

Compact accident research

Small-overlap frontal impacts involving passenger cars in Germany

Imprint

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Preliminary remarks

The content of this paper was released in the proceedings of the 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV) in Seoul 2013.

Small-overlap frontal impacts involving passenger cars have again become a topic of discussion among specialists, and more recently among the public at large. The publication of relevant test results by the Insurance Institute for Highway Safety (IIHS) [1] has triggered questions with respect to the relevance of these collisions to accident situations and with respect to the conclusions that can be drawn and any measures to be implemented. And yet this type of collision is not something that is unknown. On the contrary, among experts, it has been a matter for discussion for decades. You will, for instance, find information and the findings from investigations at the NHTSA [2], Steyr-Daimler-Puch [3] and Autoliv [4].

In Germany also, the question of how relevant small-overlap frontal impact collisions are and what the consequences of this type of collision are is currently being raised. In an attempt to clarify this, the UDV (German Insurers Accident Research) has carried out a comprehensive set of analyses using its accident database (UDB). The UDB contains a representative sample of all damage claims in Germany (all types of road users) and currently covers more than 5,000 third-party motor insurance claims from the years 2002 through 2009. All the accidents in this database involve personal injury and damage costs of EUR 15,000 or more. The objective of the current data analysis was to place small-overlap frontal impacts in the context of all collisions involving passenger cars and to derive the characteristics of such collisions on the basis of detailed accident parameters. In addition, the patterns of injury were analyzed and compared with those resulting from other collision scenarios.

The findings described in this paper are based on the retrospective analysis of 3,242 accidents involving passenger cars. 60% of these accidents ($n = 1,930$) were frontal impacts and 15% ($n = 485$) involved at least one passenger car with a small overlap at the front of the car.

The present paper provides evidence of the relevance of small-overlap frontal impacts to the accident situation in Germany and, in the opinion of the authors, justifies efforts to implement counter-measures. In this context, active systems should also play a greater role in the future.

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Database

The German Insurers Accident Research (UDV) is a department of the German Insurance Association (Gesamtverband der Deutschen Versicherungswirtschaft e.V. - GDV) and has access to all the third-party vehicle insurance claims reported to the GDV. For 2011, these amounted to 3.5 million claims, of which 2.7 million were claims involving cars. For the purposes of accident research, the UDV set up a database (referred to as the UDB), taking a representative cross-section (years 2002-2009) from this large data pool. The data collected is conditioned for interdisciplinary purposes for the fields of vehicle safety, transport infrastructure and traffic behavior. The contents of the claim files from the insurers form the basis of the UDB. Around 700 to 1,000 new cases are added to the UDB each year.

Because of the UDB design with respect to third-party vehicle claims the database is not representative for single car accidents.

Structure of the car accidents and relevance of small overlap

In this paper - both in the body of the text and in the graphics and tables - the terms "frontal collision", "small overlap", "large overlap" and "case car" are used. These terms are defined as follows:

- Frontal collision: The front of the car sustains the initial and most serious impact of the collision.
- Small overlap: The front of the car sustains the initial and most serious impact of the collision with an overlap of not more than 25% (on the right or left).
- Large overlap: The front of the car sustains the initial and most serious impact of the collision with an overlap of more than 25% (on the right or left or in the center).

- Case car: This is the car that sustains a small-overlap impact in a frontal collision. (Note: There may be more than one case car involved in the same accident.)
- Note that the figures presented in the paper apply in some cases to the accidents (when the analysis is at the accident level) and in some cases to the cars involved (when the analysis is at the level of those involved). These figures are highlighted for emphasis and better understanding of the text.

