Insurers' Request for Increased Safety of Future Cars

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Abstract
The safety of passenger cars has improved substantially within the last decade. International test standards have improved the structural deformation characteristics of cars; passive safety systems like airbags have been introduced into the market. In addition, active safety systems such as electronic stability programs are to an ever greater extent becoming standard equipment in cars. In Germany, the number of fatally injured car occupants has fallen steadily during the past few years, although the number of accidents involving personal injury has remained more or less constant. This paper provides an analysis based on accident research of the German Insurance Association (GDV) which summarizes first the general problems inherent in the important accident groups car/car, car/pedestrian, car/truck and young drivers. Secondly, this paper discusses important aspects for active safety systems such as dynamic stability control or adaptive cruise control. Finally, this paper summarizes the experience gathered using passive safety systems in cars, covering both structural components and restraint systems. Thus, even if there has definitely been a major increase in safety, the safety of occupants can be improved substantially in the future as well and a further reduction of serious injury to car occupants can be expected. However, it is necessary to sustain this process of improved safety by continued accident analysis and further harmonization of international safety standards.
1 Accident Trends in Germany

During the period from 1992 to 1998, the number of road accidents involving personal injury registered by police in the Federal Republic of Germany has declined by 4.4% despite an increase in traffic density. The number of fatalities dropped by 26.7% and is particularly striking; the number of seriously injured persons declined by 16.5%. In 1998, there were 7,792 traffic fatalities (Fig. 1).

The number of car accidents involving personal injury has decreased even more. This figure declined by 5.4% during the same period. In addition, the decline in the number of fatalities (28.0%) and seriously injured persons (18.3%) was somewhat greater than the decline in the total number of accidents. The number of persons suffering minor injuries, on the other hand, has stagnated or risen slightly by 0.3% [1]. This is an indication that traffic accidents, which formerly resulted in severe injury, today involve only minor injury, in particular due to enhanced passive safety and rescue of accident victims.

![Fig. 1: Killed road users and car passengers in Germany from 1965 – 1998 [1]](image)

2 GDV Accident Research – Accident Material

The insurance business regards the damage prevention to be the third fundamental pillar of its work in addition to insure risks and settlement of damage claims. The insurance companies that are integrated in the German Insurance Association (GDV) therefore consider their fundamental objective to be to research the causes of accidents and priority of claims, to
suggest practicable solutions to the problem and to remedy the situation in cooperation with appropriate authorities such as public authorities, automobile manufacturers and road construction, as well as by educating road users.

The Institute for Vehicle Safety (IFM) has been conducting studies since 1969 on the safety and protection of road users. In systematic individual analysis of accident files provided by insurance companies and the police, the relationships are studied between the cause of accident, the sequence of events leading up to an accident, damage to the vehicle and results of injury. The Institute has at its disposal different databases such as the FS90, car/pedestrian accidents, motorcycle/car accidents, the airbag database and RESIKO containing nearly 20,000 car accidents involving personal injury (Fig. 2).

![Diagram]

**Fig. 2: A selection of databases of the Institute for Vehicle Safety focussing on car accidents**

The number of accident parameters in the individual databases currently includes far more than 100 parameters. For instance, the data material in the RESIKO database contains 340 fields per data record.

Moreover, comprehensive statistics of serious truck accidents in Bavaria in 1997 and comprehensive statistics of bus accidents involving personal injury in Bavaria in 1998 are currently being compiled.

In the future, modern accident research will necessitate a virtually simultaneous analysis of traffic accidents, in particular due to the ever greater reduction in the development periods of
safety systems. In order to be able to meet these requirements, the IFM is currently compiling a database (FS2000) which will be supplemented annually, thus enhancing yet again the relevance of the accident data material.

3 General Problems of Important Accident Groups

A total of 2.25 million traffic accidents were registered in Germany in 1998. Of these accidents, 17% involved personal injury. Fig. 3 provides a survey of accidents involving personal damage registered by the police, the involved fatalities, as well as the distribution of car accidents and fatalities depending on the kind of accident opponent. Accordingly, special emphasis is placed on single-car accidents, car/car accidents, car/truck accidents and car collisions with unprotected road users such as pedestrians, cyclists and motorcyclists. The following will be a discussion in particular of important general problems inherent in the accident groups car/car, car/pedestrian, car/truck and young drivers.

