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## Crash Tests to Assess the Secondary Safety of Cars in the so-called “8,000-Euro Class”

### Abstract

The price of a new car increased almost every year for a long period. In recent years however, the budget available to most people for purchasing a car either did not grow or became even smaller. Therefore it was in the interest of some OEMs to offer economical car models in the so-called “8,000-Euro class”. Here an important question arose regarding the safety of these vehicles. There is no question that the very high safety level of cars reached in Europe during the last decades should not be sacrificed as a consequence of smaller budgets. Customers with sense of responsibility have the right to be properly informed about the balance between safety and price so that they can make a deliberate decision when buying either a new or a used car.

Against this background, the German magazine “AutoBILD” commissioned DEKRA to conduct full-scale frontal crash tests with a view to publishing the results. These tests have been carried out in accordance with the corresponding Euro NCAP crash test requirements and performance criteria. The tested vehicles were two new Logans produced by the manufacturer Dacia, two used cars of the type VW Golf IV (registration date 2000) and one new VW Fox.

This paper describes the safety features of the vehicles and the results of the five crash tests to demonstrate state-of-the-art safety levels and what levels may be expected from vehicles in the “8,000-Euro class”.

Looking at real-world crashes it is of interest to think about future trends in a more detailed manner. Therefore it will be more and more necessary to supplement the federal statistics with more detailed in-depth information about the consequences of accidents and the safety performance of crashed vehicles.

### Notation

resp.	respectively
$v$	velocity [m/s;km/h]
$a$	acceleration [m/s <sup>2</sup> ]
$M$	momentum [Nm]
HIC	Head Injury Criterion [-]

### Introduction

According to the “Allgemeiner Deutscher Automobil Club (ADAC)” the expenses for purchase and maintenance of a car in Germany increased by an average of 37.7% from 1991 to 2001, Figure 1. This equals an annual average increase of 3.0%. In contrast, the cost of living expenses have increased by 27.3%, which represents an annual increase of 2.2% over the same period [1]. The main cost factor there has been the increases in fuel prices. In the year 2002 these were 54.9% above the prices in 1991. The purchase price of a car rose in the same period by 18.3% and consequently the increase has been less than that of the increase in the cost of living. However, in the face of a general shortness of money and the high level of retail prices for new cars it is very desirable to save money here.

Against this background some car manufacturers have set themselves the goal to offer attractive new cars for the German market priced significantly below 10,000 Euros. In the meantime this class has become known as the 8,000-Euro class. The pioneer was Renault. In June 2005 they brought out the Dacia Logan which is assembled in Romania and offered it to the German, French and Spanish market. This car offered (almost) the same compartment and trunk dimensions as the so-called Golf class at a significantly lower price. The Dacia

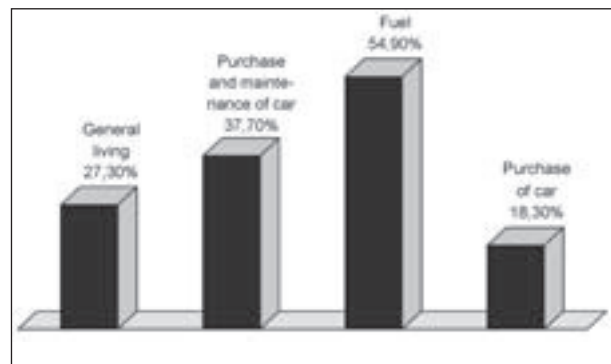


Figure 1: Pattern of cost growth in Germany

Logan is based on the same platform as the Nissan Micra and the Renault Modus. The launch of the Dacia Logan was announced in over 30 countries at the end of 2005. In Germany the list price ranges from 7,200 to 8,200 Euros without any extras. Actually the primary price was targeted to be 5,000 Euros as the "Spiegel" magazine reported in June 2005 [2].

Of course ambitions to offer new cars for little money are appreciated by the consumers. But at the same time the preservation of the high level of vehicle safety available nowadays has to be considered, too. This high level has contributed to a continuous decrease in the numbers of severely and fatally injured people in Germany from the 1970s until today. In 1970 there had been a sad negative record with 21,332 fatally injured road users in Germany. After that, it was possible to reduce this number to 5,482 by the great efforts of all parties. According to estimates made by the Federal Statistical Office this number is still decreasing – and roughly down to 5,400 [3] for 2005. Compared to 1970 this would mean a decline of 75% although the national stock of vehicles increased almost three-fold.

In countries which have not yet reached such a high level of vehicle safety it could be appropriate to set some lower requirements for vehicles. In those countries the vehicles are mostly very old, badly maintained and correspondingly unsafe. In countries like e.g. Germany no cutbacks in the requirements of safety can be tolerated if we do not want to put at risk the positive trend of fewer seriously and fatally injured. In this context also the goals in the White Paper of the European Commission [4] and the European Road Safety Charter [5] have to be taken into account. According to these the number of fatally injured in the EU should be halved by 2010 when compared with 2001. DEKRA is one of the first signatories of the European Road Safety Charter which supports the efforts to achieve this goal on a sustainable basis. In Germany, the subject safety is of much consideration also for low-price cars. The standard equipment of the vehicles includes ABS as well as driver and passenger airbag [6]. However the goals involving crash safety seem to be not always priority number one. The official rating at Euro NCAP for the Dacia Logan is 3 out of 5 possible stars. Current cars of all classes gain 4 to 5 stars [7].