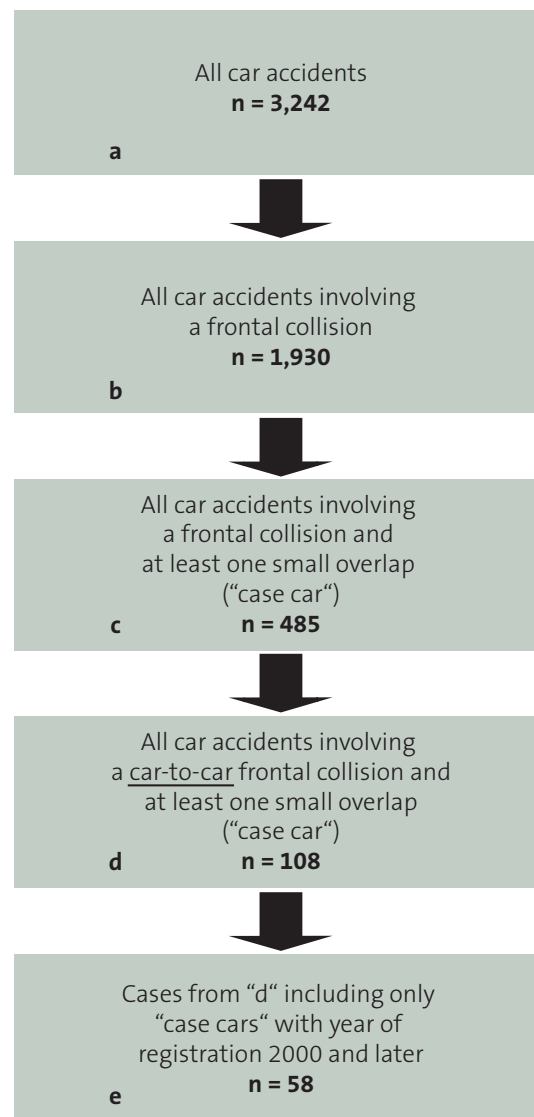


Figure 1:
Classification of the car accidents in the UDB by data pools

Relevance of small overlap

The German insurers' accident database (UDB) contains 3,242 accidents involving at least one car (not including vans/light commercial vehicles) (figure 1). The analysis of these cases showed that, in around 60% of these accidents (n=1,930), at least one car sustained a frontal impact. In this group of car frontal collisions, there are n=485 cases in which at least one of the cars involved was a case car with a small overlap. These accidents thus account for around 15% of all car accidents and 25% of all car accidents with a frontal collision. In addition to head-on frontal collisions between two vehicles, the 485 accidents also include cases in which the case car collided frontally with the rear end or side of another vehicle, against a rigid obstacle or a vulnerable road user.

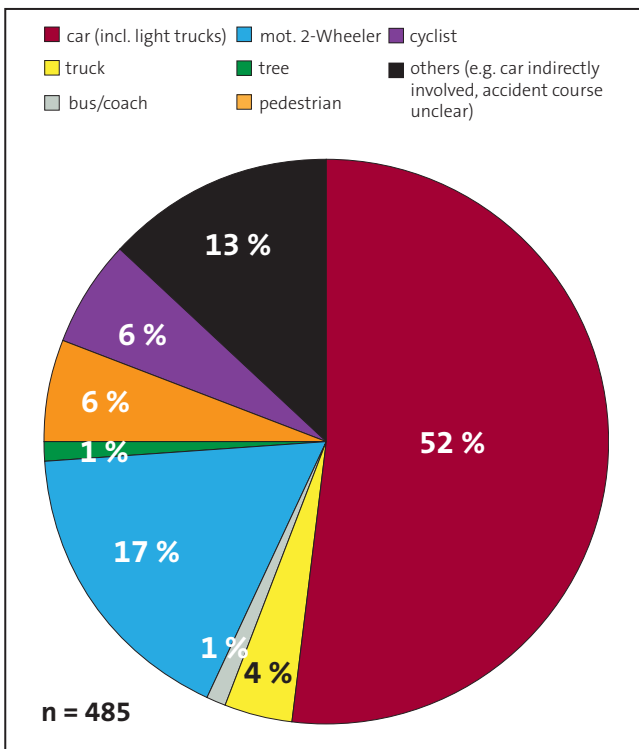


Figure 2: Car frontal collisions involving at least one small overlap, subdivided by the collision opponent of the case car (n = 485 accidents)

Collision opponents of the cars that had a “small overlap”

The 485 car accidents with at least one “small overlap” account for a total of 551 involved case cars (see figure 1, “c”). These 551 case cars make up 24% of all the cars (n=2,267) which were involved in a frontal collision in n=1,930 accidents. The cars with a small overlap most frequently collided with other cars (in 52% of cases, as shown in figure 2), followed by motorized two-wheel vehicles (17%) and vulnerable road users (12%).

Car-to-car frontal collisions with a small overlap

In order to get the clearest possible picture of the frontal collisions with a small overlap, the analyses in this section are limited to accidents involving car-to-car frontal collisions (n=108 cases). In these accidents both cars sustained an impact at the front, at least one of them with a small overlap.