![Diagram of accidents registered by the police in 1998](source: StBA)

Fig. 3: Accidents registered by police in 1998 and the distribution of car accidents involving personal injury depending on the kind of accident opponent [1]

3.1 Accident Group Car/Car

A problem with a growing tendency in car/car collisions is the incompatibility of automobiles. These differences become particularly obvious when an off-road vehicle – which are basically licensed as cars in accordance with §20 StVZO – collides with a compact car (Fig. 4).
Fig. 4: An example of incompatibility of a car and off-road vehicle

The longstanding studies carried out by the Institute for Vehicle Safety clearly indicate an interdependence between the results of an accident and the mass of the vehicles involved in the accident. The RESIKO study is a good example that illustrates this point [2]. As can be seen in Fig. 5, the passengers in heavy cars suffered comparatively minor injuries. The difference in risk became somewhat clearer when only the injuries suffered by drivers in front collisions are used as the basis. If the "reference car" is substantially lighter than the other party’s car (mass ratio from 0.4 to 0.8), critical injury (MAIS 5+) occurred [19] in these cars far more frequently (35 %) than in those vehicles which were substantially heavier than the other party. From a mass ratio of 1.2 and upwards, the comparative proportion of critical injuries (MAIS 5+) clearly drops to 10 % or even less.

Fig. 5: Degree of injury as a function of vehicle mass (passengers per mass class = 100%)

At the same time, however, reference is made to the fact that the mass of the vehicles can only be influenced to a small extent due to the differences in usage. Light cars must therefore
be protected from the aggressivity of the large car as far as the geometry and stiffness of the car front – as homogeneus as possible.

Even today, there is still no generally applicable definition of compatibility. It is essentially dependent on the mass ratio as well as on the differences in rigidity and geometry of the collision partners. Studies of real accidents, however, have also demonstrated that many parameters such as the differences in the types of collision, different biomechanical passenger criteria or driver age make an assessment of compatibility problems more difficult [3]. The studies on a realistic determination of the compatibility risk and safety requirements applied to "compatibility" must therefore be vigorously pursued and must soon result in a solution. The supplementation of the 40 % offset test by the use of a smart barrier with measurement of compatibility criteria must be implemented as quickly as possible. A multi-stage barrier characteristic can solve the energy problems associated with the impact of cars with different masses (Fig. 6).

![Deformable Barrier ADAC](image)

*Fig. 6: Multi-stage deformable barrier according to ADAC*

### 3.2 Accident Group Car/Pedestrian

In the year 1998, 1,084 pedestrians were killed on Germany’s roads. Of these, 60 % (647 pedestrians) died as a result of collisions or traffic conflicts with automobiles [1], i.e. almost 10 % of all annual traffic fatalities in Germany. The reduction in the number of accidents involving pedestrians has been the declared aim of accident research for the past 30 years. The University of Berlin, for example, developed a vehicle known as the UNI-CAR in the
1970s which had been designed with a view to partner protection for pedestrians [4]. At the European level, a test procedure was developed which made it possible to uniformly estimate the risk of injury by the front section and the components of different car models (Fig. 7). This EEVC standard has been incorporated into the EU-NCAP test procedure [5].

![Diagram of impact situations between a pedestrian/car](image)

*Fig. 7: Different impact situations between a pedestrian/car at 40 km/h in accordance with EEVC WG 10 test procedure [5]*

The Institute for Vehicle Safety has evaluated more than 1,300 car/pedestrian accidents within the framework of a pedestrian project and has reconstructed the events leading up to the respective accident [6]. The principal impact regions on the car the pedestrian made contact with are the front and windshield (approx. 68%). Serious injuries usually resulted from contact with the windshield or the A-pillar. The design of the front section tends to correlate with the severity of injury. It can be said in conclusion that the following structural design measures of the front section could positively influence the injury risk for pedestrians:

- wedge-shaped front section design
- flat, rounded front structures
- "pedestrian crumple zones" in the dangerous hood area
- elimination of the aggressivity of outside mirrors
- ban on steel bull bars
The studies of the pedestrian accident material also show that in barely 20% of all accidents, the principal impact regions were the left or right side of the car. What is conspicuous is that one-third of these side impacts were due to children less than 10 years of age. Future test procedures for assessing the compatibility of the car as far as collisions with pedestrian are concerned must therefore take this accident constellation into account as well.

Continued assessment has proved to be problematical due to the influence of vehicle-specific parameters such as collision speed and pedestrian-specific parameters such as age, size, center of gravity of the body and distance of the head to the road surface. Other detailed analyses, which have taken as many of these parameters as possible into consideration, must in the future be based on an even broader data base, if possible on European-wide data. This could serve to validate the test data.

3.3 Accident Group Car/Truck

The Institute for Vehicle Safety is currently intensively looking into the creation and evaluation of a new database containing truck accidents in Bavaria from 1997. in collaboration with the Bavarian Ministry of the Interior and the Munich Regional Statistics Office, those cases involving severe or fatal injuries to accident opponent or the truck were extracted from a total of 3,651 registered accidents. This accident material covered about 1,000 accidents.

It was found within the framework of a pilot assessment of 300 truck accidents that the other party involved in 187 accidents was mainly (62.3%) the automobile [7]. The collisions of trucks and cars had a distribution shown in Figure 8.