With this background it is of interest to investigate the safety of such vehicles and to publish the results also for the general public. The informed customer can include criteria of vehicle safety on the basis of objective information in his decision whether to buy or not. The German magazine "AutoBILD" picked up this subject first and extensively tested the Dacia Logan. To investigate secondary safety, crash tests have been commissioned at the DEKRA Crash Test Center in Neumünster. These tests were published in April 2005 [8]. A 5 year old, well preserved VW Golf IV was also used to directly provide a comparison with the passive safety of the Dacia Logan. Such a car could also be purchased for a price of 8,000 Euros. The official rating within Euro NCAP for a 1998 VW Golf IV is 4 stars [7].

Additionally another test has been made with a VW Fox which was published in June 2005 [9]. This vehicle is actually a little smaller than the Logan or the Golf but at 9,000 Euro also qualifying for the "under 10,000-Euro class".

In the following the tests and their results are presented and discussed. In contrast to the publications of "AutoBILD" this will be a mainly technical contribution in which further test results and details will be presented and discussed. Additionally the official Euro NCAP crash test with the Dacia Logan will be included [10].

## **Crash Tests Conducted with Dacia Logan and VW Golf IV**

### **Task and test configuration**

The central task for DEKRA has been the analysis of the safety for the driver and passenger in the Dacia Logan and in the VW Golf IV when involved in the frontal crash according to Euro NCAP. The corresponding article in the magazine "AutoBILD" asked if a new Dacia Logan offers the same passive safety as a used VW Golf IV. Safety relevant differences in the vehicle behaviour and its components should be identified and explained. Some possible variations have also been taken into account during planning of the tests. In addition to the possible technical variations, which are actually marginal, during the execution of such tests further results were obtained possibly due to the influence of production variations in new cars as well as to the condition of the used vehicle. Therefore two

Logans and two Golfs were tested using the same test parameters.

The chosen test configuration complied with the requirements as specified by Euro NCAP – i.e. a 40% offset frontal crash at 64km/h against a barrier, Figure 2. A deformable barrier face is mounted on the rigid barrier at the impact area which deforms in a specified manner under the influence of a force. This impact constellation and the deformation element are also defined in the regulation ECE-R 94 which is standard for vehicle homologation. However, the impact speed used is not 56km/h but 64km/h. According to the philosophy of Euro NCAP this points out differences in the crash performance of the tested vehicles because the relevant test for homologation has to be passed with a good result by all cars.



Figure 2: Test configuration

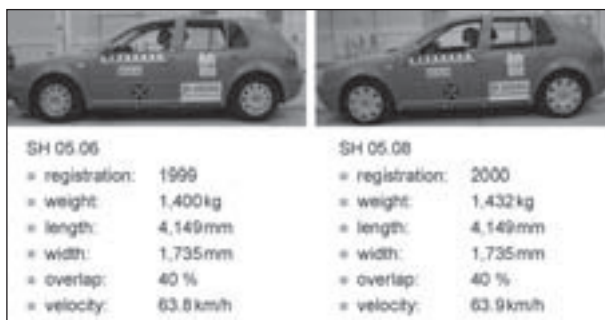


Figure 3: Test vehicles: used VW Golfs IV

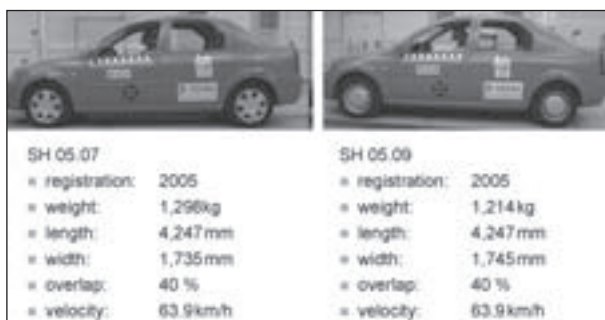


Figure 4: Test vehicles: new Dacia Logans

In addition to the standard test a force-measuring crash wall (manufacturer BIA) was mounted which monitored the magnitude and the sequence of the reaction forces at the impact of the vehicles. Instead of a real driver and passenger anthropometric test devices (dummies) type hybrid III 50<sup>th</sup> percentile male were used. Both dummies were equipped with 36 channels to measure biomechanical loads. Included are accelerations in the head, chest and pelvis in each three orthogonal directions, the intrusion into the chest as well as further mechanical loads in the neck, femurs, knees and tibia. A uniaxial acceleration sensor was used to measure the deceleration of the vehicle on each side of the vehicle's B-pillar/door sill transition. Each measurement value was recorded with built-in crash-resistant data acquisition units. After the test this data was transferred to an external PC.

