German Insurance Association

Compact accident research

An investigation into the safety risks of light weight vehicles

Dr. J. Gwehenberger, Allianz Technical Centre
Dipl.-Ing. C. Reinkemeyer, Allianz Technical Centre
Dr.-Ing. M. Kühn, Insurers Accident Research

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German Insurers Accident Research
Wilhelmstraße 43 /43G, 10117 Berlin
PO Box 08 02 64, 10002 Berlin

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Preface

The results presented in this publication are the product of a joint research project of the German Insurers Accident Research in cooperation with the Allianz Technical Centre (AZT).

The research project forms part of the loss prevention work conducted by the German Insurers Accident Research.

The results of the research project were presented during a media event in Munich and were discussed during an international symposium in Brussels (www.unfallforschung-der-versicherer.de).

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Introduction

In the course of this research report the level of safety of so-called light weight vehicles (LWV) was investigated and assessed. Table I shows how these vehicles are classified although no determination is made as yet of their construction. The focus of this report falls on vehicles featuring car-like closed occupant cells. In accordance with the definition and glossary of the German Federal Motor Transport Authority (FMTA) light weight vehicles fall in the category of motorcycles with insurance indicator but not requiring registration.

Vehicles

- Motorcycles
  Motorcycles with insurance tags not requiring registration
  - Small motorcycles (L1e, L2e)
    - i.a. three-wheeled (max. 45 km/h)
    - Light weight vehicles (L6e) (four-wheeled and applicable criteria as in Table I)
  - Motorcycles with official licence plates requiring registration
    - i.a. three-wheeled and light four-wheeled vehicles (L5e, L7e)

The respective class decisive for this project, namely Class L6e as defined in the FMTA's classification, therefore does not feature so-called "trikes", but includes so-called "quads" and "open" light weight vehicles on a two-wheeled base. In Germany no difference is made as yet between a quad and a car-like light weight vehicle, which provides certain difficulties for the purposes of making statistical assessments in terms of the different user- and accident profiles. The introduction of the German Class S driving licence in 1995 permits light weight vehicles to be driven only by persons aged 16 years and older. The test requirements for this licence are less stringent than those required for a Class B driving licence.

In many European countries light weight vehicles are being treated as mopeds by lawmakers. Thus most European countries have special light weight vehicle driving licences (e.g. Austria) or also permit bearers of moped licences to drive light vehicles.

Altogether the situation is such, that light weight vehicles can be driven by persons who do not possess a driving licence. However light passenger vehicles require nearly as much space on the road as a normal car and also resemble the latter optically, with the result that they are considered to be an obstacle in traffic and can collide with vehicles that are considerably heavier. Light weight vehicles were originally introduced

	Light weight vehicle	
	Petrol	Diesel
Kerb weight	< 350 kg	
Displacement	< 50 cm³	unlimited
Top speed	< 45 km/h	
Engine performance	unlimited	< 4 kW

Table I:
Definition of light weight vehicles

on the market in France and Italy. In these countries they can be driven practically without any driving licence, for which reason about 50% of the approximately 300,000 light weight vehicles registered in Europe are to be found in France.

The manufacturers of light weight vehicles are of the opinion that their products provide a safe and comfortable alternative to the moped, especially for elderly persons not in possession of a driving licence and living in rural areas without proper public transport available. Accordingly the typical light weight vehicle customer is 50 years old, lives in the countryside or in a small town and has an annual income of less than 6,000 Euro. Table II illustrates the age distribution and -frequencies for bearers of Class S driving licences in Germany, and confirms that persons over 60 are the predominant users of light weight vehicles. Based on own observations youths and young adults obtain this driving licence practically exclusively for the use of quads.

The Federal Motor Transport Authority carries 10,771 vehicles without official license plate but with compulsory insurance on its records (0.6% of the total number of motorcycles). Both statistics include open- as well as closed vehicles; the FMTA however does not brake down these figures.

The manufacturers claim that the accident statistics prove that their vehicles provide sufficient safety. An evaluation of early statistical information obtained within the framework of this research however shows that this claim is only partially true. Although light weight vehicles are involved in accidents less often than vehicles in other vehicle classes, the risk of being killed in the case of a collision is up to ten times higher than in a passenger car (see Illustration 1). These findings are based on an evaluation of special statistics from Austria and France. Few statistics are available that treat light weight vehicles separately and don't include them in the category of mopeds, and the driving performance is rarely considered. A further limitation to be mentioned is the fact that the statistical accident material of Austria and France is currently not sufficient in volume to make a conclusive assessment of the real accident history possible. Further in-depth analysis as conducted by the Austrian Road Safety Board as well as investigations of AFQUAD based on figures of single state statistics are to provide additional findings in respect of the accident risks in real accidents.

