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31st Annual Congress of the European Association for Accident Research and Analysis (EVU)

Performance of new-brand vehicles in RCAR tests with emphasis on seat protection potential and damage patterns

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Abstract

RCAR [1], a community of insurance-related research centers, established, among other things, uniform crash tests for risk assessment of new vehicle models and the International Insurers Whiplash Prevention Group (IIWPG). AZT Automotive GmbH (AZT) has been a very active part of this community from the beginning. In collaboration with other insurers, physicians, biomechanics, engineers and universities, a special rear impact dummy, the BioRID II, was developed and a dynamic test with appropriate evaluation criteria for seat structures was introduced in 2004 [2]. Since then, the protection potential of vehicle seats in Europe has steadily increased. However, with the increasing prosperity in the Asian region, the issue and the handling of neck distortion claims has also come to the fore in the countries there. But the topic is also becoming interesting again in the European market, as more and more new and especially Chinese vehicle manufacturers are entering the markets [3]. This raises the questions of what protection potential their vehicle seats offer and what deformation behavior the models exhibit in light rear impacts. The AZT had the opportunity to test the protection potential of driver seats with a BioRID II as well as the structural behavior of the vehicle body in some of these new-brand models as part of the tests for the German type class rating [4] and to compare them with the values of the established manufacturers in Europe. The result is presented in anonymized form. The RCAR-IIWPG has also published a paper summarizing the research and results to date on international whiplash research [8]. According to this paper, a calculation of the impact-induced change of velocity (delta-v) based on the damage patterns remains one of the bases for a plausibility check of claims. This raises the need to analyze whether new vehicle models show different damage patterns than would be expected from previous experience at a given speed.

Keywords: RCAR; IIWPG; whiplash; neck distortion; new vehicle manufacturers; seat protection potential; damage patterns

1. Introduction

Since the 1980s insurers have been observing an increasing number of claims in accidents involving rear collisions with low changes of velocity. The RCAR International Insurance Whiplash Prevention Working Group (IIWPG) was established in 1994 to systematically investigate the causes and possible improvements. This working group assisted a project organized at the University of Gothenburg, in which a dummy was developed for the rear-end collision scenario. IIWPG researched the design parameters of the dummy and developed a test standard for its application. The implementation of the BioRid II dummy in 2004, meant that for the first time it was possible to use a dummy to measure the forces and torques exerted on a best-possible biofidelic vertebral column during a rear impact.

Combined with the test standard, this helped seat designers to make a targeted improvement in the protection potential of vehicle seats. But any standardized and reproducible evaluation of the protective effect of a vehicle seat in rear impacts requires tests that are conducted using an isolated vehicle seat. Euro NCAP determines the protection potential of the seat using sled tests and varyingly severities of pulse with regards to acceleration and the impact-induced change of velocity. This means that the focus of this test is not the overall system, comprising vehicle and seat structure. AZT has also been using the BioRid II dummy in vehicle crash tests since 2006. This means that, from 2006 to the middle of 2023, there are over 100 vehicle tests available for analyzing the data captured with the BioRid II. The tests encompass passenger cars in every vehicle class, and are performed in four different test scenarios. Most of the data captured originates from the RCAR Structure Test Rear [5], but during this period, the dummy was also used for RCAR Bumper Tests [6] and certain car-to-car collisions with varying overlaps. This makes it possible

- to make general statements about the protection potential of vehicle seats over time,
- to determine the effects of modified vehicle structures or materials on occupant loads,
- to assess the behavior of individual seats in a range of impacted-induced changes of velocity (Δv), and
- to verify the findings from the standard crash tests regarding their limitations in relation to the non-deformable fixed barrier, using car-to-car crash tests as the basis.

The purpose of AZT´s investigation is to observe the influence of the maximum and mean vehicle acceleration, the impact-induced change of velocity (delta-v) and the vehicle model year on the data captured using the dummy. In addition, the influences of new vehicle structure developments associated with new propulsion technologies, materials or new vehicle manufacturers from other markets can be identified. In 2022 and 2023, the market launches of new vehicle models by new market entrants increased. In Germany, the registration figures of some new Chinese passenger car models are higher than those of traditional importers such as Honda, Alfa Romeo or Lexus [3]. The number of registrations of new-brand models or models built through joint ventures with a new brand will grow very strongly in the next few years and determine the design, body structure and price of the vehicle market.
For this reason, AZT Automotive GmbH decided to take a closer look at the new-brand vehicles with regard to their performance in light rear-end collisions and with emphasis on seat protection potential and damage patterns.

2. Methods & Material

The paper is based on over 95 RCAR crash test results with the BioRid II dummy in the driver's seat, and specifically on 20 rear impact tests with new-brand models. The tests were conducted in the course of the initial classification of the vehicles into a German insurance type class [4]. The tests and damage to the vehicles were documented and compared in detail at AZT. It was evaluated whether there were differences in the dummy loads and the extent of damage compared to the established vehicle manufacturers. The Euro NCAP seat rating scales [2] were used to classify the severity of the dummy loads. At least so far, low-speed crash tests with these new models are not available in public databases. For a better understanding and classification of the damage according to the tests

- new vehicle brands, to which the results refer, are listed by way of example
- the German type class system and the crash tests included in this rating are presented with reference to their documentation at AZT Automotive GmbH
- body repair times after the Structure Test Rear [5] of established and new brands on the German market are compared.

2.1. Overview of new brands on the German market in 2022 and 2023

AZT carried out tests with pre production models for the primary insurance type classifications on behalf of the vehicle manufacturers. For confidentiality reasons, the results can only be published without any reference to individual manufacturer, make or model. The following general listings of vehicle manufacturers and models that came or will come onto the German market in 2022 or 2023 include many models that were tested by AZT Automotive GmbH and to which the later results refer. Table 1 shows the corporate structure and models of the largest Chinese car manufacturers, which currently enter the German market (list does not claim to be exhaustive):

Table 1: Examples for new brands: Chinese vehicles that came or will come onto the German market in 2022 or 2023 [3]

Group	Brand	Model
Aiways	Aiways	U5, U6
Saic	MG Roewe	MG4, MG5, ZS EV, EHS, Marvel R
Geely	Lotus	Eletre
	Smart	#1
	Lynk&Co.	01
	Zeekr	001, X
	Volvo	C40, S60, V60, S90, V90, XC40, XC60, XC90, EX90
	Polestar	1, 2, 3, 4
BYD	BYD	Seal, Atto 3, Dolphin
GWM	Ora	Funky Cat, Coffee 01
Nio	Nio	ET7, ET5, EL7

2.2. Rear impact tests for structure and bumper

The AZT was instrumental in defining and establishing the crash tests for insurance rating not only for Germany. This was achieved through the worldwide association of insurance research centres in the RCAR consortium, whose aim is to share knowledge on repair and safety research, define uniform test standards and reduce the risk of vehicles and traffic. All test descriptions can be found on the website www.rcar.org [1].
The AZT rear impact repair test often referred to in Germany corresponds to the RCAR standard “Low velocity structural crash test rear impact” [5]. The AZT bumper test rear equates to the RCAR standard “Bumper Test” [6]. For simplicity, this conference paper refers to RCAR Bumper Test Rear and RCAR Structure Test Rear.