Car-to-car frontal collisions with a small overlap characterized by light conditions, road conditions and by accident location. Around 70% of the 108 accidents involving car-to-car

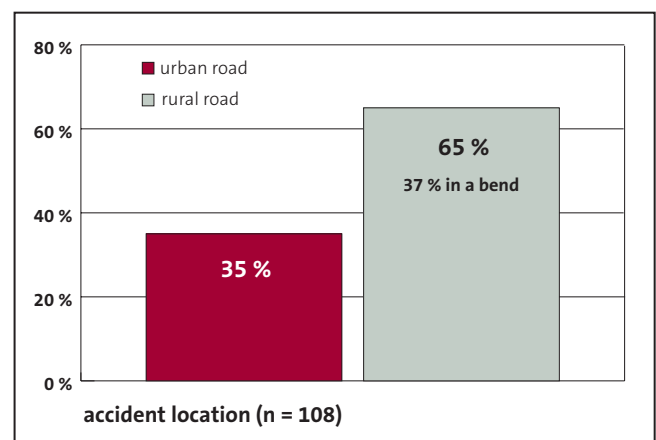


Figure 3: Car-to-car frontal collisions with a small overlap, broken down by accident location (n = 108 accidents)

frontal collisions with a small overlap took place in daylight, and around 60% took place on a dry road surface. In more than a third of the cases, the road surface was wet or slippery. As far as the accident location is concerned, the analyses revealed that almost two-thirds of the accidents occurred on rural roads (figure 3), with 37% of these occurring in the vicinity of a bend. This gives reason to believe that a collision with a small overlap often happens because the party responsible for the accident gets into the oncoming lane unintentionally as a result of a driving error or due to inappropriate speed.

Accident types in car-to-car frontal collisions with a small overlap The accident type “driving accident” makes up 29% and has the highest share within the n = 108 accidents involving car-to-car frontal collisions and a small overlap. 74% of these driving accidents took place in the vicinity of a bend (figure 4). These figures strengthen the suspicion that departing from your own lane and the subsequent frontal

collision with a small overlap can often be attributed to driving errors or driving at inappropriate speeds. It was also possible to establish that the case-car driver in driving accidents was the main party responsible for the accident in around two-thirds of the cases. Accidents caused by “turning off the road” also account for a high percentage of these accidents (27%) and are the second most frequent accident type. These mostly involved a driver violating the right of way of the oncoming traffic when turning to the left and colliding with the oncoming car (86%). In around half of these cases, the case-car driver was the main party responsible for the accident. The third most frequent accident type is the “accident in longitudinal traffic” (24%). A considerable proportion of these are overtaking accidents (43%), around half of which were caused by the case-car driver.

It is worth pointing out here that figure 4 also provides key information indicating which accidents, in particular, could be addressed by

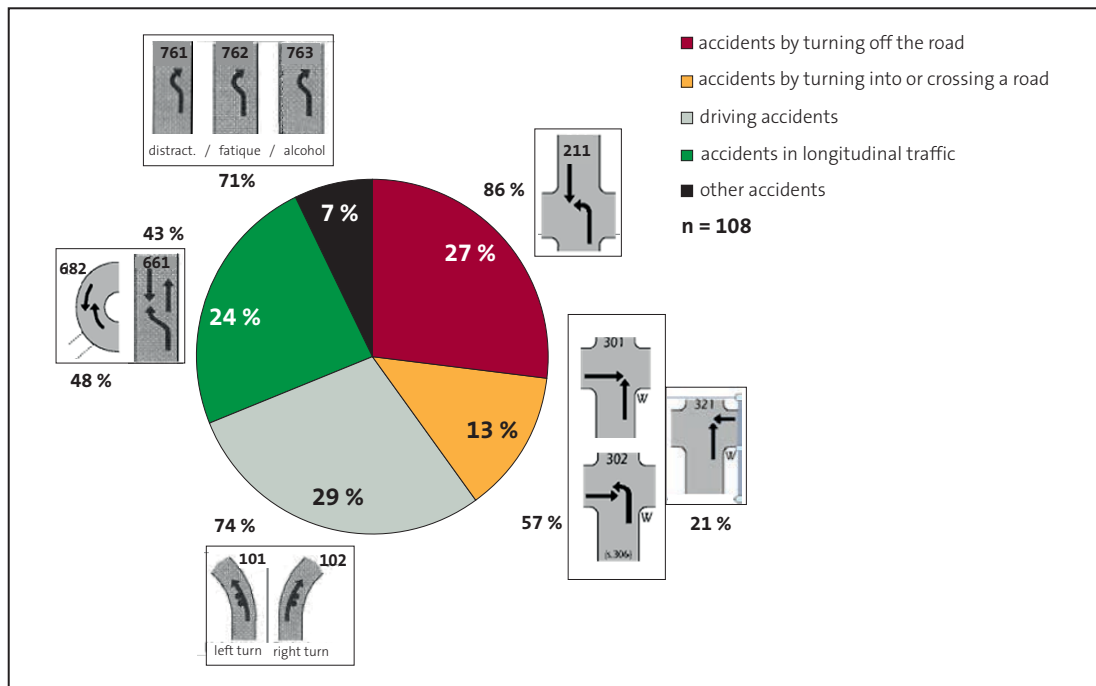


Figure 4: Car-to-car frontal collisions with a small overlap, subdivided by three-digit accident type (n = 108 accidents)

advanced driver assistance systems in order to improve safety as much as possible. For example, an advanced driver assistance system that handled both “turning off the road” accidents and “turning-into or crossing a road” accidents would address around 40% of the accidents examined here.