<table>
<thead>
<tr>
<th>Collision-Type</th>
<th>Injured car occupants</th>
<th>Fatally injured car occupants</th>
<th>Number of Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Front/Front</td>
<td>69</td>
<td>25.2</td>
<td>17</td>
</tr>
<tr>
<td>Front/Side</td>
<td>55</td>
<td>20.1</td>
<td>7</td>
</tr>
<tr>
<td>Front/Rear</td>
<td>29</td>
<td>10.6</td>
<td>2</td>
</tr>
<tr>
<td>Rear/Front</td>
<td>51</td>
<td>18.6</td>
<td>2</td>
</tr>
<tr>
<td>Side/Front</td>
<td>46</td>
<td>16.8</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>24</td>
<td>8.8</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>274</td>
<td>100.0</td>
<td>32</td>
</tr>
</tbody>
</table>

*Fig. 8: Distribution of truck/car types of collisions in accidents with fatalities or severe injuries as well as injured and fatally injured persons in the car*
According to this diagram, almost one-quarter of all accidents involving personal injury in the car were front/front collisions, 21.6% of the trucks collided against the side of the car, and in third place, the car collided against the back of the truck in 18.9% of all cases.

A first comparison of the test data with the total accident survey of truck accidents in Bavaria in 1984 [8], in which truck accidents also involving minor injuries were investigated, provides good correlation in the distribution of casualties in the car in front/side (1984: 19.4%), rear/front (1984: 15.8%) and side/front collisions (1984: 20.5%). Front/front collisions, on the other hand, were overrepresented in 1997 with 25.2% as compared to 15.6% in 1984 since, when analyzed from a relative point of view, fewer minor casualties occurred in this type of collision. In 1997, personal injuries in which the truck crashed into the rear of the car, were underrepresented. When analyzed from a relative point of view, there are more minor casualties in this case.

What is especially obvious is the high risk of being killed in a car involved in a front/front collision. Seventeen fatalities or, put in a different way, more than half of all 32 car passengers killed were killed in this type of collision in which the difference in mass, the influence of collision speed and incompatibility of vehicles become especially evident.

![Images of collisions](image)

*Fig. 9: Examples of incompatibility between car and truck*

As earlier studies have already demonstrated [8: 9], the central problem is the incompatibility between the truck and the car as the most frequent collision partner. Figure 9 provides a survey showing examples of car impacts to the front, side and rear of the truck. Hence, further
optimization of partner protection between trucks and cars has top priority. Measures such as the introduction of energy-absorbing underrun protection systems for trucks and the continued improvement of rear underrun protection systems for trucks and trailers are necessary.

The demand for a reinforced rear underrun protection system has been substantiated by two crash tests in which an Audi A4 travelling at 35 km/h or 50 km/h crashed against the rear of a trailer with 75 % overlap [10]. The results of the study were that the car will slide one meter beneath the trailer at a collision speed of 35 km/h. At a speed of 50 km/h, the underrun protection system failed completely and the trunk sill penetrated the passenger compartment (Fig. 10).

![Fig. 10: Crash test: An Audi A4 with 75 % overlap and \( v_k = 50 \text{ km/h} \) against a trailer with a conventional underrun protection system](image)

3.4 Young Drivers

One of the main problems in traffic accidents in the Federal Republic of Germany is currently the number of accidents caused by young drivers between the ages of 18 and 24 inclusively. One out of every four fatalities is a young driver, although young persons make up only 7.7 % of the general population. In addition, since 1991 the number of young beginning drivers killed between the ages of 18 and 20 has leaped to approx. 30 %, although they continue to make up about the same proportion of the population (approx. 3 %). The relative risk of deadly injuries in this group is six times as high as in the comparison group containing drivers 25 years or older (Fig. 11) [11].
This high risk for young drivers can only be effectively counteracted with an entire bundle of measures which are implemented systematically and consistently. In addition to a further improvement of basic driver education in theory and practice, it will also be necessary to introduce an adequately long period of subsequent supervision and a second phase of driver education during the probationary period. Experience has shown that young drivers tend to overestimate their driving capabilities after a certain time – about 6 to 12 months after they have obtained their driver's licence. Special courses, instruction in new car engineering and driver safety training during a second phase of driver education could help to reduce the greater potential risk of young drivers when combined with supporting measures and conditions during the probationary period of the driver's licence such as special speed regulations and a general ban on alcohol.

4 Important Aspects for Active Safety

One important objective of accident research is to prevent traffic accidents entirely. The promotion of measures for active car safety as well as driver education and sensitization of persons involved in road traffic still continue to remain the central aims. This section provides a survey illustrating a few important recommendations and demands. This list, however, in no way claims to be complete.
4.1 Dynamic Stability Control

As studies of three independent sets of accident statistics involving a total of about 2,500 car accidents have shown, the risk situation "skidding in the pre-crash phase" occurs much more frequently than previously assumed [12]. Approximately 25% of all car accidents involving severe passenger injury can be traced back to collisions that occurred after skidding. In three quarters of these accidents, the driver had been inattentive or had made a mistake; approximately one-fourth can be traced back to the cause "dodging an emergency situation". Such skidding especially frequently ended up as a side collision: due to a sudden dodging motion or violently jerking the wheel around causes the driver to lose control of the vehicle which then ultimately turns sideways and hits either another oncoming vehicle or an obstacle on the shoulder of the road. Figure 12 shows a typical accident. In this case, the light vehicle hit the passenger side of the dark car front. The driver was killed, although he had been secured by a seatbelt.