2.3. Documentation of tests using measuring equipment and cameras

AZT’s test records including photos, measurement data and videos. A BioRid II with a mass of 78 kg in line with the RCAR/IIWPG standard is placed on the driver's seat of the impact vehicle. Its sensors measure the accelerations, forces and torques exerted on the head, the pelvis, the neck, the thoracic and the lumber vertebrae. A sensor located on the head restraint determines the time of the initial and final contact with the head restraint. The data captured is in line with the RCAR-IIWPG protocol [7]. The dummy coordinate system according to SAE J211 is used for the evaluation.

2.4. Repair times after Structure Tests Rear @ 15 km/h from 2020 to mid-2023

With the type class system, the German Insurance Association (GDV) provides the market with an aid for calculating a relative insurance risk class for passenger vehicles. Vehicle models are assigned to a type class based on their statistically recorded claims history [4]. However, new vehicle models require an initial classification as a forecast for their future risk premium. Therefore, the classification committee meets five times a year, in order to classify new vehicle types. The following influencing factors are taken into account in motor own damage insurance (MOD):

- results from RCAR Structure Tests Font and Rear @ 15 km/h
- results from the RCAR Bumper Tests Front and Rear @ 10 km/h
- theoretical calculation of a repair after a side impact
- the repair times and costs for the standard repair defined by the manufacturer, as well as the costs for replacement parts and paint materials
- statistical data on the damage frequency of the comparable vehicle type, taking into account engine power and propulsion

Since the beginning of 2020 until mid-2023, 207 new vehicle models have been classified by the German Insurance Association (GDV). This includes 15 new brands that were rated for the German market for the first time. For the rating, repair calculations are prepared after each crash test. From the repair calculations after Structure Test Rear, on the one hand the total repair costs were taken and on the other hand only the pure body repair work without disassembly and assembly work. This shows whether new brands are conspicuous either in the spare part prices or in the repair times. If the repair time is high, this indicates greater deformation of the vehicle structure. If the total repair costs are high but the repair times are low, the spare parts prices are higher than the average for the other brands.

3. Results

Test evaluations show how the dummy load has changed over the years in the RCAR Structure Test Rear. The values from 2020 include vehicles from new brands. Exemplary parameters of the Euro NCAP seat assessment were considered. In addition, the damage patterns according to the RCAR structure and bumper rear tests are dealt with and conspicuous features are pointed out which must be taken into account in the delta-v calculation.

3.1. Seat developments based on consumer protection tests

From the test videos and the data collected with the dummy, it is clear that the behavior of the dummy in today's cars is very different from what was observed in models that came to market 1990 to 2007; Figure 7 to Figure 9.

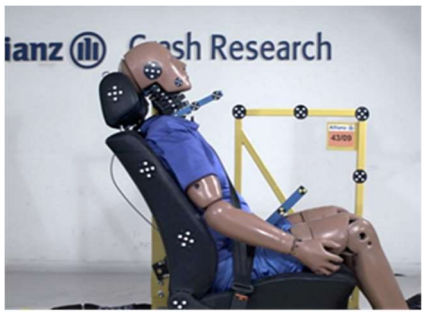


Figure 7: VW Golf III seat, built 1991,
delta-v= 8.6 km/h,
maximum extension of dummy

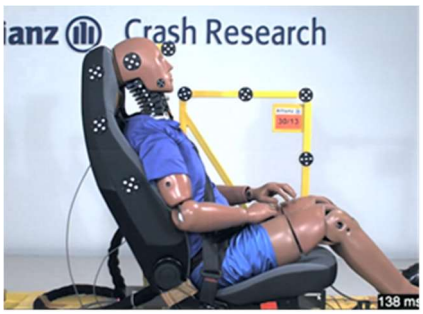


Figure 8: Smart Fortwo seat, built 1998,
delta-v= 10.1 km/h,
maximum extension of dummy

Figure 9: Dummy in Ford Focus, built 2012,
delta-v=10.4 km/h,
maximum extension of dummy

Figure 7 is taken from a test with a seat from a VW Golf III. Even though the Δv was just 8.6 km/h, the seat back was considerably deformed during the test, and the head restraint slid downwards during head contact. A seat of this kind offers only little protection potential in a rear impact.
Figure 8 is taken from a test on a 1st generation Smart-Fortwo seat. Its integrated head restraint meant that, for its time, this seat provided good protection potential in a rear impact. Even though, at 10.1 km/h, the Δv was higher than for the test conducted on the VW Golf III seat, there was a significantly lower degree of retraction, extension and flexion of the cervical spine of the dummy.
Figure 9 is taken from a car-to-car test "VW Golf VII on Ford Focus Turnier DYB 100% overlap". In this case, with a Δv of 10.4 km/h, an even smaller differential movement between head and upper body is apparent. For positive development for the occupants is based on the by now established consumer protection tests.
The implementation of the BioRid II saw the development of seat assessment tests with protection criteria for occupants. With a Δv of 16 km/h, the IIWPG Crash Pulse was the first of its kind in 2006. The criteria for a good seat were derived from real world accident situations. To this end, statistics were produced showing how frequently neck distortion claims were made in which vehicle models involved in an accident. If a vehicle model appears there at a rate that is far below average – adjusted for the numbers of new registrations – it may be assumed that it was fitted with a seat offering a high level of protection potential. These seats were then fitted with a BioRid II and tested using the specified crash pulse.
The IIWPG Crash Pulse corresponds to today's Euro NCAP Medium Severity Pulse [2]. Back then a seat was viewed as "good" (meaning it was given a green rating under the Euro NCAP criteria), if the upper neck tension was less than +750 N and the upper neck shear force was less than +150 N. To obtain a green rating today, the upper neck tension must be less than 360 N and the upper neck shear force less than 30 N, Figure 10. The seat assessment criteria have been repeatedly tightened over the years. These criteria do not reflect a person's physical load tolerance limits. Nevertheless, it is because of them that today's vehicle seats have been optimised towards this accident severity level, offering a significantly higher level of protection for vehicle occupants than before [1].
For its vehicle whiplash assessment, from 2008 to the end of 2019 the Euro NCAP carried out three crash pulse tests of varying severity with seats placed on a test sled in order to encourage the wide-ranging design of occupant safety systems. The factors on which the seat assessment were based included the protection criteria for the cervical vertebra, i.e.

- NIC (Neck Injury Criterion) and
- Nkm (linear combination of forces and torques),
- rebound velocity,
- upper neck sheer force and tension,
- maximum acceleration of the first thoracic vertebra
- time to first contact with the head restraint and
- head restraint contact time.