**Test vehicles**

**VW Golf IV**

Test numbers are used to distinct the tests and the results. For the tests SH 05.06 and SH 05.08 two VW Golf IV were used, Figure 3. The vehicles were licensed in 1999 and 2000 respectively and therefore about 5 years old at the time of the tests. The length of the cars was 4,149mm and the width 1,735mm. The weights including dummies and measurement equipment were 1,400 and 1,423kg resp. The lighter car had been equipped with rims made of aluminium, the heavier one with steel rims. The measured velocities at impact were 63.8 and 63.9km/h resp. The Golf IV is equipped with 3-point seat-belts for driver and passenger. In addition these belt systems have a belt-force limiter. The safety belts are supposed to support the airbags to restrain driver and passenger.

**Dacia Logan**

Two new Dacia Logans (registration date 2005) were used for the tests SH 05.07 and SH 05.09, Figure 4. The length of the vehicles was 4,247mm and the width 1,735mm. The test weights were 1,214 and 1,298kg resp. The heavier car had been equipped with air conditioning and a bigger rim-wheel combination. Both vehicles impacted at 63.9km/h. The Logan is equipped with 3-point seat-belts for driver and passenger without a belt-force limiter. Frontal airbags are also part of the restraint system.

## Impact behaviour

### Vehicle structure

All four test vehicles showed a generally similar behaviour by the structures during impact. A detailed inspection showed that the deformation at the Golf appeared a little more harmonic and steady. No differences could be recognized with the two almost identical sequences of the measured forces at the crash wall. However the deceleration of the Golfs took a little longer than the deceleration of the Logans and the peak values of the Golf were lower than the respective values of the Logan. The survival space for the occupants remained adequate. The A-pillars suffered only marginal distortion at the impact side. The displacement of the A-pillars was measured 100mm beneath the window aperture (top) and 100mm above the sill (bottom). The displacement for the Logans was between 7mm at the top and 29 and 30mm resp. at the bottom. For the Golfs it was between 7 and 8mm resp. at the top and 43 and 46mm resp. at the bottom (see Table 1).

The rearward vertical displacement of the upper steering column was 2 and 23mm resp. for the Logans and 27 and 39mm resp. for the Golfs. The displacement at the lower steering column was 12 and 14mm resp. for the Logans and 52 and 65mm resp. for the Golfs.

	VW Golf		Dacia Logan	
	SH 05.06	SH 05.08	SH 05.07	SH 05.09
Door opening forces [kN]				
Driver door opening 45°	242	137	<b>blocked</b>	<b>blocked</b>
	641	631	458	171
passenger door opening 45°	76	75	33	21
	55	45	30	24
Door left backseat opening 45°	36	52	42	25
	53	56	48	33
Door right backseat opening 45°	70	56	24	26
	75	50	36	28
Displacements [mm]				
Upper A-pillar	8	7	7	7
Lower A-pillar	46	43	29	30
Gas pedal	36	83	9	14
Brake pedal	80	87	54	21
Clutch pedal	135	129	<b>222</b>	170
Upper steering column	27	39	2	23
Lower steering column	65	43	14	12

**Table 1:** Door opening forces and vehicle distortions

Further measurements were made. The rearward displacement of the pedals for the Logan was: brake 21/54mm, clutch 170/222mm, throttle 14/9mm. For the Golfs: brake 87/80mm, clutch 129/135mm, throttle 83/36mm. The pedals released mechanically because of the impact loads. This technique is nowadays common and reduces the bruise loads on the feet and lower extremities. The Logan did not have such a mechanism.

The doors on the passenger side of all four vehicles could be opened using normal hand force as well as the back doors on the driver's side. But there was a significant difference when trying to open the driver's doors. While the doors of the Golfs could be opened with moderate hand force (242kN/137kN), the doors of the Logan had to be opened using a crowbar. The reason for this was clamping of the lock mechanism of the pin-type lock. Unlike the Logan the Golf is equipped with the bracket-type lock commonly used today which prevents such clamping occurring.

Another positive effect observed at all tests has been that no door opened during impact. This is required according to technical standards to prevent passengers from being thrown out of the car. It is furthermore required that at least one door per seat row can be opened without using any tools. As one door could be opened after the test with the Logan this requirement was fulfilled, but a door which can not be opened easily after a crash complicates the care and rescue of injured people – in this case especially for the driver.

### Restraint systems

The airbags in the Golfs worked in a normal manner at both tests. This is shown by a firm inflation of the airbag while the passengers are still moving forward relative to the car due to their inertia. In this early phase the passengers are already restrained by the belts. To lower the peak loads for the upper body regions belt-force limiters are activated at a certain trigger force. Such a limitation of the restraint force is common for today's seat-belts in combination with airbags. That is because the fully deployed airbag can protect the head and upper body and therefore support the restraint efficiency of the belt. In the further sequence the airbag is further compressed by the passengers which are still moving. At this point, airbag gases escape through exhaust vents. During the design of a new vehicle the restraint systems are accurately

coordinated to achieve best results which means passenger loads are kept below the biomechanical limits and there is no steering wheel contact with the body or the head. The same applies to the passenger side.