**Fig. 12: Typical skidding accident with side collision against a car front**

Electronic dynamic stability control systems such as electronic stability programme (ESP) could provide the driver with indispensable assistance while stabilizing the vehicle and promise a clear reduction in the number of accidents caused by skidding, particularly since the study shows that about two thirds of all cases cover a critical path between 40 and 70 meters long and in another 20%, this distance exceeds 70 meters in length (Figure 13). Very short critical paths are involved in only every fifth or sixth skidding accident.
<table>
<thead>
<tr>
<th>car/car accident</th>
<th>&lt; 40 m</th>
<th>40 - 70 m</th>
<th>&gt; 70 m</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>straight road</td>
<td>3</td>
<td>7.3</td>
<td>27</td>
<td>65.9</td>
</tr>
<tr>
<td>curve right</td>
<td>7</td>
<td>18.4</td>
<td>27</td>
<td>71.1</td>
</tr>
<tr>
<td>curve left</td>
<td>9</td>
<td>17.3</td>
<td>28</td>
<td>53.8</td>
</tr>
<tr>
<td>total</td>
<td>19</td>
<td>14.5</td>
<td>82</td>
<td>62.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>single car accident</th>
<th>&lt; 40 m</th>
<th>40 - 70 m</th>
<th>&gt; 70 m</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>straight road</td>
<td>23</td>
<td>26.7</td>
<td>35</td>
<td>40.7</td>
</tr>
<tr>
<td>curve right</td>
<td>8</td>
<td>15.7</td>
<td>33</td>
<td>64.7</td>
</tr>
<tr>
<td>curve left</td>
<td>9</td>
<td>13.3</td>
<td>43</td>
<td>88.2</td>
</tr>
<tr>
<td>total</td>
<td>40</td>
<td>20.0</td>
<td>111</td>
<td>55.5</td>
</tr>
</tbody>
</table>

Fig. 13: Length of the critical path as a function of the course of the road [12]

ESP, however, promises to be advantageous in the light of accident prevention and active safety, but also in view of passenger protection and passive safety as well. Even if a collision proves to be unavoidable, ESP increases the likelihood of a collision with the front section of a vehicle, since the vehicle is kept "on course" as long as possible and transverse skidding is at least reduced (refer to Figure 14). This could reduce the high proportion of side collisions which are extremely dangerous for the passengers.

Fig. 14: Reconstruction of real accident compared to the Simulation with ESP [13]
The accident researchers from German automobile insurers therefore recommend offering dynamic stability control in all vehicle classes if possible and integrating them in standard automobile equipment. Reference must be made in this context, however, to the fact that a reduction in the number of accidents would only result as long as drivers do not change their behavior behind the wheel. Especially persons who enjoy taking high risks must be told that even these systems are subject to the laws of physics and only if the driver conducts himself as the situation warrants can enhanced safety be expected.

### 4.2 Adaptive Cruise Control

Owing to the motoring safety of modern vehicles, the quality of the roads, and the comfort of modern automobiles, today's driver is not fully aware of the driven speed. The necessary safety clearance is often underestimated, as indicated by the number of rear-end collisions. The percentage of rear-end collisions in accidents involving personal injury was 53.9 % in [14] (Figure 15). The introduction of distance warning systems as standard equipment must therefore be promoted more forcefully, although it must be noted that the current systems cannot be expected to bring about an extremely great reduction in the number of rear-end collisions, since they are designed as comfort systems.

<table>
<thead>
<tr>
<th>Front/Front</th>
<th>Front/Side</th>
<th>Front/Rear</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>13.6 %</td>
<td>32.5 %</td>
<td>53.9 %</td>
</tr>
</tbody>
</table>

*Fig 15: Distribution of collision types of car/car accidents with personal damage [14]*

### 5 Passive Safety

Numerous accident studies, in-depth analyses and field studies in the past few years have given rise to special priorities in car accidents and injuries suffered by car passengers. This
section is devoted to pointing out the demands and recommendations of German automobile insurers as far as passive safety is concerned, in particular with respect to restraint systems and structural measures for future automobiles. There is a clear potential improvement with respect to the rescue of accident victims due to the advances that have been made in the field of information technology. Finally, recommendations are suggested.

5.1 Restraint Systems

5.1.1 Smart Seatbelt Systems

The studies carried out within the RESIKO framework reconfirm that, in an above-average number of cases, seatbelts are frequently not worn, especially in accidents involving severe and fatal injuries, in particular at night [2]. There are three times as many unbelted persons who caused accidents as innocent persons involved in the accident. Not wearing a seatbelt is also observed often in accidents involving alcohol. It has also been shown that passengers were not wearing seatbelts in approximately 30% of all fatal car/car accidents.