The lower neck and seatback deflection measuring points were added in 2020. Therefore, no long-term values are available for it yet.

Whiplash Test	Medium Severity Pulse			High Severity Pulse		
SafetyWissen by carhs	Higher Limit	Lower Limit	Capping Limit	Higher Limit	Lower Limit	Capping Limit
NIC	11.00	24.00	27.00	13.00	23.00	25.50
Nkm			0.69			0.78
Rebound velocity (m/s)			5.2			6.0
Upper Neck $F_{x,shear(+ve)}$ (N)	30	190	290	30	210	364
Upper Neck $F_{x,shear(-ve)}$ (N)			360			360
Upper Neck $F_{z,tension}$ (N)	360	750	900	470	770	1024
Upper Neck $M_{y,extension+flexion}$ (Nm)			30			30
Lower Neck $F_{x,shear(ABS)}$ (N)			360			360
Lower Neck $M_{y,extension+flexion}$ (Nm)			30			30
T1 acceleration (g)			15.55			17.80
T-HRC (ms)			92			92
Seatback Deflection (°)						32

Figure 10: Euro NCAP dynamic seat assessment criteria, “Safety Companion 2023” published by Carhs [9]

Figure 10 shows the seat assessment criteria for the various test pulses in 2023. Since 2020, the low severity pulse is no longer tested. The figure gives an idea of the forces that can be exerted on vehicle occupants in a rear impact with a Δv up to 24 km/h. With volume models, the dummy loads measured in the AZT were generally below the Euro NCAP limit values for a good seat.
In a real world accident, however, the seat behaviour cannot be viewed in isolation from the vehicle behaviour. This is why the AZT uses the BioRid II for rear crash tests even if the severity of the crash pulse is less than in the consumer protection tests. Figure 11 sets out the Euro NCAP test pulses compared against the RCAR rear impact tests considered here. In terms of the Δv, the RCAR test pulses all fall below the standard sled seat tests. The delta-v of the cars in the RCAR tests depends on the structural stiffness and the vehicle mass and therefore varies. Delta-v values in the range of 5.1 and 10.6 km/h were achieved in the RCAR Structure Test Rear. In the RCAR Bumper Test Rear, values between 10.3 and 13.9 km/h were measured.

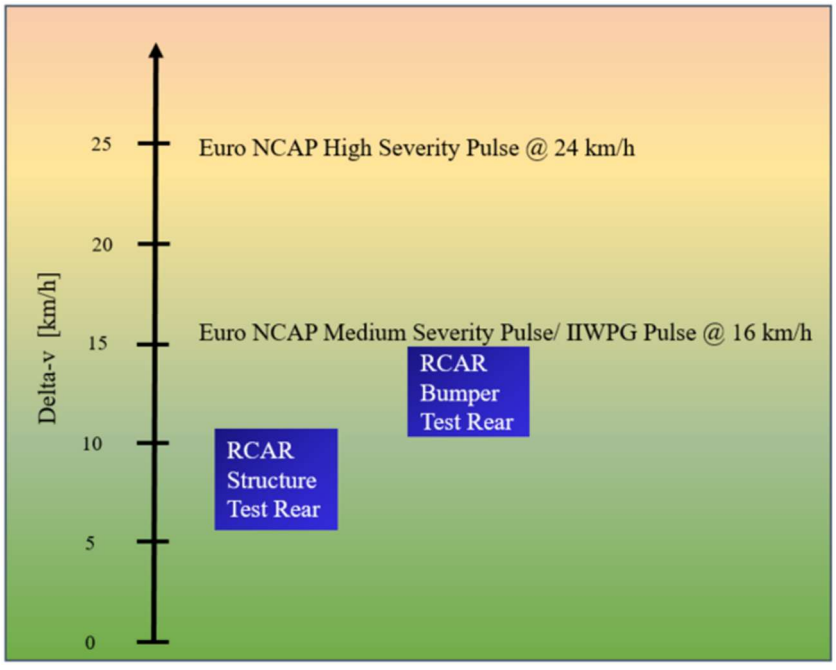


Figure 11: Delta-v from Euro NCAP crash pulses for seat assessment compared to AZT crash tests

3.2. Dummy load according to Euro NCAP parameters for RCAR tests for the vehicle model years 2004 to 2023

The following test evaluations show how the dummy load has changed over the years in the RCAR Structure Test Rear. The values from 2020 include vehicles from new brands. Exemplary parameters of the Euro NCAP seat assessment were considered.
The positive forces at the upper neck force measuring point of the dummy have, with a few exceptions, decreased over the years in 77 RCAR Structure Tests Rear in passenger car volume models, Figure 12. The maxima relate to the time from collision T-zero to the end of head contact with the head restraint. If the instrumentation is configured in accordance with SAE J211, positive shear shall indicate head-rearwards motion. In this way, the severity of the extension can be quantified. Started at over 110 N, the values now oscillate between zero and 50 N. The value of 50 N from 2023 belongs to a new brand but comes from a test with a cross member for a trailer hitch. This resulted in a very hard and short impact during the test with the steel barrier, which would not occur in this way in a real accident with contact of a deformable vehicle front. Nevertheless, the seat offers good protection potential. The two higher values in 2019 relate to a vehicle with very narrow sports seats in which the dummy could not be positioned well, and a prototype of a small urban vehicle in which only a concept seat was installed at the time of the crash test. Both values therefore do not refer to series production or volume models and were also not from new brands. On the contrary, the new brand models fit well into the trend of decreasing upper neck forces and did not show any conspicuities.