Detailed analyses for selected case cars in car-to-car frontal collisions

The only accidents described in this section are the 58 accidents involving car-to-car frontal collisions with a small overlap in which the case car was registered in the year 2000 or later (see also figure 1) in order to be sure that the vehicles involved were designed to meet EuroNCAP requirements and thus have a certain level of passive safety. This selection criterion (car-to-car frontal collision, small overlap, registered in the year 2000 or later) was met by a total of 68 cars involved.

Direction and location of the impact

Of the 68 case cars with a small overlap thus selected, there was information on the direction of the impact for a total of 63 of them (figure 5). The direction of the impact refers to the direction of the force to which the vehicle is subjected during the initial collision. The analyses revealed that the impact was sustained at an angle in a clear majority of the cases (i.e. in the case of 70% of the 63 case cars involved). In addition, it was possible to ascertain the location of the impact on the case car for the three most common directions of impact, which were 11, 12 and 1 o'clock (figure 6). In most of the cases, the impact was sustained on the left-hand side of the front of the vehicle (the driver's side). In collisions with impact

direction 12 o'clock (which is often the scenario in crash tests), the impact was sustained by the left-hand side of the front of the vehicle in 100% of the cases.

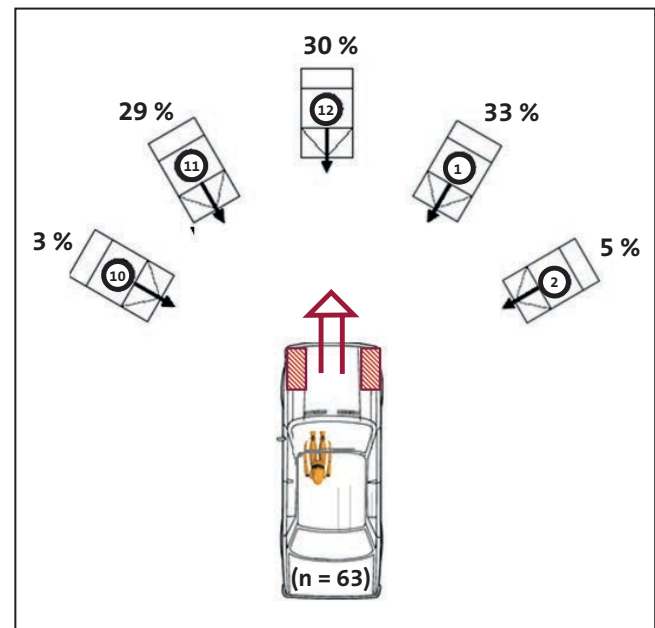


Figure 5: Direction of the impact from the viewpoint of the case car in car-to-car frontal collisions with a small overlap (n = 63 case cars involved)

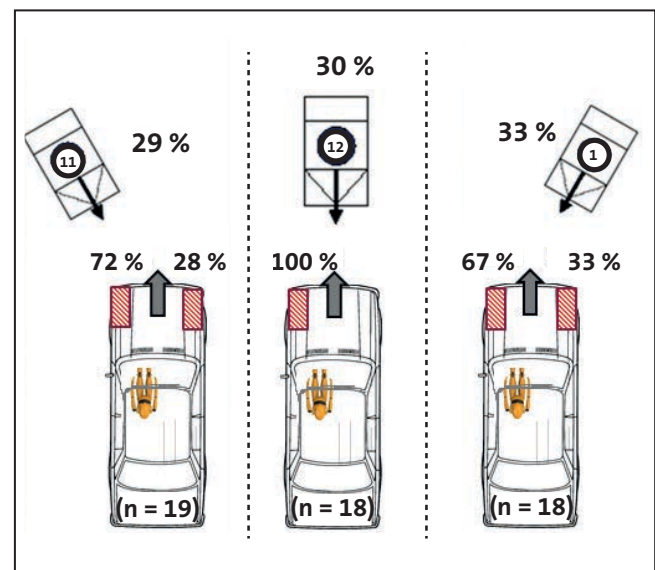


Figure 6: Location of the impact on the case car for the three most common directions of impact in car-to-car frontal collisions with a small overlap (n = 18, respectively n = 19 case cars involved)