In addition to more intensive inspection of the belt wearing rate – especially outside of city limits and at night – alcohol inspections in conjunction with smart seatbelt systems comprising seatbelt tensioners, seatbelt force limiters and seatbelt reminders (Figure 16) must urgently be recommended.

![Image of a car interior with seatbelt reminder]

Fig. 16: Seatbelt reminder (optical and acoustical)

This system is intended to ensure that when the passenger fails to buckle his seatbelt, he will be reminded to do so by acoustic and/or optical signals which increase in intensity. At the same time, the seatbelt reminder should be set in such a way that it not only sounds when
the driver starts to drive away before buckling his/her seatbelt, but that it also constantly monitors the status of the seatbelt, even for rear-seat passengers, while the car is in motion.

### 5.1.2 Front Airbags

Studies so far have indisputably confirmed the protective action of the front airbag as a supplementary restraint system to the three-point seatbelt for the driver. This protective effect is found in particular in highly severe accidents. A comparison of drivers secured by seatbelts only and drivers secured by seatbelts and airbags (Figure 17) revealed that the risk of being severely or even fatally injured is reduced by more than 40% by the driver airbag. Severe head injuries (AIS 2+) in particular are reduced by approximately 45%, facial injuries (AIS 2+) are almost entirely prevented.

<table>
<thead>
<tr>
<th>Damage degree</th>
<th>MAIS 0</th>
<th>MAIS 1</th>
<th>MAIS 2</th>
<th>MAIS 3</th>
<th>MAIS 4</th>
<th>MAIS 5</th>
<th>MAIS 6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - slightly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - moderate</td>
<td>35%</td>
<td>53%</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>3 - severely</td>
<td>13%</td>
<td>67%</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>4 - extreme</td>
<td>8%</td>
<td>24%</td>
<td>44%</td>
<td>12%</td>
<td>12%</td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>5 - total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50%</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damage degree</th>
<th>MAIS 0</th>
<th>MAIS 1</th>
<th>MAIS 2</th>
<th>MAIS 3</th>
<th>MAIS 4</th>
<th>MAIS 5</th>
<th>MAIS 6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - slightly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - moderate</td>
<td>52%</td>
<td>47%</td>
<td>1%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>3 - severely</td>
<td>34%</td>
<td>63%</td>
<td>3%</td>
<td>0.2%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>4 - extreme</td>
<td>12%</td>
<td>68%</td>
<td>16%</td>
<td>3%</td>
<td>0.7%</td>
<td>0.1%</td>
<td>0.3%</td>
<td>100%</td>
</tr>
<tr>
<td>5 - total</td>
<td>1%</td>
<td>28%</td>
<td>33%</td>
<td>20%</td>
<td>9%</td>
<td>3%</td>
<td>6%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Fig. 17: MAIS distribution as a function of the degree of damage in frontal collision for belted driver (with and without airbag) [15]

Compared to the driver, front-seat passengers secured by both seatbelt and airbag demonstrated a slightly increased risk of injury (Fig. 18) which can probably be traced back to a less correct sitting position in the vehicle, possibly also to coordination problems between the seatbelt and airbag of the first generation.

On the statistical average, we were unable to prove in the previous "airbag material" any substantially greater protective action due to the seatbelt and airbag compared to the front-seat passenger who had been secured solely by a seatbelt. Only in individual cases of ex-
treme accident severity did the airbag clearly prove to have an additional protective effect for the belted front-seat passenger and save lives.

![Graph of MAIS distribution for drivers and front-seat passengers](image)

*Fig. 18: Distribution of the maximum injury severity MAIS of driver and front seat passenger with deployed twin airbags [15]*

In Germany, virtually 100 % of all new cars are nowadays equipped with front airbags. At the same time, however, this has proved to unfortunately have negative effects in the form of deteriorating seatbelt moral. It is therefore a central objective in this context to continue to more intensively sensitize and educate the general public. The passengers must realize, for example, that the airbag can only attain its full protective action if the driver also uses the seatbelt and sits in the correct position -- at a distance of approx. 30 centimeters between the upper body and the front airbag.

### 5.1.3 Improved Side Impact Protection, Side Airbags

Due to the safety improvements in front collisions, today approximately 60 % of all fatal injuries suffered by belted passengers can be traced back to side collisions [2]. As the risk of injury due to front collisions continues to be reduced as more and more cars are equipped with front airbags, the relative percentage of side collisions with fatalities will continue to rise. Passengers on the struck side are at particular risk. They have been accorded the highest potential danger both in the biomechanical injury scales (AIS/ISS) and in the monetary assessment of the consequences of injury (Injury Cost Scale, ICS) [20]. In the case of severely injured passengers (Figure 19), AIS 2+ injuries to the head (35 %), thorax (35 %) and pelvis
(33 %) predominate. Head and thoracic injuries are also the most frequent life-threatening injuries (AIS 4+) with a frequency of 8 % and 12 %.