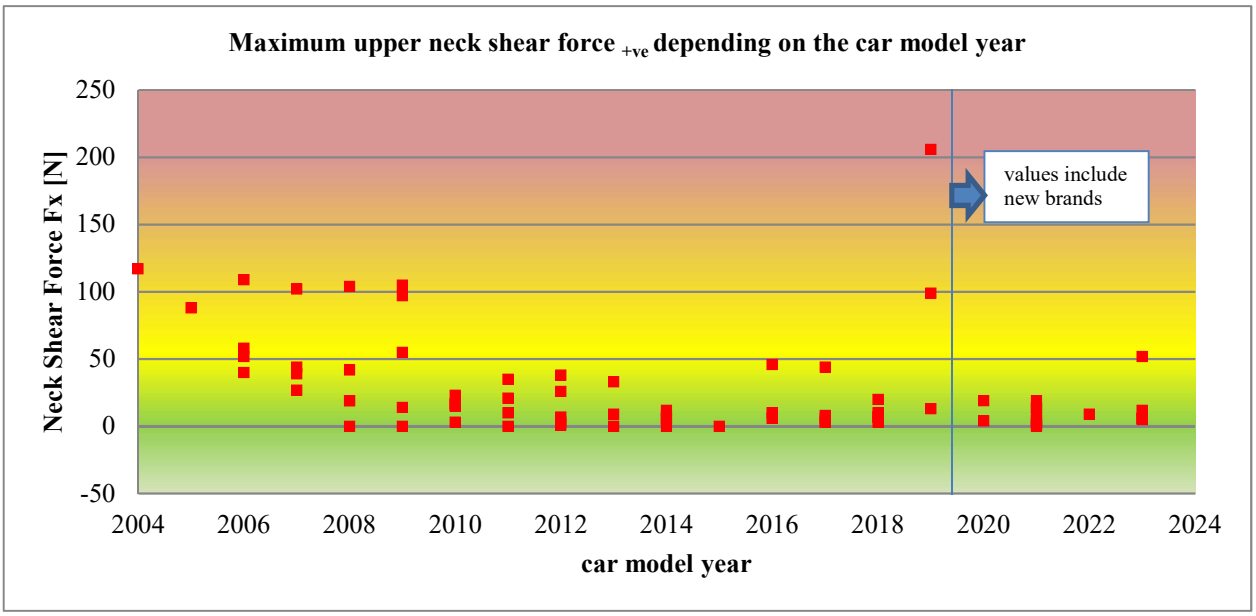


Figure 12: Maximum upper neck shear force $_{+ve}$ depending on the car model year, values from 77 RCAR Structure Tests Rear at AZT

The measured value upper neck force$_{-ve}$ was included in the Euro NCAP assessment only in 2020. It was also not previously determined in tests at AZT. There are 46 AZT test evaluations available since 2008. It was noticeable that in recent years the negative maximum represented a higher force on the neck than the positive maximum, Figure 13. This means that flexion is higher than extension and the head is pushed forward very early by the headrest. In real accidents, this even goes so far that occupants report only a forward movement into the belt and a hard contact with the head restraint even in rear impacts. However, there is a tendency to see a decrease in the load here as well. In the AZT tests, all values were far from the Euro NCAP capping limit of 360 N.

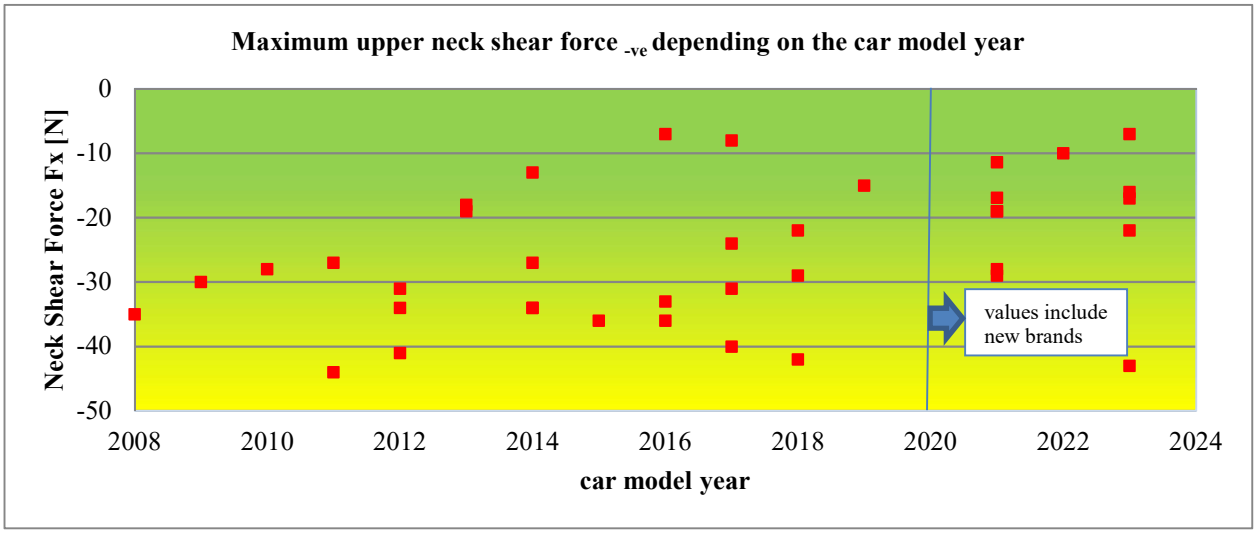


Figure 13: Maximum upper neck shear force $_{-ve}$ depending on the car model year, values from 46 RCAR Structure Tests Rear at AZT

The Neck Injury Criterion (NIC) is based on the relative horizontal acceleration and velocity of the occipital joint relative to vortex T_1. To calculate NIC, two data channels are needed, which are the head x-acceleration and average T_1 x-acceleration. Figure 14 shows the development of the values. Since 2010, only the value of the concept seat has been above the protection criteria level of 15 m²/s². And since 2020, only the value of a Nissan Qashqai has exceeded the Euro NCAP limit of 11 m²/s² for a good seat rating. The new brands showed good results.

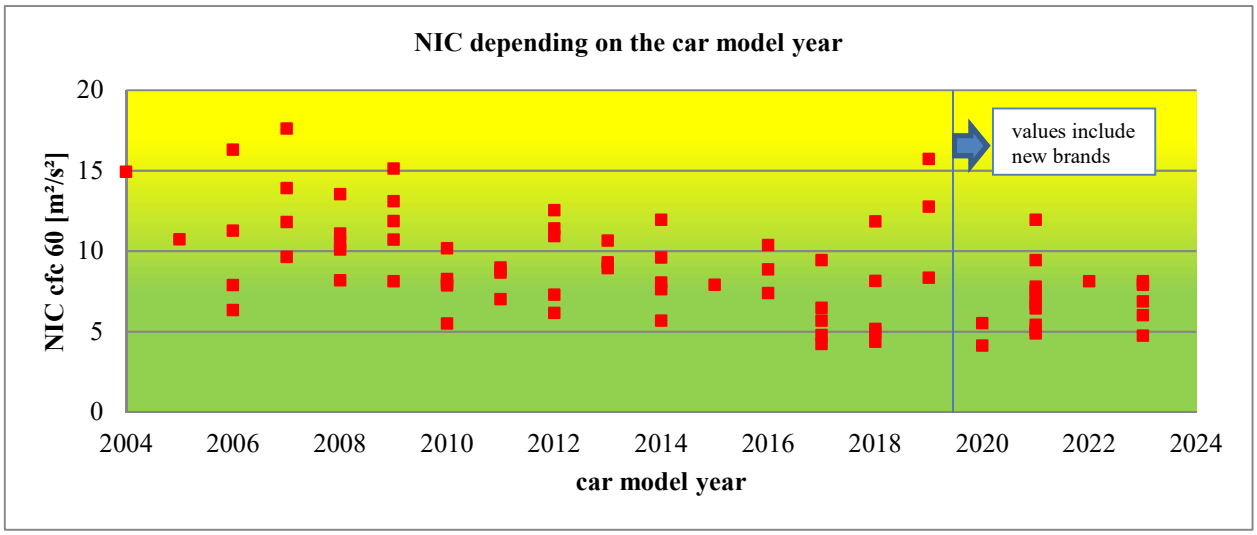


Figure 14: Neck Injury Criterion (NIC) depending on the car model year, values from 77 RCAR Structure Tests Rear at AZT

The Euro NCAP capping limit of the rebound velocity is 5.2 m/s. This limit has never been exceeded over the years. Here, too, the trend is towards lower values of even less than 2 m/s. This development towards a slower and less pronounced body movement as a result of a rear impact should defuse the experience of a rear-end collision for the occupants.