At both tests with the Logan, a behaviour was observed which was classified as unusual. The airbag gases escaped very early. At this early point the airbag could not really support the seat-belts. Significant interaction of the airbag and the passenger could be seen fairly late and during a phase in which the airbag is already droopy because of the escaped gases. Therefore the seat-belts basically restrain the passengers with the result that the measured belt forces are higher for the Logans than for the Golfs.

No bottoming out of the airbags could be observed for either the Golf or the Logan.

### Dummy loads

As described before, the survival space for the Golf as well as for the Logan remained almost intact. This adequately complies with an essential part of the basic principle of secondary safety while the measured dummy loads determine the vehicle's safety performance. Firstly, consideration is given to some common used test results of the dummies. Afterwards the dummy loads especially of interest for Euro NCAP will be analysed.

#### Common used load data

##### Driver

The technical regulations specify the Head Injury Criterion HIC as well as the highest resulting head acceleration during a time interval of 3ms ( $a_{3ms}$ ). The HIC is a nondimensional value with a limit of 1,000. The resulting head acceleration has the limit

Driver Loads	VW Golf		Dacia Logan	
	SH 05.06	SH 05.08	SH 05.07	SH 05.09
Head HIC	358	393	943	855
Head $a_{3ms}$	45.15g	46.87g	78.49g	67.34g
Neck $M_y$	33.15Nm	29.76Nm	9Nm	22.7Nm
Chest deflection	26.72mm	24.42mm	27.72mm	26.64mm
Chest $a_{3ms}$	41.8g	38.05g	41.8g	48.46g
Pelvis $a_{3ms}$	40.6g	39.21g	40.6g	51.08g
Upper femur $F_z$ right	1.94kN	1.75kN	1.94kN	1.84kN
Upper femur $F_z$ left	1.68kN	1.38kN	1.68kN	1.25kN

**Table 2:** Driver loads

$a_{3ms}=80g$ . If these values are exceeded irreversible injury of the brain and the skull are very likely. The values for the Golf (HIC=358 and 393 resp. and  $a_{3ms}=45g$  and  $47g$  resp.) are far below the biomechanical limits, Table 2. This has been a trend-setting feature of vehicles of this generation. Mandatory requirements for these good test results consist of accurately coordinated restraint systems like the safety belt with belt-force limiter and airbag. With a HIC of 943 and 855 resp. and  $a_{3ms}=79g$  and  $67g$  resp. the head-load values for the Logan are very high and very close to their limits. This indicates a correspondingly higher risk of injury.

The vertical neck momentum (tension/extension) is used to rate the neck stresses and strains. For the Golfs the measured values were  $M_y=33Nm$  and  $30Nm$  resp. and for the Logans  $M_y=9Nm$  and  $23Nm$  resp. The relevant limit is  $57Nm$  which is significantly higher than the measured values. Important test results by which to assess the chest loads are the resulting chest acceleration  $a_{3ms}$  and the geometrical deflection of the chest. The relevant limits are  $a_{3ms}=60g$  and  $s=50mm$  resp. The test results for the Golfs were  $a_{3ms}=42g$  and  $38g$  resp. and  $s=27mm$  and  $24mm$  resp., and for the Logan  $a_{3ms}=51g$  and  $49g$  resp. and  $s=31mm$  and  $27mm$  resp. These values are far below the relevant limits. For the pelvis area the  $a_{3ms}$ -value is used, too. Here the limit is  $60g$ . With results of  $a_{3ms}=41g$  and  $39g$  resp. for the Golfs and  $a_{3ms}=53g$  and  $51g$  resp. for the Logans these values are not critical. Finally the maximal compressive force of the femur will be addressed. The usual limits are  $10kN$  although some literature mentions  $8kN$ . Both the Golfs (left femur:  $1.81kN$  and  $1.75kN$  resp. and right femur:  $2.16kN$  and  $2.25kN$  resp.) and the Logans (left femur:  $1.27kN$  and  $0.97kN$  resp. and right femur:  $1.4kN$  and  $1.14kN$  resp.) are on the same level and far below the limits.

Overall, the reported values show, that the head of the driver of the Logan was exposed to significantly high loads. This means there would be a high risk of injuries of the head. For other body regions the differences between the Logans and the Golfs are not significant and always below the biomechanical limits.