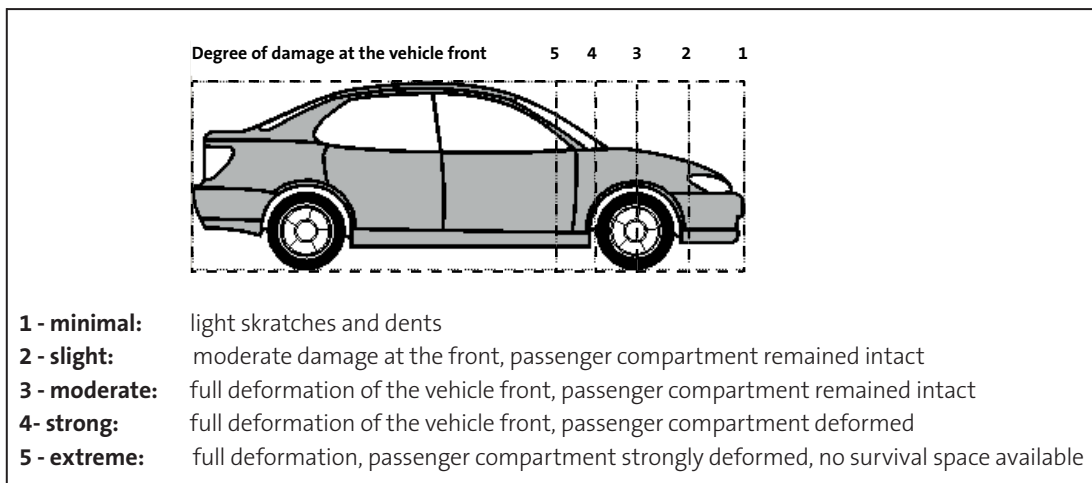


Figure 7:
Degrees of damage at the front for cars in accordance with the UDV definition

Airbag equipment, airbag deployment and degree of damage

All of the considered 68 case cars with year of registration 2000 or later were equipped with a driver's airbag. It was possible to ascertain whether the airbag was deployed in the case of 55 of the case cars involved: The driver's airbag was deployed in 38 cars (69%); in the other 17 cars, the airbag had not deployed.

For the case cars with a deployed airbag and an impact on the driver's side ($n=28$), it was possible to determine the degree of damage at the front of the case car in accordance with the UDV definition (figure 7). It emerged that in the most cases the degree of the damage was slight or moderate (degrees of damage 2 and 3). However, 21% of the case cars involved sustained a strong damage at the front (degree of damage 4), which amounts, according to the definition, to deformations of the passenger compartment and restriction of the survival space (figure 8). No extreme damage (degree of damage 5) occurred in this case material.

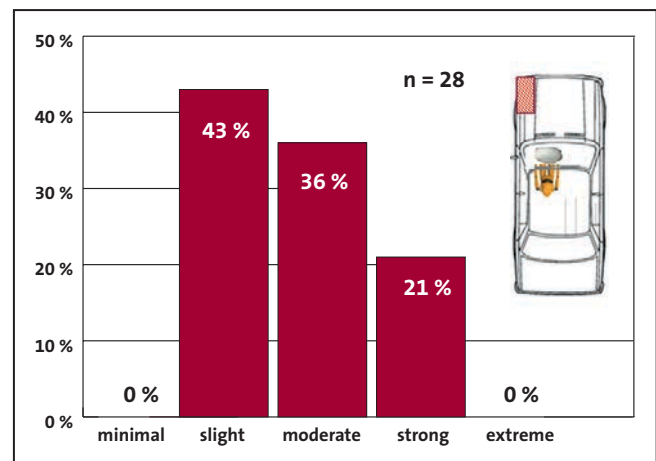


Figure 8:
Relative distribution of the degrees of damage at the front for case cars with deployed driver's airbag and with an impact on the driver's side ($n = 28$ case cars)

Technical rescue of the drivers

For 59 of the total of 68 case cars examined here, there was information available about the technical rescue of the driver (figure 9). In most cases (85%) the drivers were able to free themselves. However, in 15% of the cases professional rescue services had to free them using light or heavy equipment. The use of rescue equipment indicates that it is highly likely that the driver was trapped in the car.