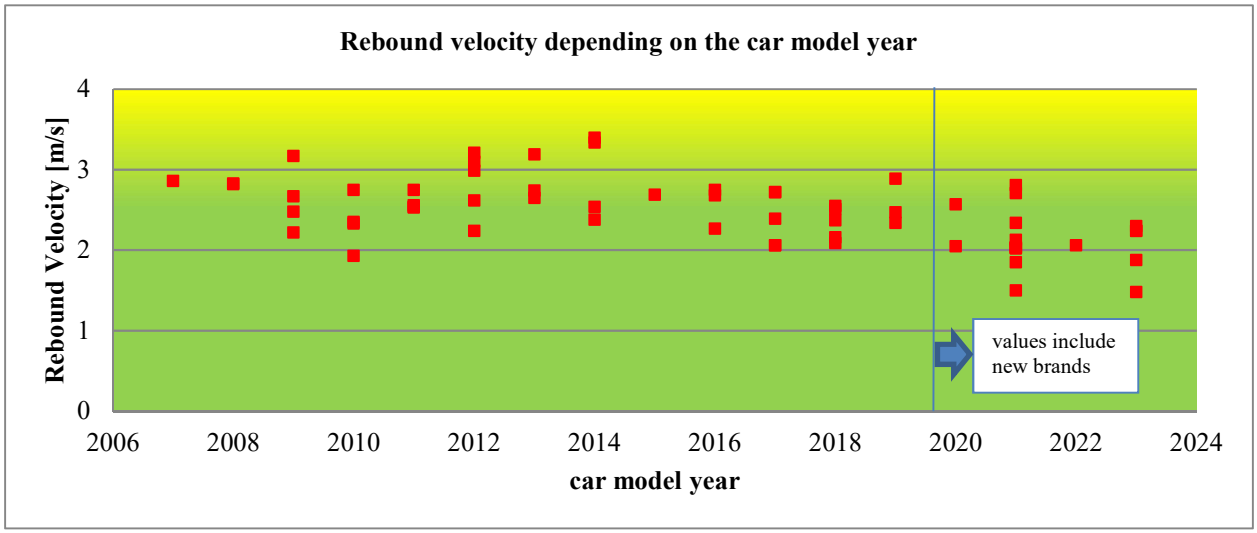


Figure 15: Rebound velocity depending on the car model year, values from 77 RCAR Structure Tests Rear at AZT

Finally, the acceleration of the T1 vortex in the x-direction is discussed. Figure 16 shows that here too the Euro NCAP capping limit of 15.55 g was never reached due to the lower test pulses. However, no clear downward trend is evident either. Nevertheless, the new brands remain inconspicuous.

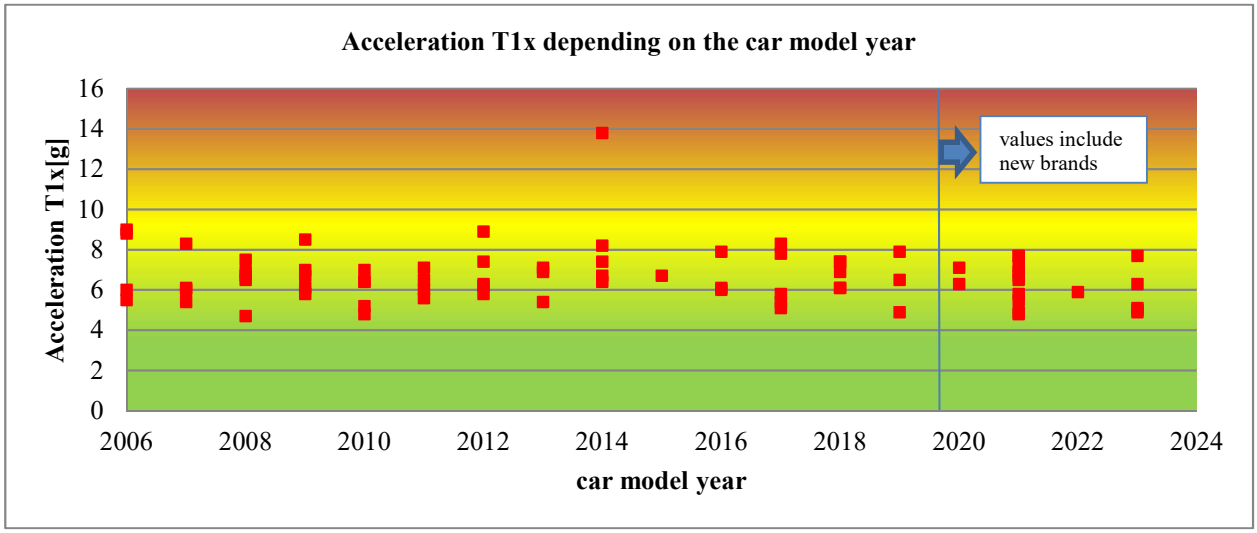


Figure 16: Rebound velocity depending on the car model year, values from 77 RCAR Structure Tests Rear at AZT

The measured values of the BioRid II show a comparable performance of seats in new brands. This is in line with Euro NCAP results. Table 4 shows the overall star rating and the points achieved in the whiplash rating for some new models on the German market. Since Euro NCAP constantly adjusts the rating, the maximum achievable number of points in the whiplash rating differs in the different test years. The values are taken from the Euro NCAP homepage https://www.euroncap.com/en [2].

The NCAP seat rating is familiar to new brands especially from China, as there is also a similarly weighted whiplash rating in the China NCAP. The protection potential of the seats is thus comparable to that of established manufacturers in Europe. However, the insurance rating procedures and tests for the initial type class at market launch have not been familiar to some new brands in the development phase of the vehicle models. A five-star rating in Euro NCAP is no guarantee of a good performance in low speed crash tests. For this reason, the next chapter deals with the damage patterns after the RCAR tests.

