)

Body region	Dummy measured value	Driver
Head	$a_{res,\ max}$ [g]	10.91
	$a_{res,\ 3\ ms}$ [g]	10.73
	HPC_{36} [-]	46
Chest	Compression [mm]	12.25
	VC [m/s]	0.05
	$F_{y,\ back\ plate}$ [kN]	0.58
	$F_{y,\ T12}$ [kN]	0.47
	$M_{x,\ T12}$ [Nm]	47.92
Lower body	$F_{res.}$ [kN]	0.26
Pelvis	$F_{pubic\ symphisis}$ [kN]	0.62

All the measured values lie below the relevant higher performance limits so the maximal 4.0 points could be awarded to the protection level relating to each of the 4 body regions of head and neck, chest, abdomen and pelvis. Consequently, the overall total of the points awarded amounted to 16.0.

The evaluation in accordance with the Euro NCAP requirements of the modifiers to be taken into account with respect to the side-impact barrier collision (ease of door-opening after the collision, the effect of force upon the back plate and the thoracic vertebra T 12, momentum-effect upon the thoracic vertebra T12) did not result in any additional negative consequences. There, the initially awarded total of 14.0 points represents the final result for the evaluation of the occupant safety level for the driver involved in a side-impact barrier collision.

In the context of a child dummy in a side-impact barrier collision only the loadings experienced by the head are relevant. The associated measured values are shown in Table 5. In this case, too, all the values lie

below the relevant higher performance limits. This means, therefore, that each dummy receives the maximal awardable points of 4.0 for the head region.

Since no hard contact between the head and features within the internal compartment of the vehicle could be observed, this also represents the overall result. This means that in the event of a side-impact collision the occupant protection level for a 1 ½ year old child strapped in the Römer Baby Safe Plus - and equally for a 3-year old child in the Römer child seat Duo Plus - is evaluated as the maximal possible awardable points, namely 4.0 in each case.

Table 5.
Child dummy loads barrier side impact

Body region	Measured value	Dummy P3	Dummy P 1 ½
Head	$a_{res,\ max}$ [g]	21.14	22.59
	$a_{res,\ 3\ ms}$ [g]	19.86	22.25

Pole impact

The external damage suffered by the test vehicle after collision with a vertical pole is shown in Fig. 15.

With respect to the original outer contour of the vehicle body the maximal penetration depth by the pole was measured at 392 mm.

When the impact occurred the thorax air bag and the head air bag were activated in the expected manner.

In the evaluation of the occupant protection level by means of this test only the values shown in Table 6 for loadings experienced by the head of the (ES-2) Dummy are definitive.

Figure 15. Test vehicle after pole impact

Table 6.
Driver dummy head loads (ES-2 pole impact)

Body region	Dummy measured value	Driver
Head	$a_{res,\ 3\ ms}$ [g]	46,78
	HPC_{36} [-]	221

Both values lie below the relevant higher performance level so in this case the maximal awardable points (2.0) can be given. Since the airbag opened in the expected manner there was no reason for a deduction to be made by the relevant modifier.

Overall result of side impact collision tests

In arriving at the overall result, two additional points can therefore be awarded on account of the positive result of the pole-impact test, i.e. to the existing total of 16.0 points awarded for the barrier/side-impact collision. The occupant protection level available to the driver in the Mercedes-Benz Viano in the event of a side-impact collision can thereby be established as the maximal point count of 18.0 as determined in accordance with provisions of Euro NCAP.

The associated occupant protection levels determined for the individual body regions are shown by the coloured manikins in Fig. 16.

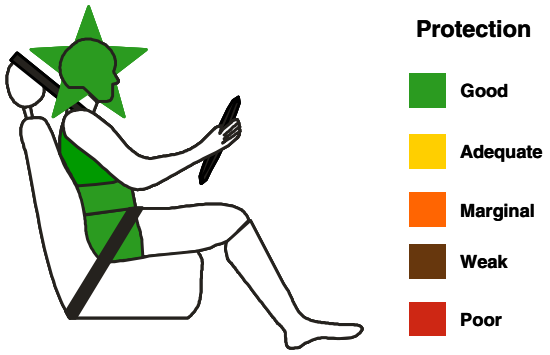

Figure 16. Side-impact collision protection for the driver with respect to individual body regions

VEHICLE ASSESSMENT RESULT

All the evaluation findings made in accordance with the requirements of the Euro NCAP are finally summarised as a single vehicle-related result. For this purpose, the lowest grading, i.e. the lowest number of points awarded for each test and body region defines the overall result, as shown in Table 7.

Seatbelt reminders are provided for the driver seat and the front passenger seat of the Mercedes-Benz Viano and for this reason two additional points are awarded.

Consequently, the vehicle acquires a total of 33 points and this amounts to 92% of the maximal possible 36 points.

On that basis the Mercedes-Benz Viano attains a final star rating of 5 out of a possible 5 stars under the provisions of the Euro NCAP. In other words, the safety of its occupants corresponds to the level offered by modern cars. Taking into consideration the fact that the high weight of the vehicle is equal to that of a van, that outcome is a significantly satisfactory result setting the trend for this class of vehicle.

Table 7.
Overall vehicle assessment result

	Body region	Points driver	Points passenger	Overall result
Frontal impact	Head/ neck	4,00	4,00	4
	Chest	2,34	2,47	2
	Knee, femur, pelvis	4,00	4,00	4
	Lower leg, foot and ankle	4,00	4,00	4
	Subtotal	**13,34**	**13,47**	**13**
Side impact barrier	Head	4,00	-	4
	Upper body	4,00	-	4
	Abdomen	4,00	-	4
	Pelvis	4,00	-	4
Side impact pole	Head	2,00	-	2
	Subtotal			**18**
Seat belt reminder				**2**
Total				**33**

REFERENCES

[1] http://www.euroncap.com

[2] Zinser R: Injury patterns of delivery van occupants. Proceedings 5th International DEKRA/VDI Symposium Safety of Commercial Vehicles, Neumünster, Germany October 12-13, 2006