When viewed from the perspective of available findings on the users the hypothesis can on

	14 - 17	18 - 20	21	22	23	24	25 - 29	30 - 34	35 - 39	40 - 49	50 - 59	60 and over	Total
Total	512	177	18	25	7	7	14	28	106	427	387	1062	2770
Men	387	152	13	15	5	4	12	18	81	304	291	880	2162
Women	125	25	5	10	2	3	2	10	25	123	96	182	608

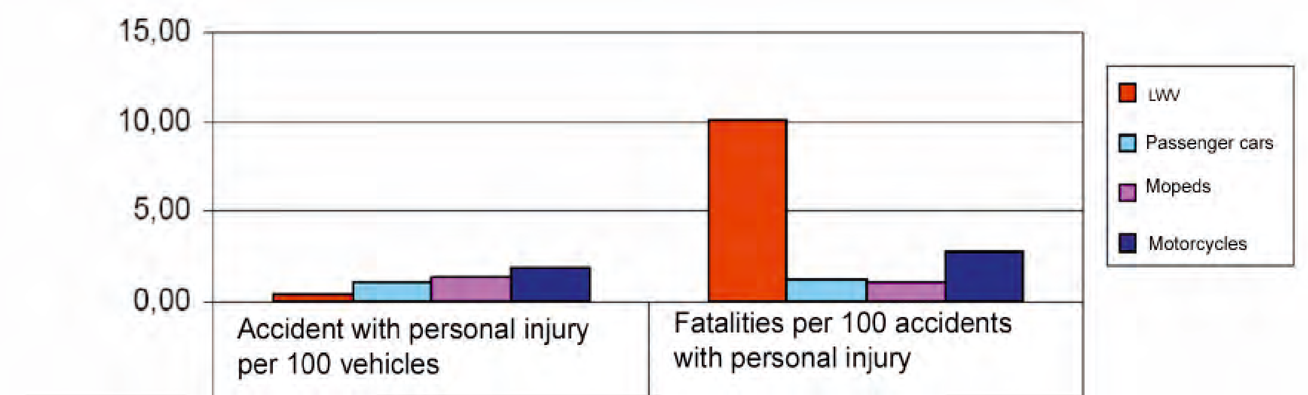
Table II:
Age distribution and -frequencies for Class S driving licences in Germany
(FMTA, Status: 01.01.2006)

the other hand be developed that individual kilometres traveled is below the average. Excluding the factor of kilometres traveled, the risk of having an accident with a light weight vehicle thus increases even more.

As far as the user profile is concerned, it should be complemented for purposes of traffic safety by the fact that the vehicles thus described are in part being used by physically impaired persons as an alternative to the so-called powered wheel chair, which is restricted to a maximum speed of 25 km/h. The tragic details of a corresponding accident in which a 50-year old disabled woman driving a light weight vehicle at a speed of 45 km/h was fatally injured when turn into n a rural road, is documented by the police in Neu Isenburg. The disabled person relied on her vehicle's assumed outward appearance of safety, an optical appearance that is normally projected by a passenger vehicle.

As such the conclusion is drawn that light weight vehicles are mainly used by elderly persons with insufficient driver's training (even though limited training is done for a Class S driving licence in Germany). In the case of non-German accident statistics a lack of driving knowledge and -experience could thus be a reason for the higher accident risk to which the drivers of light weight vehicles are exposed when compared to other road users. Initial figures lead to the assumption that drivers of light weight vehicles are more often responsible for the accidents in which they are involved.

In Germany merely insurance is compulsory for light weight vehicles but registration is not obligatory, which explains why these vehicles, comparatively speaking, do not even have to meet the legally prescribed passive safety requirements applying to passenger vehicles. Exceptions are the safety belt and the requirements of having a reflective warning triangle and a first-aid kit in the vehicle.



	Accident with personal injury per 100 vehicles	Fatalities per 100 accidents with personal injury
LWV	0,40	10,08
Passenger cars	1,05	1,17
Mopeds	1,39	1,10
Motorcycles	1,83	2,80

Illustration I:
Accident statistics Austria
(Source: Road Safety Board, Statistics Austria, 2006)

Physical bases

The empty mass of a light passenger vehicle corresponds to approximately one quarter of the mass of an average passenger car. The laws of physics, like the conservation of momentum and of energy, result in light passenger vehicles always experiencing the bigger difference in velocity and thus bigger deceleration when involved in collisions with heavier vehicles.