Table 4: Results Euro NCAP overall rating and whiplash rating of some Chinese manufacturers on the German market in 2022 and 2023

Group	Brand	Model	Euro NCAP Star rating	Euro NCAP Whiplash rating points
Aiways	Aiways	U5	***	1.4 / 2
		U6	data not available	
Saic	MG Roewe	MG4	*****	3.0 / 4
		MG5	data not available	
		MG ZS EV	*****	1.7 / 2
		MG Marvel R	****	3.0 / 4
		MG EHS	data not available	
		MG HS	*****	1.8 / 2
Geely	Lotus	Eletre	data not available	
	Smart	#1	*****	3.8 / 4
	Lynk&Co.	01	*****	3.8 / 4
	Zeekr	001	data not available	
		X	data not available	
	Volvo	C40	*****	3.6 / 4
		S60	*****	1.9 / 2
		V60	*****	1.9 / 2
		S90	*****	2.8 / 3
		V90	*****	2.8 / 3
		XC40	*****	1.8 / 2
		XC60	*****	2.8 / 3
		XC90	*****	2.8 / 3
		EX90	data not yet available	
	Polestar	2	*****	4.0 / 4
BYD	BYD	Seal, Dolphin	data not yet available	
		Atto 3	*****	3.9 / 4
Nio	Nio	ET7	*****	3.6 / 4
		ET5	data not yet available	
		EL7	data not yet available	

3.3. Conspicuities in the damage patterns after the RCAR tests

After the RCAR tests, some new brands showed a strikingly high severity of damage, which was not expected. If the delta-v were to be determined after a real accident on the basis of the damage pictures using a traditional approach, the delta-v would be calculated too high for these vehicles. As long as not all new brands do not have a readable event data recorder, the damage pattern remains the only indicator for the severity of the accident and the delta-v. At present, the databases do not contain a sufficient number of crash tests with new brand vehicles, so that crash test results from vehicles that are comparable at first glance must be used to determine an EES value. But even if the vehicles are similar in shape, size and mass, their bumper crash structure can show completely different behavior.
To better illustrate this, the good crash result of an Opel Grandland X (for a more technical detailed description, see Table 5) will be compared with damage patterns of vehicle from new brands after the RCAR Structure Test Rear. Then it will be shown how to find out whether the crash structure of a vehicle shows a good behavior in terms of damage minimization or rather not in case of light rear impacts.

Table 5: Relevant technical data of the Opel Grandland X test vehicle

Brand:	Opel
Type:	Z
Model:	Grandland X 1.5 CDTI (96 kW)
VIN.:	WOVZCYHZXKSO18731
First Registration:	28.11.2018
Mileage:	8.618 km

After both RCAR rear impact tests, the rear bumper cover as well as the bumper cross member with the deformation elements had to be replaced. There was no damage to the tailgate, the rear end panel, the trunk floor, side members, wiring or sensors, Figures 17 to 22. These were very good crash results. The dimensions and shapes of the components as well as the placement of brackets and cables show the many years of experience of Opel engineers in the RCAR tests. As a strong competitor to VW, Opel tried to attract young drivers by offering a more favorable insurance rating. Less experienced engineers or manufacturers who pay less attention to insurance type classifications drive up repair costs after RCAR tests due to poorly shaped or placed add-on parts or insufficiently dimensioned cross members and deformation elements. Below are some examples of damage at three different cars from new brands after the RCAR rear impact tests, which the AZT would not have expected, Figures 23 to 44.
However, it cannot be said across the board that all new brands have achieved poor test results. But there were striking damage patterns among for example in some Chinese cars. Chinese vehicles based on platforms built in cooperation with traditional manufacturers performed better than Chinese vehicle manufacturers who market completely independent new developments.
Even if the seats are good, the unusually high vehicle damage at low speed would lead to an incorrect delta-v calculation and supposedly higher risk of whiplash, as the biomechanics would assume too high a crash energy. Since almost no comparative tests with new brands are yet available in the crash databases, the delta-v in these cases would be assumed to be too high. The AZT is also not yet allowed to publish its test results.

Table 6: Damages of the Opel Grandland X test vehicle after both RCAR rear impact tests

Damages after RCAR Bumper Rear @ 10 km/h	**Damages after RCAR Structure Rear @ 15,3 km/h**

Figure 17: damaged rear after Bumper Test Rear

Figure 18: damaged rear after Structure Test Rear

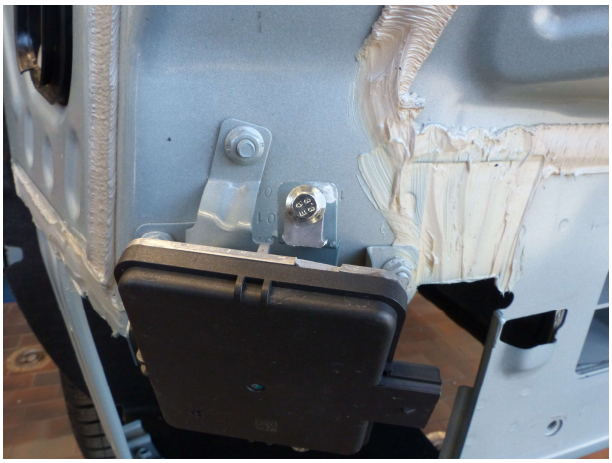
Figure 19: deformed cross member and deformation elements

Figure 20: deformed cross member and deformation elements

Figure 21: deformed cross member and deformation elements

Figure 22: no damage to the rear end panel and the flange plate apparent

Table 7: Damages of three different Chines cars after both RCAR rear impact tests

Vehicle 1	
Damages after RCAR Bumper Rear @ 10 km/h	**Damages after RCAR Structure Rear @ 15,3 km/h**
	
Figure 23: cross member is heavily depressed in the middle while the deformation elements have hardly absorbed any energy	Figure 24: cross member as well as the rear end panel are dented on the left side
	
Figure 25: rear panel is deformed	Figure 26: radar holder is broken with the housing
	
Figure 27: rear end panel and the rear lock carrier are deformed	Figure 28: wiring is squeezed

Vehicle 2

Damages after RCAR Bumper Rear @ 10 km/h
Vehicle was not admitted to the rear bumper test due to its geometry.

Damages after RCAR Structure Rear @ 15,3 km/h

Figure 29: cross member is heavily depressed in the middle while the deformation elements have hardly absorbed any energy

Figure 30: compression folds on side wall and roof frame

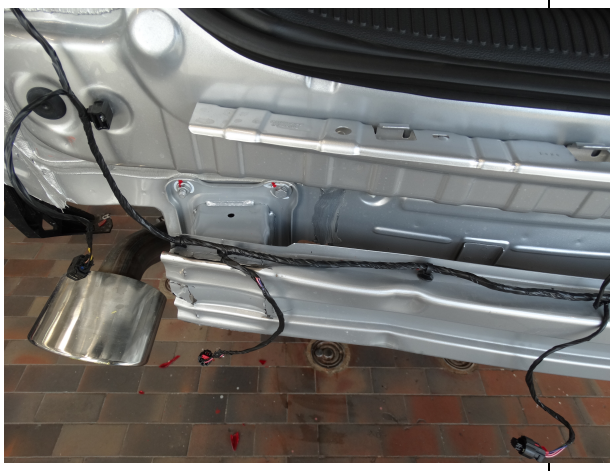


Figure 31: cross member and flange plate heavily depressed while the deformation elements have hardly absorbed any energy