##### Passenger

A high level of stresses and strains can be observed when looking at the test results for the head of the Logan's passenger. In both tests the

limit for the HIC has been exceeded (HIC=1,197 and 1,016 resp.). The limit for the resulting acceleration of 80g has been exceeded once ( $a_{3ms}=83g$ ) and the other time almost ( $a_{3ms}=75g$ ). The corresponding values for the Golfs (HIC=270

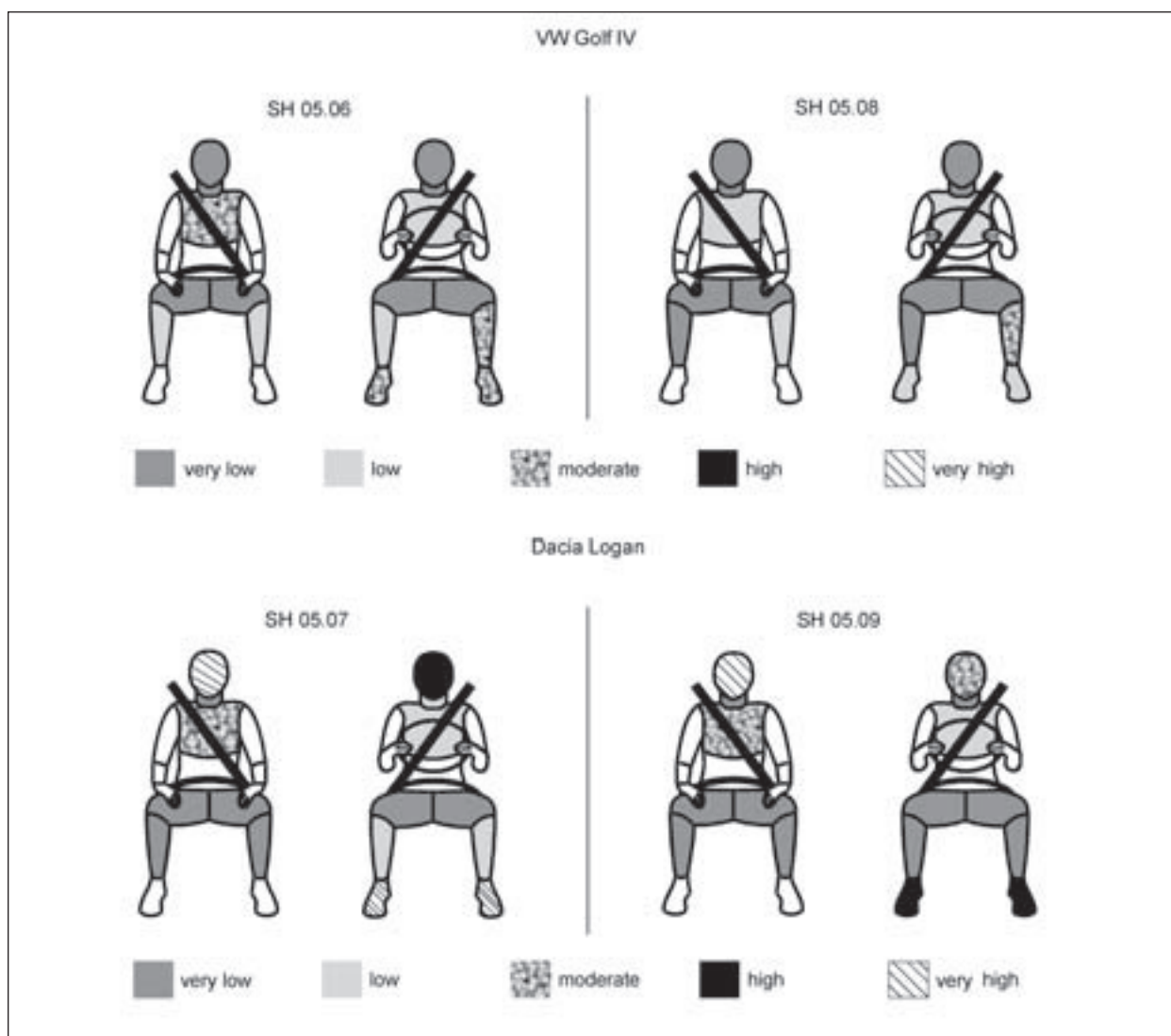
and 172 resp. and  $a_{3ms}=40g$  and  $32g$  resp.) are far below those of the Logans. The other body regions of the passenger have also been measured by reference to the load variables already stated. Those are more or less on the same level for both vehicles and below the biomechanical limits.

Passenger Loads	VW Golf		Dacia Logan	
	SH 05.06	SH 05.08	SH 05.07	SH 05.09
Head HIC	270	172	1197	1016
Head $a_{3ms}$	39.67g	32.26g	82.53g	75.16g
Neck $M_y$	21.22Nm	27.43Nm	28Nm	33Nm
Chest deflection	31.98mm	31.24mm	38.47mm	37.56mm
Chest $a_{3ms}$	33.5g	30.31g	41.71g	41.01g
Pelvis $a_{3ms}$	37.51g	37.33g	52.52g	46.69g
Upper femur $F_z$ right	1.36kN	1.49kN	0.99kN	1.21kN
Upper femur $F_z$ left	2.37kN	1.97kN	1.16kN	1.4kN