In order to quantify the impact of the forces in comparison to a passenger vehicle, physical observations were made. The evaluation of different accident constellations with the aid of a mathematical model lead to the conclusion that a vehicle can only offer sufficient protection when the weight ratio between the heavier and the lighter vehicle does not exceed 2:1.

The following illustration shows the change in velocity as a measure of the effect of the forces impacting on the light weight vehicle's occupants in comparison to other vehicles (assuming a head-on collision with a respective velocity of 45 km/h).

The intensive impact of forces on occupants of light weight vehicles makes the need for high quality restraint systems inevitable. Unfortunately the restraint systems currently found in the light weight vehicles available on the market do not take cognisance of this situation, because only very simple safety belts are being used and only one manufacturer offers an airbag at additional cost.

Crash tests

Al the test series described in the following section were conducted with two light weight vehicles, the Microcar MC1 Dynamic (with driver airbag) and the Ligier X-Too.

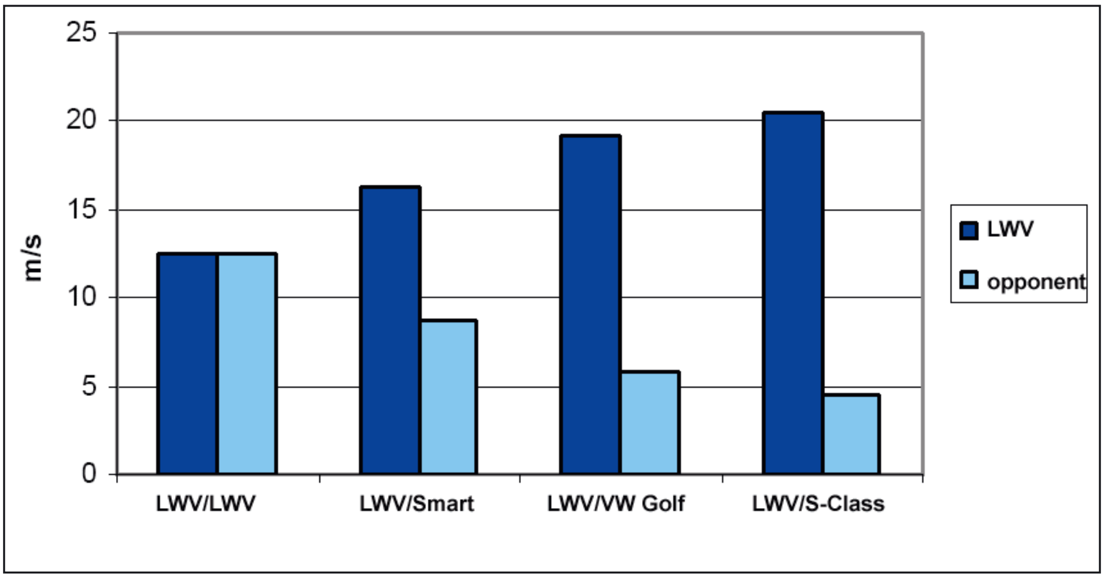


Illustration II:
Calculated chage of velocity

AZT repair tests (RCAR - Test front-end and rear-end)

The AZT repair front-end test, which serves primarily as the test for the reparability behaviour of light weight vehicles, in principle allows for only restricted assertions to be made on the aspect of passive safety. However, it became clear that even at low velocity the chassis of light weight vehicles comes under severe stress, the deformations are markedly greater than in passenger vehicles and the effect of safety belts is insufficient. The AZT rear-end crash tests provided a clear picture: the seats, headrests and the respective mountings are not rigid enough to provide occupants with sufficient protection.

Seat- and headrest evaluation

Further crash tests were conducted at low velocity in accordance with the test log of the International Insurance Whiplash Prevention Group (IIWPG) in order to evaluate the seats and the headrests. These tests are used for the evaluation of neckl injury risks in the case of a rear-end collision. Two light weight vehicle car seats were tested in accordance with IIPWG. When compared to normal passenger car seats, both seats show that an increasingly high likelihood of suffering an injury to the cervical spine exists in the case of a rear-end collision. Although some passenger car seats achieved similar low scores in IIPWG-tests, the results of the light weight vehicle seats tested in this case are exceptionally bad, e.g. the mountings of the headrests broke.