![AIS 2+ and AIS 4+ injuries](image)

**Fig. 19:** Distribution of the AIS 2+ and AIS 4+ injuries for the sample "side collisions / struck-side", differentiated according to body regions (n=199 belted passengers) [2]

These studies reveal that measures for protecting passengers in side collisions such as an improvement in the structural strength of the passenger compartment and the cushioning of possible contact surfaces have utmost urgency. In addition, side airbags must be included as standard equipment in new cars, the prerequisite being that the thoracic/pelvic region being comprehensively protected to effectively reduce the high risk of injury to the pelvic/thigh region. Moreover, side protection can only be effective if an airbag near the head (Fig. 20) diminishes the grave risk of injury to the head in side collisions. Finally, the action of the side airbags should last as long as possible to be able to afford additional protection to the non-struck-side passengers during secondary collisions and when the side structure is intruded.
5.1.4 Airbags with Intelligent Activation System

Another safety contribution might be made in the future by airbags with "intelligent activation systems" ("smart airbags"). Now that restraint systems including the airbag have become standard equipment in cars, a flexible, situation-related regulation of these systems must be the next development objective. The smart airbags should feature passenger presence detection, have a multistage activation characteristic depending on the severity of the accident and, in particular, constantly check the passenger's sitting position to avoid "out of position" risks. Appropriate systems will be ready to go into mass production in the near future at some manufacturers. Figure 21 shows one example.
These "smart" restraint systems not only contribute to a further reduction of injuries but also preclude repair costs as a result of unnecessary releases of the front passenger airbag. A projection based on the GDV studies revealed that approx. 70 million Deutschmarks annually in repair bills would have to be paid in Germany if 50% of all cars were equipped with front passenger airbags and if they would also deploy in the event that the front passenger seat is not even occupied. In 1997 this caused additional repair costs of 20 million Deutschmarks (when less than 15% of all cars were equipped with a front passenger airbag).

5.1.5 Child Restraint Systems

According to IFM studies, unrestrained children in cars run a sevenfold greater risk of being severely injured or killed than restrained children. These results from accident research are reflected in the official statistics. Since the introduction of the compulsory use of child restraint systems (CRSs) in motor vehicles in 1993, the restraint rates in Germany have increased permanently [1] or have remained at a very high level (Figure 22).

![Compulsory use of CRS since 1st April 1993](image)

**Source:** Federal Highway Research Institute (BAST); Germany

*Fig. 22: The development of restraint rates of children in cars from 1991 to 1998 [1]*

Due to the increase in the restraint rates, the number of child fatalities (between the ages of 0 – 12 years) in cars has declined markedly (Figure 23). It dropped from 165 at the beginning of the 1990's to 100 in 1998 [17]. In spite of this exceedingly positive trend, the number of child fatalities in cars is still higher than the number of children killed as pedestrian or cyclists (refer to Figure 23). A further increase in the restraint rates of children in cars barely appears
to be possible (at least not in Germany) which means in turn that – in order to further enhance protection – the child restraint systems themselves must be optimized.

![Graph showing comparison of child, pedestrian, and cyclist fatalities in road accidents between 1991 and 1998.](image)

**Fig. 23: Number of child (from 0 to 11 years of age) fatalities in road accidents**

Further potential for improvement is to be found in the way of restraining the children. A field study carried out by IFM showed that mistakes are made in restraining children and in fixing the CRSs in almost two thirds of all cases (e.g. loose seat installation), and serious mistakes in one-third of all cases. Comparison tests [17] with and without misuse (lack of seatbelts) have shown that the dummy loads are 30-40% higher due to the loose seat installation compared with the load values when the restraint is installed properly (Figure 24). The improvement of the quality of restraint and the prevention of misuse is thus a substantial milestone to greater safety of children in cars.

<table>
<thead>
<tr>
<th>Belt</th>
<th>Sled speed</th>
<th>Sled acceleration</th>
<th>HIC 36</th>
<th>Max. acceleration</th>
<th>Head excursion</th>
</tr>
</thead>
<tbody>
<tr>
<td>slack</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>49.4</td>
<td>24.0</td>
<td>453</td>
<td>50.9</td>
<td>36.3</td>
</tr>
<tr>
<td>no</td>
<td>49.4</td>
<td>24.6</td>
<td>402</td>
<td>45.5</td>
<td>41.2</td>
</tr>
<tr>
<td>yes</td>
<td>49.4</td>
<td>24.2</td>
<td>613</td>
<td>70.4</td>
<td>55.6</td>
</tr>
<tr>
<td>yes</td>
<td>49.9</td>
<td>24.3</td>
<td>579</td>
<td>61.3</td>
<td>46.6</td>
</tr>
</tbody>
</table>

**Fig. 24: Rear seat from a VW Golf IV: 3-point belt attachment of the CRS with and without misuse (belt slack)**
One far-reaching possibility of preventing mistakes in installing child restraint systems is a standardized, rigid attachment between the CRS and the vehicle and is known as the ISOFIX system (examples see Figure 25).