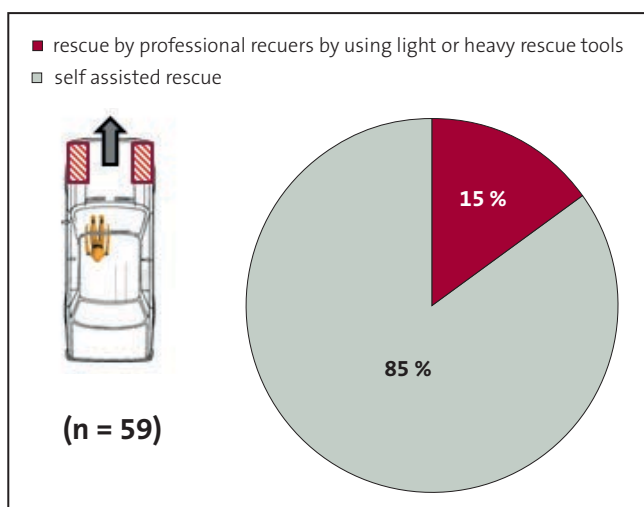


Figure 9: Technical rescue of the driver from the case car in car-to-car frontal collisions with a small overlap (n = 59 case cars examined)

Severity of the injuries to protected drivers

Appendix 1 shows the maximum injury severity (MAIS code) and the individual injuries in accordance with the Abbreviated Injury Scale (AIS) [5] for the drivers of the case cars. Only those drivers who were wearing seat belts, whose airbag was deployed and whose car was impacted at the front on the left-hand side with a small overlap are included here. This information was available for exactly 24 drivers.

It is noteworthy that of 16 drivers who had minor injuries (MAIS 1), 11 had an AIS 1 injury of the neck (whiplash-type neck distortion), and only in five cases was the MAIS code obtained from a different injury. Two of these were elbow injuries, two were chest injuries, and one was a facial injury.

In the MAIS 2+ injury range, in addition to chest injuries and abdominal injuries, serious injuries to the upper extremities and, in particular, the lower extremities were relatively common. Only one driver suffered a serious head injury (AIS 3).

None of the drivers studied here suffered critical or fatal injuries (AIS 4+).

Analyses of the front-seat passengers

There were only relatively few front-seat passengers in this accident material, so detailed analyses were not carried out. However, the following statements can be made as far as the front-seat passenger is concerned:

- In most cases, the front of the car was impacted on the left-hand side, most frequently at an angle.
- In cases where the front-passenger airbag was deployed and the impact was on the passenger's side, the front of the car sustained only slight to moderate damage, and there was therefore no serious deformation of the passenger compartment on the passenger's side.
- None of the front-seat passengers in a case car had to be freed by rescue services. In other words, they were not trapped.
- The injuries of the front-seat passengers protected by a seat belt and an airbag were almost exclusively AIS 1 injuries, most of which were whiplash-type neck distortions.

Comparison between car-to-car frontal collisions with small overlap and those with large overlap

As indicated in the introductory section of this paper, small-overlap collisions are of not inconsiderable relevance in the car accident statistics, accounting for around 15% of all car accidents. In order to examine the importance of these accidents in detail, a number of comparative analyses were carried out. To this end, accidents that met all of the following criteria were taken from the group of n = 1,930 car acci-

dents involving a frontal collision (see figure 1):

- The cars had to be involved in a frontal collision with another car.
- The driver had to be wearing a seat belt.
- The extent of the overlap at the front of the car had to be known.

That left a pool of n = 162 accidents involving a total of n = 256 cars. In the first step, n = 95 cars were identified in this pool that had sustained an impact with a small overlap (an overlap of up to 25% at the front of the car). The other n = 161 cars in the pool were used as the comparison group. These were cars that were involved in a car-to-car frontal collision with a large overlap (an overlap of between 25% and 100% at the front of the car).

Figure 10 shows the distribution of the cars involved in car-to-car frontal collisions (n = 256) in the two groups with a small overlap and a large overlap. Around a third of the cars invol-

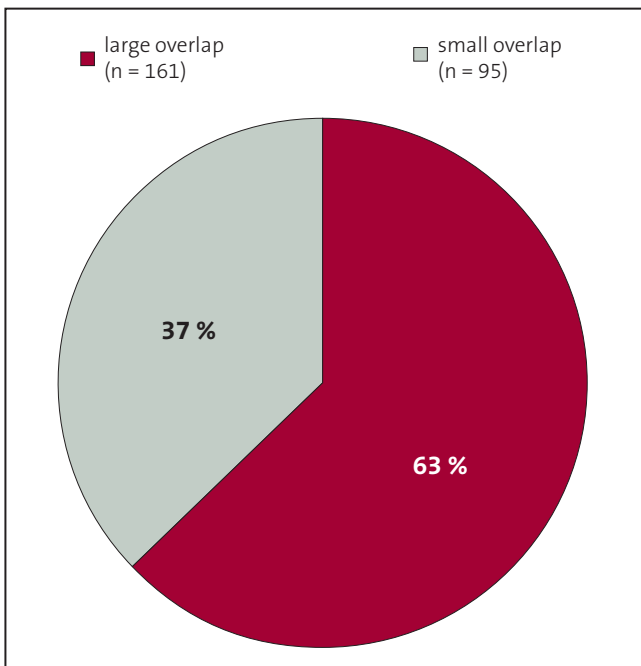


Figure 10: Percentages of cars with a small overlap and cars with a large overlap in car-to-car frontal collisions (n = 256 cars)

ved in car-to-car frontal collisions sustained an impact with a small overlap at the front.