The following illustrations show the most extreme scenarios during the IIPWG-tests. In the case of the light weight vehicle seats (Illustration III) the marked S-whiplash of the cervical spine can be clearly recognised. In comparison the deformation of the cervical spine in a Volvo passenger car seat (Illustration IV) is markedly smaller. What aggravates the matter is the fact that the tested difference in velocity is already reached in relatively harmless rear-end collisions, a fact which characterises the majority of in-town accidents.

Illustration III: Light weight vehicle seat

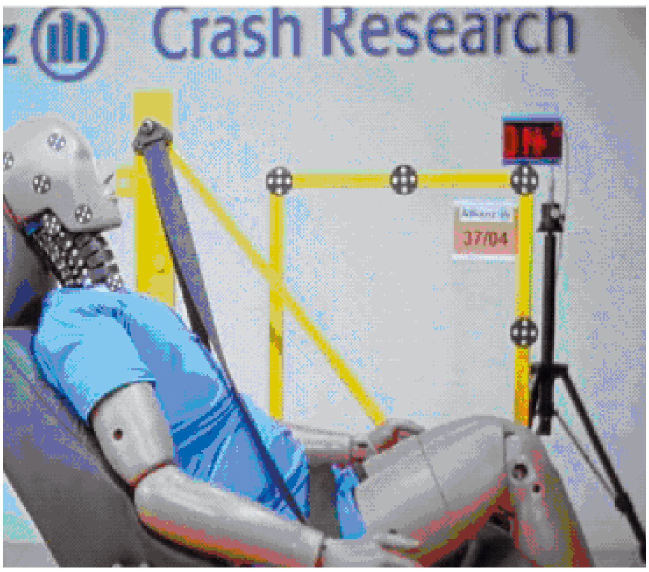


Illustration IV: Volvo passenger car seat

Head-on collision (ECE R-94)

In respect of vehicles liable to registration the legal minimum requirements of ECE R-94 (front-end crash) and ECE R-95 (side crash) apply inter alia in respect of the evaluation of occupant safety. These requirements do not necessarily have to be complied with by light weight vehicles, however, accidents in which light weight vehicles can become involved, are comparable to those of passenger cars.

Die Testgeschwindigkeit im Frontal- The test velocity in a head-on crash is 56 km/h and thus is above the maximum speed of a light weight vehicle. This may be surprising at first, but the test velocity is affected by the change velocity experienced in a vehicle in a head-on collision with another vehicle. As can be seen in Illustration II the change velocity of the light weight vehicle easily exceeds 56 km/h in collisions with heavy vehicles. In addition it should be noted that a head-on collision against a wall in principle merely represents a collision of two vehicles of equal mass travelling at the same speed. A more likely collision opponent would carry a vehicle mass of approximately 1,400 kg, for which reason the performed test represents a rather light accident for a light weight vehicle.

Thus it was not surprising that the occupant values were predominantly below the minimum permissible limit. In the test solely the impact on the front-seat passenger exceeds the minimum permissible value of neck whiplash, whilst the driver is protected by the airbag (Table III). Furthermore the shift of the steering wheel would make passing the ECE-test impossible.