Fig. 25: ISOFIX system for forward- and rearward-facing child restraint systems (left: Audi/VW, right: Klippan)

A study involving 150 adults [17], who were supposed to install both a conventional seat and an ISOFIX seat in a car, demonstrated that the ISOFIX seat was installed incorrectly in only 4% of all cases (Figure 26). In addition, ISOFIX systems provide not only easier handling, but also a higher level of safety than conventional child restraint systems. The rigid ISOFIX attachment to the vehicle makes it possible for the restrained child to participate in a direct and controlled manner in the deceleration of the car body in the event of a front collision, thus causing lower loads to occur than in the case of conventional attachment with the seat-belt of the vehicle.
The topic "child safety and side protection" has been neglected in the past. The relative risk of injury MAIS 2+ is clearly higher in the case of side collisions (25.8 %) than in front collisions (15.9 %). For this reason, additional protective measures and in particular safety standards for side collisions must be developed and compiled. In order to take the safety shortcomings in this area into account, a test procedure for side impact with child restraint systems is currently being developed in ISO/TC 22/SC 12/WG 1 under the guidance of IFM.

5.2 Seat/Headrest System

54 % of all car/car collisions involving personal injury are rear-end collisions [14]. Whereas approx. 20 % of all injured passengers complained of injury to the cervical vertebrae in 1970, the figure today is approximately 35 %. The estimated damage to the German national economy amounts to approx. 1 billion Euros annually. Annual expenditures of approx. 10 billion Euros have been estimated for the entire European Union.

Barely 70 % of all cervical spine injuries during rear-end collisions occur at a relative velocity not exceeding 15 km/h. Technical and medical analyses have revealed that a large number of the accidents in this speed range currently have inadequate medical documentation. A reduction in the number of cervical spine injuries can therefore be achieved by medical measures such as a uniform definition and interpretation of cervical spine distortion, standardized diagnosis, improved therapy and the quickest possible identification of problematic cases.
First and foremost, technical measures to reduce the outcome of accidents are necessary. A series of sled tests using seat/headrest systems developed by the ETH Zurich in collaboration with IFM have revealed clear differences. Figure 27 shows two sled tests that compare different seat/headrest systems. The seat at the top has a large horizontal head/headrest distance. A high NIC value of 23 m²/s² and a recoil speed up to 5 m/s were measured for the first extension phase of the head. The bottom portion of the picture illustrates a test using a state-of-the-art seat/headrest design with a small distance to the head in which moderate values for NIC (10 m²/s²) and recoil speeds (1 m/s) were determined.

![Comparison of two seat/headrest designs in a sled test](image)

*Fig. 27: Comparison of two seat/headrest designs in a sled test (delta v = 15 km/h, mean sled acceleration = 6 g, hybrid III dummy with TRID neck)*

Besides educating the car driver about how to correctly adjust the seat and headrest, it is imperative to improve the car design standards for headrests and seat back elasticity and to improve the definition of dynamic seat test standards. At present, IFM together with an expert group from science and industry are ascertaining test parameters which are especially sensitive and must be tested during seat tests. The neck injury criterion (NIC), forces and torques exerted on the head as well as the head velocity during the rebound phase should be measured if possible using a delta v of 15 km/h and a crash pulse of 6 – 7 g [21]. Seat systems optimized on the basis of such test procedures indicate a reduction of cervical spine load in about 70 % of all rear-end accidents.
5.3 Footwell Design

An above-average proportion of drivers frequently suffer severe leg and foot injuries during front collisions with partial offset. Owing to the prolonged healing and rehabilitation measures, these injuries cause enormous costs to the national economy and are at the top of the list in a monetary assessment of the consequences of injury (Figure 28).

<table>
<thead>
<tr>
<th>Body area</th>
<th>AIS 2+ percentage (%)</th>
<th>costs/person (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>30.4</td>
<td>13,890</td>
</tr>
<tr>
<td>Face</td>
<td>8.7</td>
<td>5,150</td>
</tr>
<tr>
<td>Thorax</td>
<td>37.0</td>
<td>15,590</td>
</tr>
<tr>
<td>Abdomen</td>
<td>8.7</td>
<td>8,170</td>
</tr>
<tr>
<td>pelvis internal</td>
<td>2.2</td>
<td>1,590</td>
</tr>
<tr>
<td>upper arm</td>
<td>4.3</td>
<td>1,170</td>
</tr>
<tr>
<td>Forearm</td>
<td>26.1</td>
<td>23,150</td>
</tr>
<tr>
<td>pelvic bone</td>
<td>13.0</td>
<td>22,220</td>
</tr>
<tr>
<td>Femur</td>
<td>21.7</td>
<td>40,520</td>
</tr>
<tr>
<td>lower leg</td>
<td>37.0</td>
<td>36,570</td>
</tr>
<tr>
<td>Foot</td>
<td>19.6</td>
<td>19,980</td>
</tr>
</tbody>
</table>