When these two groups are compared in terms of the severity of the injuries of the drivers involved (drivers wearing seat belts only, with and without airbag), it becomes clear that small-overlap collisions have less serious consequences than large-overlap collisions (figure 11). The number of drivers killed in the latter group, for example, was many times higher.

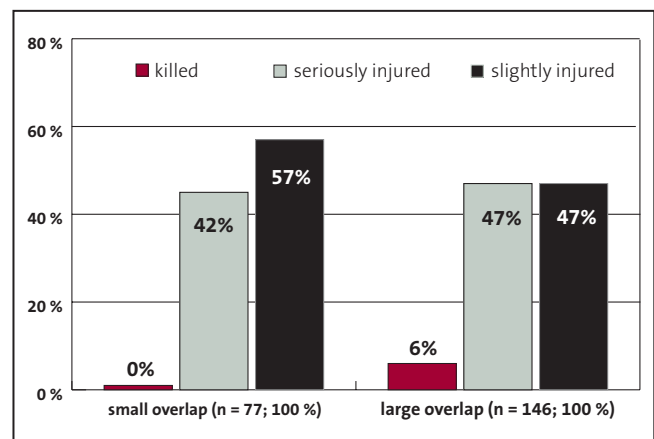


Figure 11: Injury severity of drivers wearing seat belts in small-overlap and large-overlap cars involved in car-to-car frontal collisions

Figure 12 shows a more in-depth analysis of injury severity. It is clear from this that around twice as many drivers wearing seat belts remain uninjured in cars with a small overlap compared to cars with a large overlap. In addition, AIS2 injuries are more than twice as common in cars with a large overlap compared to cars with a small overlap. Only the injury severity MAIS 3 occurs with around the same frequency in both groups (11% and 12%). Injuries with a severity of MAIS 4+ only occurred in cars with a large overlap in this accident material.

Appendix 2 shows the individual AIS 3+ injuries of drivers wearing seat belts for the two

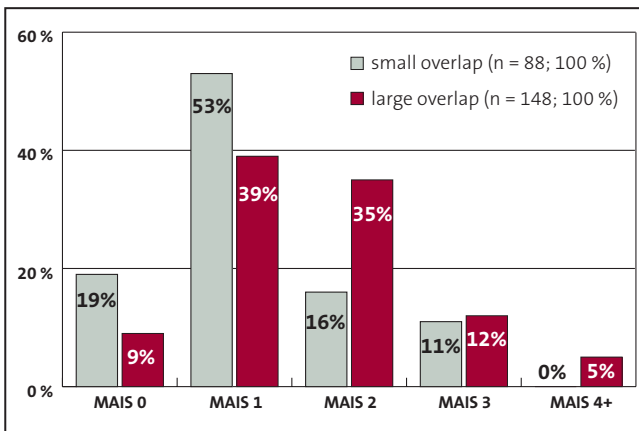


Figure 12: MAIS distribution for drivers wearing seat belts in small-overlap and large-overlap cars involved in car-to-car frontal collisions

groups. It indicates that around 40% of all AIS3 injuries of drivers of cars with a small overlap were to their lower extremities (femur, lower leg, foot). In contrast, only 24% of drivers of cars with a large overlap had these injuries. The analyses of AIS 2 injuries revealed a similar picture.

Since experience shows that injuries to the lower extremities are associated with long healing processes and are thus cost intensive [6], the drivers involved were compared in terms of how long they were completely unable to work (figure 13). This revealed that drivers of cars with a small overlap are almost twice as likely to be completely unable to work for a lengthy period (three months or longer) than drivers of cars with a large overlap.

The longer period of being unable to work and the relatively cost-intensive injuries of the drivers of cars with a small overlap are also reflected in the documented claim costs of the insurers. In the small-overlap cases, which were more costly, the high costs involved were demonstrably attributable to complex foot injuries of the drivers involved that take a long time to heal.