Figure 32: Side member and trunk floor are compressed

Figure 33: side member compressed

Figure 34: trunk floor compressed

Vehicle 3

Damages after RCAR Bumper Rear @ 10 km/h

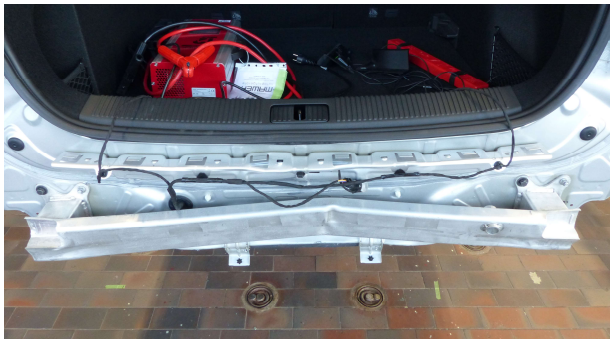


Figure 35: after disassembly of the bumper fascia: rear cross member heavily bent in the center, upper wire harness mounting bracket bent

Figure 37:Rear panel damaged by deformed cross member; PDC wiring harness not damaged

Figure 39: detailed view on unfolded cross member crash-box on driver's side.

Damages after RCAR Structure Rear @ 15,3 km/h

Figure 36: cross member and flange plate heavily depressed while the deformation elements have hardly absorbed any energy

Figure 38: cross member and flange plate in detail

Figure 40: flange plate and deformation element in detail

Figure 41:detailed view on the deformed rear panel

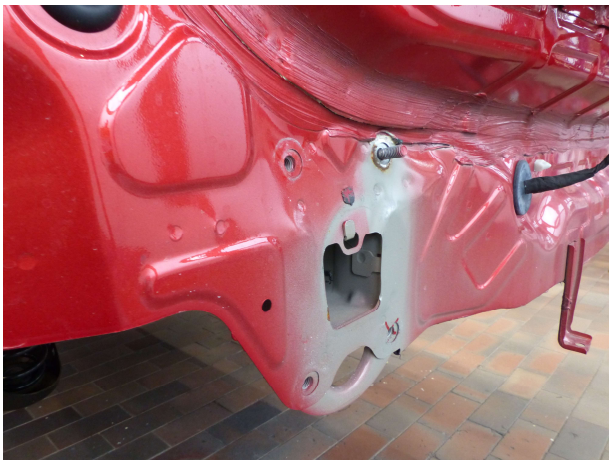


Figure 42: detailed view on the deformed rear panel

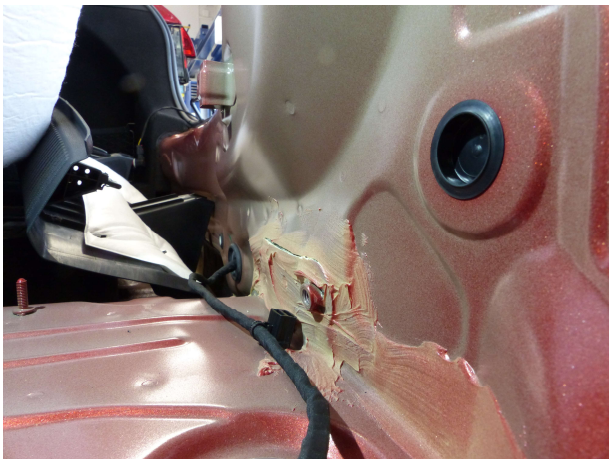


Figure 43: side member and trunk floor are compressed

Figure 44: side member and trunk floor are compressed

3.4. Repair times after RCAR Structure Tests Rear @ 15 km/h

As already mentioned at the beginning, the RCAR test results flow into the initial type class rating of the vehicle motor own damage insurance. The vehicle manufacturers have a direct influence on the type class classification through favorable repair methods and spare parts prices. If a vehicle is new to the market and you want to know something about its crash behavior in the event of minor front or rear impacts, it is therefore worth taking a look at the type class rating. But beware, the manufacturer may be able to cushion the high repair costs after the tests somewhat by offering favorable prices for spare parts. In exactly the same way, the manufacturer can also negatively influence the repair expenditure with very high spare parts prices even if the damage is only minor. The type class is therefore an indication, but the deformation behavior cannot be derived one-to-one from it. You need additional information about the manufacturer's market strategy, the direct competitor vehicles and the spare parts price.
Table 8 gives an overview per vehicle class of how high the repair costs were on average after the Structure Test Rear. The evaluation is based on hourly wages and spare parts prices in Germany in 2022. The average values relate to new vehicle registrations in Germany in 2022. While major deformations more often drive up repair costs for smaller vehicles, spare parts prices are more likely to be the price drivers for luxury cars and sports cars. On average, the repair costs were around € 2200 after RCAR Structure Test Rear.

Table 8: overview per vehicle class of repair costs on average after the Structure Test Rear in 2022

vehicle class	market share in Germany 2022 [%]	average repair costs after RCAR Structure Test Rear [€]
mini car	5.5	1899.83
small car	12.4	2038.72
compact car	15.9	1859.14
mid-size car	10.2	1653.65
upper mid-size car	2.9	2937.89
luxury car	1.0	3244.41
SUV	29.3	2233.19
off-road vehicle	11.3	1977.66
sports car	1.0	3673.40
mini van	0.9	1626.20
van	2.2	1677.30
utility	4.1	1761.84

Since the beginning of 2020 until mid-2023, 207 new vehicle models have been classified by the German Insurance Association (GDV). This includes 15 new brands that were rated for the German market for the first time. For the rating, repair calculations are prepared after each crash test. From these repair calculations, on the one hand the total repair costs after a Structure Test Rear were taken and on the other hand only the pure body repair work without disassembly and assembly work [see figure 45]. This shows whether new brands are conspicuous either in the spare part prices or in the body repair times. If the body repair time is high, this indicates greater deformation of the vehicle structure. If the total repair costs are high but the repair times are low, the spare parts prices are higher than the average for the other brands.