**Table 3:** Passenger loads

#### Rating according to Euro NCAP

Additionally to the already mentioned test results the dummies yielded further measurements for the knee and tibia. All of the collected data of summarized to calculate and display the body-related injury risk according to Euro NCAP. Manikins are used to provide easy and clear information to the customers. The injury risks for the head, chest, pelvis, femur, tibia and feet are presented visually by using different segments. Additionally, the feet of the driver show the effects



**Figure 5:** Driver and passenger injury risks as results of the crash tests conducted with Dacia Logan and VW Golf IV

of pedal intrusions. The classification is made by a mathematical algorithm using the dummy measurements as described in the official Euro NCAP protocol [11]. This calculation will be explained in detail considering the head as example. Furthermore the score generated from dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or when involved in accidents of slightly different severity, can be expected to be less effective than that indicated by the dummy readings or deformation data alone. In any single body region, the score may be reduced by a maximum of up to two points. No modifier has been used by DEKRA in these calculations.

The different segments of the manikins reflect the injury risks, see Figure 5. According to Euro NCAP the loads for the femur and knee were consistently low. The injury risk for the tibia were rated from very low to moderate and for the chest from low to moderate. Also some variances for the same type of car can be seen because of slight differences in the dummy loads. This can be seen particularly clearly if a value is located between two risk groups, e.g. between a low and a moderate risk of injury. A low to moderate injury risk has been assessed for the feet of the driver in the Golf. For the Logan it was rated moderate to high.

#### Singularity of the head rating

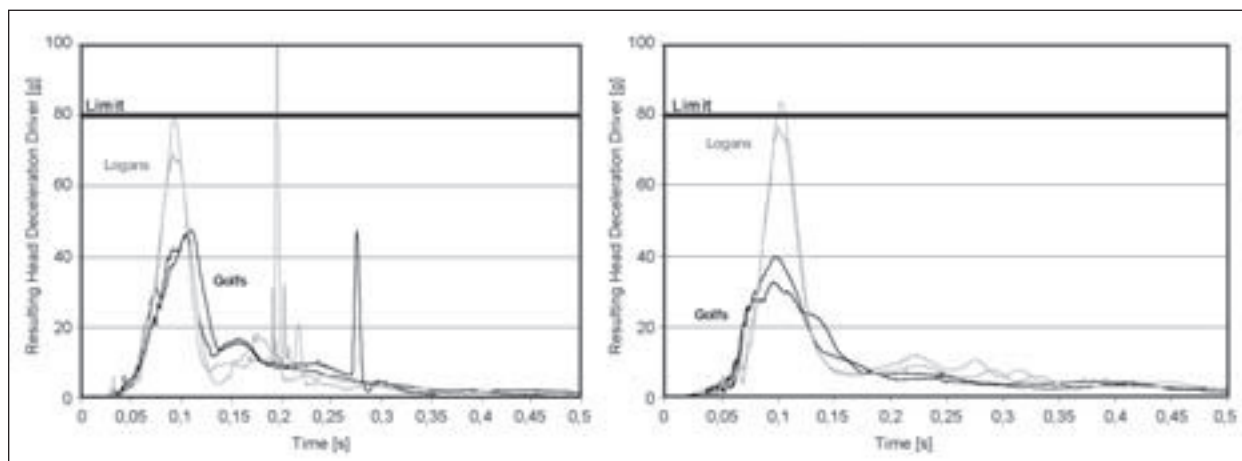
The described high risk of injury for the driver and passenger of the Logan is shown by the different segments of the Euro NCAP manikin. While the Golf was rated with dark grey heads for very low injury, the Logan was assigned with different heads which mean a high or even a very high risk of injury for the head. During the analysis of the test results a discussion came up because the DEKRA test results for the head differed from the official Euro NCAP ones [10]. In this context the Euro NCAP algorithm to calculate the results has to be considered.

Each body region (head and neck, chest, pelvis, femur and knee, tibia and feet) can be awarded a maximum of 4 points. The requirement is that the load of each body region is below or equal the so-called "higher performance limit". The higher performance limit refers to the car not to the occupants. The corresponding risk of injury is very low and displayed by a dark grey body region. The

worst rating is 0 points and awarded if one dummy measurement of the body region is equal or over the "lower performance limit". The corresponding risk of injury is very high. Within these two performance limits a "sliding scale" relates the measured value and the awarded points. Within the 0 to 4 achievable points there are further fragmentations which separate the injury risk into low, moderate and high. If one or more loads on one body region result in a rating lower than 4 the worst rating is used for the total result and for the different segments of this body region of the manikin.