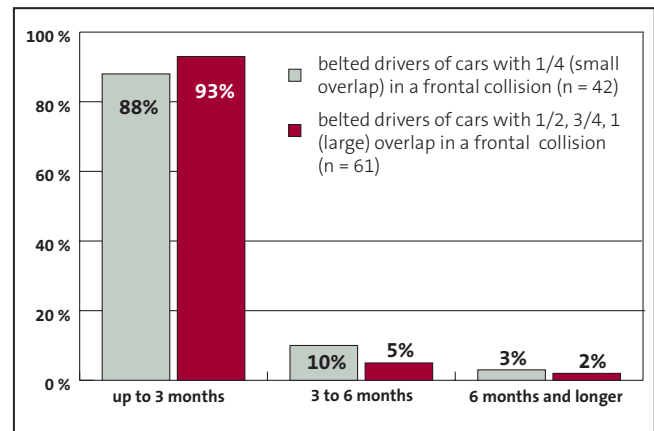


Figure 13: Duration of the period of being completely unable to work - comparison of drivers wearing seat belts in small-overlap and large-overlap cars involved in car-to-car frontal collisions

Summary of the results

Frontal collisions with a small overlap account for around 15% of all car accidents and 25% of all car accidents involving a frontal collision. In accidents with a small overlap, the car collides with another car in 52% of the cases. Collisions with rigid obstacles (trees, posts) are very uncommon (1%) in this database.

The consequences of the accidents for the drivers involved tend to be less serious than for drivers involved in frontal collisions with a large overlap. Nevertheless, small-overlap collisions have specific patterns of injury for drivers protected by seat belts and airbags that differ from those of large-overlap collisions. In particular, cost-intensive injuries to the lower extremities, which entail a long period of treatment and frequently result in permanent damage, are considerably more common in cars with a small overlap than in cars with a large overlap.

It thus emerges that car accidents involving a small overlap are at least as relevant as accidents involving a large overlap in the damage claims of insurers following car accidents. This

relevance increases or decreases depending on the reference level selected:

- In terms of fatalities, the relevance of small-overlap car accidents is low.
- In terms of serious injuries (AIS₂₊) to the lower extremities, the relevance of small-overlap car accidents is high.

From the view of the UDV, following countermeasures can be derived from the analysis of car accidents involving a small overlap:

- Improved specific passive safety measures to the vehicle structure
- Active safety measures which are able to handle “turning off the road” accidents as well as “turning into or crossing a road” accidents.

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MAIS	Head	Face	Neck	Chest	Thorax	Arm	Forearm/ Elbow	Hand	Abdomen	Lumbar Spine	Pelvis	Femur	Lower leg/ Knee	Foot
1	0	0	1	0	0	0	0	1	0	1	0	0	0	0
	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	0	0	1	0	0	0	0	1	0	0	0	0	0	0
	0	0	1	0	1	0	0	0	0	0	0	0	0	0
	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	1	0	0	0	0	0	0	0	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1
 Individual injuries by regions of the body for belted drivers of small overlap case cars in which the driver's airbag was deployed and the impact was sustained on the left-hand side of the front of the car.

MAIS	Head	Face	Neck	Chest	Thorax	Arm	Forearm/ Elbow	Hand	Abdomen	Lumbar Spine	Pelvis	Femur	Lower leg/ Knee	Foot	Overlap
															Small
3	0	0	0	3	0	2	3	0	3	2	2	3	3	2	
	0	0	0	0	0	0	0	0	0	0	0	3	2	0	
	3	0	0	3	0	0	0	0	3	0	0	0	0	0	
3	0	0	1	0	0	0	0	0	0	0	0	0	3	0	
	0	0	0	2	0	0	3	0	0	0	0	0	0	2	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	3	1	0	0	0	0	0	0	0	
	0	0	0	3	0	0	2	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	1	0	1	0	0	0	1	0	0	0	1	0	3	
	0	0	0	0	0	0	2	0	0	0	0	0	3	0	
	0	0	0	1	3	0	0	0	0	0	0	0	0	1	
	0	0	0	1	2	0	0	0	0	3	1	0	0	0	
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	2	0	0	0	0	0	3	1	
	0	0	0	0	3	0	0	0	2	2	0	0	0	0	
	0	0	0	3	3	0	3	1	0	3	0	0	0	0	
4	0	0	0	3	0	2	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	2	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	2	0	2	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
5	4	0	4	0	0	0	0	0	0	0	0	0	0	0	
	4	0	0	0	0	0	2	0	0	0	0	0	0	0	
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	0	0	5	3	0	0	0	0	0	0	0	3	1	0	
	0	0	0	6	0	3	0	2	4	0	3	3	2	2	
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	4	1	6	4	0	2	0	0	3	0	0	0	3	2	
	0	0	0	6	0	0	0	0	0	0	0	0	0	0	

Appendix 2:
Distribution of MAIS 3+ injuries by regions of the body for belted drivers of small-overlap and large-overlap cars involved in car-to-car frontal collisions



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