Fig. 28: Costs of injury (n = 46 belted drivers/front collisions with partial offset) [2]

Optimization of the footwell must therefore be vigorously pursued just like the minimization of the danger of injury caused by pedals. In addition to cushioning the footwell trim and the lower area of the instrument panel, the use of small airbags in the knee area should also be examined. Impact injuries from the instrument panel and longitudinal loads placed on the thigh can be reduced in this way. Finally, future test dummies should be equipped with suitable biomechanical sensors in the area of the lower leg, foot and pelvis which make it possible to determine other established biomechanical load characteristics.

5.4 Automatic Accident Emergency Call Function

Every measure that speeds up the receipt of accident information is decisive to assist emergency rescue, which is currently well organized in Germany. Three quarters of all car fatalities die within an hour after the accident; every minute saved by the early deployment of rescue services may save a life. Hence, an automatic emergency call (Figure 29) should be provided as standard equipment in all future cars that is based on the global positioning system (GPS) in combination with the car telephone (GSM). On the whole, the following recommendations are given for short-term implementation:
The car owner should not incur any costs for the special service "automatic emergency call".

A minimum accident severity should be defined for the automatic accident emergency call via the crash sensor or the release of airbags. In order to avoid false alarms, the driver should be able to deactivate the automatic accident emergency call function if the deployment of the medical rescue service is unnecessary.

Work on the necessary infrastructure should be carried out even today with special priority so that the automatic accident emergency call can be transferred directly to the respective rescue dispatcher without delay.

A consistent accident emergency call standard appears necessary for all of Europe.

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**Preconditions:**
- Car with airbag technology
- Recognition of passenger
- GSM (mobil - phone)
- GPS - navigation
- Computer-with voice accustical

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Fig. 29: Automatic accident emergency call on the basis of GPS and GSM – schematic

6 **Overview of Demands and Recommendations**

Accident research at the Institute for Vehicle Safety reveals for the future a bundle of measures designed to reduce the risk of a car accident and the consequences that arise from it. One sound pillar is the systematic and complete analysis of car accidents. Furthermore, measures are necessary for active and passive safety. The demands and recommendations of the German insurers have been compiled in the survey below. Detailed information of the "How" and "Why" relating on the demands and recommendations are provided in the text above.
Accident Group Car/Car
- Establishment of a generally acceptable definition of compatibility
- Reduction of the aggressivity of large car front sections as far as geometry and stiffness are concerned
- Supplementation of the 40 % offset test by the use of a smart barrier (multi-stage barrier) with measurement of compatibility criteria

Accident Group Car/Pedestrian
- The constellation “pedestrian impact against the side of the car respectively the wind-shield frame” should be taken into account for safety considerations.
- Enlargement of the pedestrian database, if possible European-wide for detailed analyses and for validation of test data

Accident Group Car/Truck
- Introduction of energy-absorbing front underrun protection systems for trucks
- Improvement of rear underrun protection systems for trucks and trailers

Young Drivers
- Improvement of basic driver education in theory and practice
- Special courses, instruction in new car engineering and driver safety training during a second phase of driver education
- Special speed regulations and a general ban on alcohol during the probationary period

Dynamic Stability Control
- Provision of dynamic stability control in all vehicle classes if possible and their integration as standard automobile equipment

Adaptive Cruise Control
- Introduction of distance regulation systems as standard equipment

Restraint systems
- Introduction of smart seatbelt systems comprising seatbelt tensioners, seatbelt force limiters and seatbelt reminders, even for rear-seat passengers
- Protection of passengers in side collisions such as an improvement in structural strength of the passenger compartment and cushioning of possible contact surfaces
- Introduction of side airbags as standard equipment in new cars
- Introduction of airbags with an intelligent activation system (“smart airbags”)
Child Restraint Systems

- Introduction of ISOFIX
- Development and compilation of additional protective measures and in particular an international accepted safety standard for side collisions

Seat/Headrest System

- Education of the car driver about correct adjustment of seat and headrest
- Improvement of car design standards for headrests and seat back elasticity
- Improvement of dynamic seat test standards
- Uniform definition and interpretation of cervical spine distortion
- Medical measures such as standardized diagnosis and improved therapy

Footwell Design

- Cushioning the footwell trim and the lower area of the instrument panel
- Examination of the use of small airbags in the knee area
- Future test dummies should be equipped with suitable biomechanical sensors in the area of the lower leg, foot and pelvis

Automatic Accident Emergency Call Function

- Introduction of automatic emergency call as standard equipment in all future cars

7 Acknowledgements

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8 References


[19] „Abbreviated Injury Scale – 1990“, Association for the Advancement of Automotive Medicine, Des Paines, IL, 1990