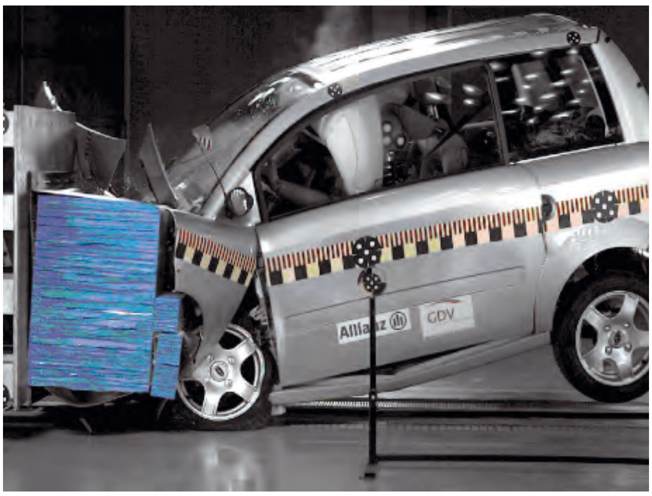


Illustration V:
ECE R-94 test, after 30ms

Illustration VI:
ECE R-94 test, shortly before final position

Characteristic load value	Limit	Microcar MC1	
		Driver	Front seat passenger
Head injury criterium HIC	1000	341	203
Head acceleration a_{3ms}	80 g	49 g	37 g
Neck shear force	3,1 kN	0,53 kN	1,09 kN
Neck pulling force	3,3 kN	1,72 kN	1,44 kN
Neck momentum	57 Nm	33 Nm	61,3 Nm
Chest deflection	50 mm	36,9 mm	42,7 mm
Thorax performance criteria (Viscous Criterion)	1 m/s	0,4 m/s	0,2 m/s
Upper leg axial force left	9,07 kN	1,33 kN	1,64 kN
Upper leg axial force left	9,07 kN	1,54 kN	1,41 kN
Lower leg criterium top right	1,3	0,35	0,41
Lower leg criterium top left	1,3	0,54	0,29
Lower leg criterium bottom right	1,3	0,54	0,17
Lower leg criterium bottom left	1,3	0,23	0,33
Lower leg axial force right	8 kN	1,4 kN	1,17 kN
Lower leg axial force left	8 kN	1,4 kN	1,00 kN

Table III:
Measured injury criteria in accordance with ECE R-94

Side-crash (ECE R-95)

The concluding test is a side-crash in accordance with ECE R-95, which better illustrates the real accident history. The results showed a clear picture: the light weight vehicle chassis could not cope with the impact at all. Both doors were torn from the vehicle and both longitudinal chassis beams broke. The driver's door offered no mentionable resistance. Despite the high door sill the barrier penetrated the vehicle interior deeply and pushed the dummy from its seat (see Illustrations VII and VIII). Even though the measured impact values were predominantly below the permissible limit, it is obvious that light weight vehicles of current make and construction would not pass the legally prescribed side-crash test.

Indicators	Limit	Value
Head Performance Criterion (HPC)	1000	239
Chest deflection top	42 mm	23,4 mm
Thorax Performance Criteria top (Viscus criterion VC)	1 m/s	0,21 m/s
Chest deflection middle	42 mm	34 mm
Thorax Performance Criteria middle (Viscus criterion VC)	1 m/s	0,42 m/s
Chest deflection bottom	42 mm	44,8 mm
Thorax Performance Criteria bottom (Viscus criterion VC)	1 m/s	0,8 m/s
Pubic symphysis	6 kN	4,26 kN
Stomach force	2,5 kN	0,89 kN

Table IV:
Measured injury criterias according to ECE R-95

Illustration VII:
Dangerous intrusion and pendular head rotation

Illustration VIII:
Final position of the dummy

Conclusions

The theoretical observations made on the basis of crash tests performed and first evaluations of accident data show that a passenger car look-alike light weight vehicle with an empty weight of below 350 kg and moving at 45 km/h holds a considerable safety risk. A collision at mere “city speed” exposes the driver to a much higher risk of suffering an injury. The prescribed weight restrictions do not as such make the use of modern safety measures and sufficiently rigid chassis possible. Additionally the stricter safety requirements as developed in respect of normal passenger cars over decades and constantly being optimised, do not exist.

The likelihood of youths changing from mopeds to light weight vehicles in the near future is rated as being low given the “elderly people” image of the latter. Against the background of the extremely high accident risk of “juvenile drivers” in relation to the limited active- and practically absent passive safety offered by light weight vehicles, the age restriction for driving light weight vehicles should be increased to 18 years.

Furthermore it is not foreseen that the number of light weight vehicles in Europe will undergo mentionable growth. However it should be borne in mind that vehicle concepts of this kind will gain in attractiveness against the background of increasing traffic density in congested urban areas and the climate debate – not only for older users. The main users are a few elderly people living in rural areas, who wish to be mobile within a small radius of activity around their villages. It is however necessary to increase the safety level of light weight vehicles even for this small group of road users. In this respect an effective point of departure could be complex technical solutions or an increase in the kerb weight. Simultaneously a moderate increase in the maximum permissible speed to approx. 55 km/h and a moderate increase in engine capacity could make a contribution to improving the active safety. With these measures passive safety could be enhanced on the one hand, and a friction-free integration into the “easy flow” of urban traffic assured on the other hand.

GDV
DIE DEUTSCHEN VERSICHERER

German Insurance Association
Wilhelmstraße 43 / 43G, 10117 Berlin
PO Box 08 02 64, 10002 Berlin

Phone: +49 30 2020-5000, Fax: +49 30 2020-6000
Internet: www.gdv.de