To rate the injury risk for the head the resulting acceleration  $a_{3ms}$  and the HIC are used. The lower performance limits are  $HIC=1,000$  and  $a_{3ms}=88g$ , the higher performance limits are  $HIC=650$  and  $a_{3ms}=72g$ . For the Golfs all measured values were lower than the higher performance limit and classified as very low. This can be seen from the dark grey heads for both driver and passenger. The measured loads for the driver dummy of the Logan were  $HIC=943$  and  $855$  resp. and  $a_{3ms}=78.49g$  and  $67.34g$  resp.. These values are slightly lower than the lower performance limit of  $HIC=1,000$  and  $a_{3ms}=88g$  but inside the sliding scale. Taking the worst rating these values result in a moderate risk of injury and a high risk of injury respectively. For the head of the passenger dummy the measured values were  $HIC=1,197$  and  $1,016$  resp. and  $a_{3ms}=82.53g$  and  $75.16g$  resp.. In both tests the lower performance limit for the HIC of 1,000 was exceeded. This means a high risk of injury for the head. As mentioned above, the risks of injury to the head revealed by the tests have been published to a partial extent in the magazine "AutoBILD". In the meantime the official result of Euro NCAP has also been released. In this the head of the driver and passenger of the Logan has been rated with a very low risk of injury which is reflected by a dark grey head for the manikin [10]. This rating results from a special condition in the Euro NCAP protocol which requires a hard contact with the head to actually rate the risk of injury to the head as high. This hard contact is recognized if the peak value of the resulting acceleration of the head is over 80g. If this is not the case the risk of injury for the head is assessed as "very low" – irrespective of the HIC.

Under this special condition the head injury risk would have been rated high (red) only once –



**Figure 6:** Head decelerations for driver and passenger for all tests conducted with Dacia Logan and VW Golf IV

namely for the passenger of test SH 05.07 ( $a_{3ms}=82.53g/HIC=1,197$ ). The passenger in the second test with a peak acceleration of a  $max=76.37g$  which is below  $80g$  would have received a dark grey head despite an  $HIC$  of  $1,016$  and  $a_{3ms}=75.16g$ . In the face of these high values relative to the biomechanical limits as well as the higher values for the Dacia Logans when compared to the Golfs this special condition was not applied by DEKRA for the rating results published by Auto BILD and the  $HIC$  was used to rate the passenger. This resulted in a very high head rating for the second test, too.

The measured maximum values of the resulting head acceleration of the Logan driver were  $a_{max}=79.97g$  for test SH 05.07 ( $HIC=943/a_{3ms}=78.49g$ ) and  $amax=79.1 g$  ( $HIC 855/a_{3ms}=67.34g$ ) for test SH 05.09. If the special condition had been applied the rating would have been a very low risk of injury. Regarding the test SH 05.07 the small gap of merely  $0.03 g$  would have been decisive for this unrealistic rating. Here too, the special condition was not applied by DEKRA and the rating was made by using the  $HIC$  value. This resulted in a high risk of injury for test SH 05.07 and a moderate risk of injury for test SH 05.09.

During the discussion this approach was considered to provide the most consistent option within the limits of the rating possibilities representing the real risks of injury to the head. This applies also to the absolute value of the loads and on the other hand to the direct comparison with the low values for the Golf. The test results for the Logan represent a marginal case which should be

considered in the further development of the official Euro NCAP-protocol.

### Crash Test Conducted with VW Fox

Finally, consideration of the results of a frontal test involving a new VW Fox confirms the level of secondary safety which can be already achieved with vehicles in the lower compact class. The Fox is equipped with a seat-belt system with seat-belt pretensioner and seat-belt-force limiter both for both driver and passenger. In a very early phase of the crash the seat-belt pre-tensioner reduces the belt slack. Additionally the Fox is equipped with an airbag for driver and passenger.

The test vehicle weighed  $1.238kg$ . Its length was  $3.828m$  and width  $1.660m$ . In accordance with Euro NCAP the offset was  $40\%$  and the test velocity  $63.9km/h$ . A harmonic deformation of the vehicle crumple zone could be observed during the crash. The passenger cell remained almost intact and the survival space for the occupants remained fully intact. At the driver's side the A-pillar distorted to an insignificant degree. The rating according to Euro NCAP was carried out by DEKRA without using modifiers. The loads on the passenger were consistently very low (all body parts dark grey). For the driver all body parts apart from the chest and the left tibia have been rated a very low risk of injury (dark grey). The chest and tibia have been rated a low injury risk, see Figure 7.

With these results the VW Fox meets the level of the current VW Golf V. The Golf V was rated 2004 with the maximum result of 5 stars [7].



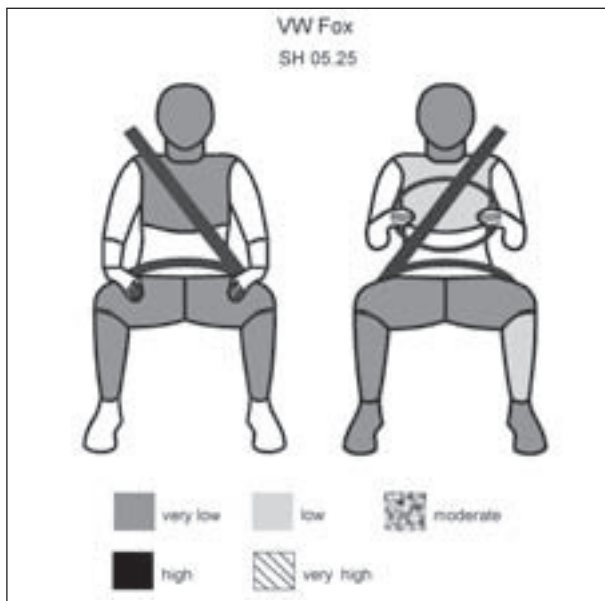


Figure 7: Driver and passenger injury risks as results of the crash test with a VW Fox

## Summary and Prospects

Assessing the safety rating for the occupants of vehicles is a complex task. The first consideration must be the safety equipment of the car itself. After that the interaction of the restraint systems and the body structure as well as the behaviour of the occupants during crash loads is decisive.