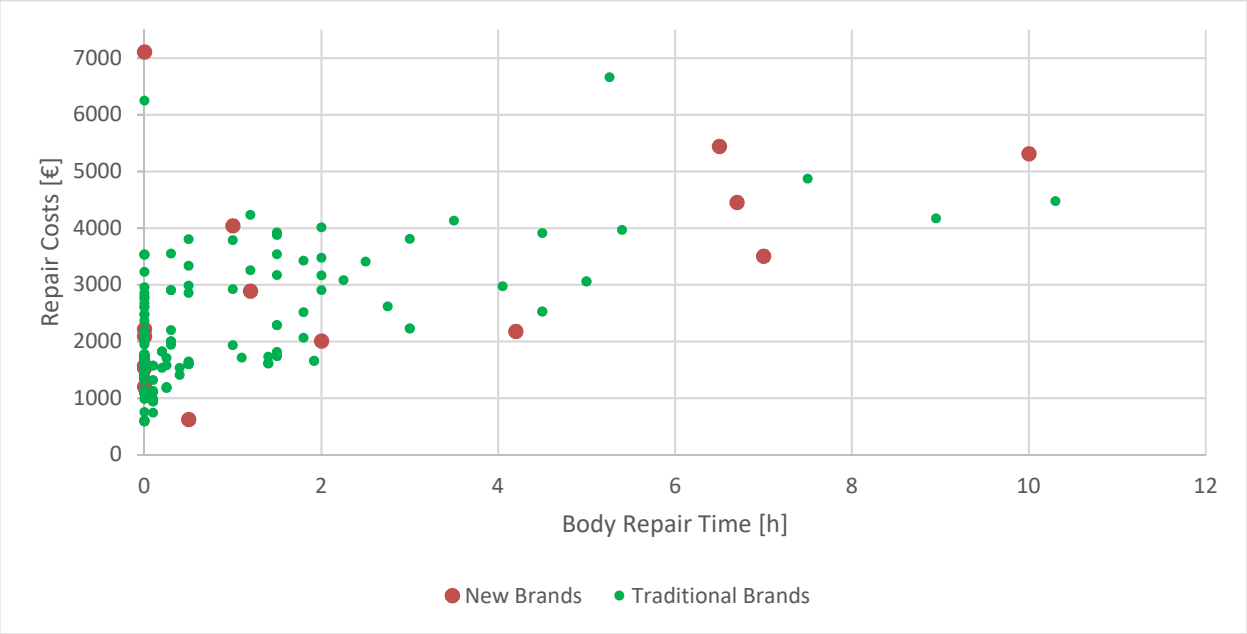


Figure 45: Repair costs and body repair times of vehicles reclassified by GDV from 2020 to 2023

Figure 45 shows the repair costs and body repair times of vehicles reclassified by GDV from 2020 to 2023. The red values represent 15 new-brand models and the green values 192 new models from traditional manufacturers on the German market. 57% of established manufacturers show no body repair times, while only 40% of new brands required no body repair. While the average body repair time for the 192 new models from established manufacturers is 0.7 hours, the average for 15 new-brand models is 2.6 hours. The difference becomes more serious when you look at the duration of the required body repair time in detail. Only 22% of established manufacturers with repair time exceeds one hour and only 3% more than five hours. For the new manufacturers, on the other hand, 47% of the vehicles require more than one hour of body repair time and as many as 27% require more than five hours. This suggests that new brands have not yet focused on the low-speed crash in their vehicle development.
However, the graph also shows that the vehicle with the longest repair time does not entail the most expensive repair costs. Since the same hourly rates were always used, this can be explained by lower spare parts prices. It is therefore not possible to draw conclusions about the deformation of the vehicle purely on the basis of damage costs. The body repair times must be taken into account.
The large scatter in repair costs and body repair times shows that a delta-v calculation on the basis of a vehicle damage is difficult to make without taking other connecting factors into account. The delta-v can very easily be set too high or too low. In any case, the damage to the collision partner must also be included. Crash tests or digital accident data can also help. But these are rarely available, especially with new brands.

4. Discussion

The evaluation of the Structure Tests Rear with regard to vehicle body behavior and occupant load has almost raised more questions than it has answered. Even though seats with high protection potential are installed in new brands vehicles thanks to the worldwide established consumer protection tests, unexpectedly high body damage results in an incorrectly calculated delta-v. Further crash tests are needed to address this problem in the long term. As a first remedy to correctly assess the risk of whiplash, the results of the Euro NCAP seat assessment and the calculation of the delta-v can be used. If no EDR data or other digital accident data are available, the delta-v must be calculated on the basis of the vehicle damage. However, special care must be taken here.
As it can be observed that some new brands such as Nio and Lotus also want to belong to the premium class, a further increase in car size and car mass can be expected. This means new challenges for the vehicle crash structure of the bumped as well as bumping vehicle.
The discussion about Whiplash claims will not fall asleep but is just coming to life in the Asian markets. Previous European studies as well as new Asian studies will be used in the argumentation for or against a claim. RCAR is currently working on a paper that summarizes relevant international studies and provides a guideline for the plausibility check of whiplash claims [8]. This may help to keep an overview of the increasingly Asian-driven market. It also makes clear that the delta-v and the acceleration have to be calculated in order to plausibilize claims. As long as not all new-brand models do not have a readable event data recorder, the damage pattern remains the only indicator for the severity of the accident.

5. Conclusion

Claims for compensation for pain and suffering reported to the insurance company due to a neck distortion as a result of a rear-end collision are stagnating in Germany. In Asian countries, prosperity is on the rise and so are insurance benefits. This raises the question of an appropriate plausibility check of whiplash claims in these countries as well. It is precisely from these markets that more and more vehicles are entering the European market. In Germany, the registration figures of Chinese manufacturers are growing by more than 100 %. European manufacturers are also increasingly orienting their design and equipment towards the Chinese market. Thanks to the globally established consumer protection tests, seats with a high protection potential are nowadays installed in high-volume passenger cars. The loads on the dummy in the tests carried out at the AZT have been decreasing continuously for years. So, the entire movement sequence of the occupants in the rear impact has changed significantly. In the Structure Test Rear, for example, purely forward movements of the dummy in the direction of the seat belt are registered more and more often, similar to the movement in a front impact. Most of the new manufacturers and brands are no exception.
However, the very high body damage after the RCAR Structure Test Rear is striking in some new brand models. Buckled side members and compressed vehicle rear bodies are no longer typical damage patterns at this low accident severity. A five-star rating in NCAP tests is no guarantee for good results in low speed crash tests. Body structure and ease of repair after minor collisions still need much improvement in some new brands. More than 53% of the tested models from new brands have an above-average repair time compared to established manufacturers.
Currently, there are not enough crash tests with new brands in European crash test databases to narrow down the EES after a collision on the basis of the vehicle damage and to finally calculate the acceleration and delta-v. However, the body repair times from both cars and digital accident data can give an indication of accident severity.
Further crash tests and the publication of these are required to really provide certainty for the delta-v calculation and to get a better feeling for the body behavior of new brands and manufacturers. The AZT is planning RCAR tests first, which will not be subject to nondisclosure.

6. Acknowledgements

I would like to thank Dr. Christoph Lauterwasser, the long-time managing director of AZT Automotive GmbH, for his commitment to RCAR, which led to the international establishment of research findings and test standards developed at the AZT. He also allowed the safety research team great freedom as well as financial support for whiplash research projects at the AZT crash track. Only because of this was it possible to carry out the time-consuming and numerous tests on the AZT crash track with the BioRid II dummy or even volunteers as well as various special test set-ups with elaborate documentation over many years.

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