When a frontal impact occurs it is necessary for the structure of the front end to transform as much impact energy as possible into deformation by controlled and harmonic crumpling. The survival space located behind the front end should remain almost intact. It is also beneficial if the pedals intrude only marginally into the footwell and transfer only low stress to the feet. Inside the passenger cell the occupants are decelerated by the restraint systems. At this stage it is important to keep the loads on passengers below the critical limits above which there is a significant risk of injury being suffered. An early and sustained deceleration of the vehicle is beneficial. Hereby the passengers should participate as early as possible. Seat-belt pretensioners are state-of-the-art. The expansion of the belt under the load enables a further forward movement of the occupants. This lowers the deceleration loads still further so that seat-belt force limiters can optimize the controlled forward displacement. In a subsequent stage airbags support the seat-belts and prevent injury by protecting the occupants against impacts with the steering wheel or the dashboard.

The frontal crash tests produced a multitude of results which may not always lead to the same good or even very good rating. But as described with the Euro NCAP protocol they allow a clear overall rating of the occupant safety to be made and also a comparison between single vehicles. Therefore the tests were conducted in accordance with Euro NCAP requirements, namely with a velocity of 64km/h and an offset of 40% and gave the following insights:

The behaviour of the body of the Dacia Logan was positive. There was no collapse and the survival space for the occupants remained intact. A negative finding was that the driver doors could only be opened after the test with the use of tools and considerable force. The reason for was a jammed pin-type door lock. This may complicate the recovery and rescue of injured people. Furthermore the high head loads experienced by the driver and the passenger are criticised. The reason for the high loads is probably less than ideal coordination of the seat-belts and the airbags. This is also indicated by the high measured seat-belt forces which means that the seat-belts are providing the main restraint for the passengers. The airbags also show an unusual behaviour. They deflated relatively early before contributing to the restraining of the passengers. Furthermore the rearward movement of the rigid pedals leads to higher loads on the driver's feet.

The Golf IV showed several significantly better results in the direct comparison. In the Golf the survival space also remained intact and the doors could be opened without any problems. All loads could be rated according to Euro NCAP procedure as very low to moderate. Especially the head loads were at a significantly lower level compared to those experienced in the Logans. The seat-belts equipped with seat-belt force limiters and the airbags gave a very well coordinated performance. The release mechanism of the pedals reduces the risk of bruise loads to the driver's feet.

The VW Fox showed a better structure performance in the direct comparison with the Golfs and the Logans. The seat-belts, equipped with force limiter and pre-tensioner, combined with the airbags contributed to the low dummy loads. Consequently, the improvement in secondary safety of current new cars is there to be seen by all. Recently, occupant safety is no more a privilege of middle- or upper-class cars.

The improvement of vehicle safety is nowadays a common European goal. Against the background of accident events and vehicle population the Dacia Logan can be seen as a real economic alternative in some European countries. It could contribute to the replacement of old, badly maintained vehicles and therefore increase the general level of vehicle safety. Indeed this basically applies to Germany and other Western Europe countries, too. But in these latter regions the vehicle population is not that extremely outdated as it is in some countries of Eastern Europe or local Southern Europe. As the test results have shown for vehicles in the "8000-Euro class" a well maintained used car equipped with the relevant safety-related features can be an equal alternative. It is for the consumer to consider the importance of vehicle safety when deciding if he prefers a new low-cost vehicle or a used vehicle that could be more safe. If vehicle safety is of priority 1 and size does not matter, new cars in the "8000-Euro class" are not available but new vehicles can be purchased in the "10,000-Euro class". The achieved level of vehicle and road safety in Germany and other European countries must not be jeopardized. It has to be extended still further to keep on lowering the still unacceptable high number of severe or fatally injured people. That is why the requirements for the safety of new vehicles may not be lowered. On the contrary, the trends towards more safety have to be recognized and strengthened. Finally we must accept that this will not happen for free.

In this context consumer crash tests like those organised by Euro NCAP in addition to crash tests carried out for public magazines are welcome. This contributes to more interest being taken in secondary safety by the consumers. The consumer can include safety provisions based upon objective information when considering his buying decision. The tests made by DEKRA on behalf of "AutoBILD" have also shown that there is a further need for professional discussions to be held on the subject of the rating scheme.

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