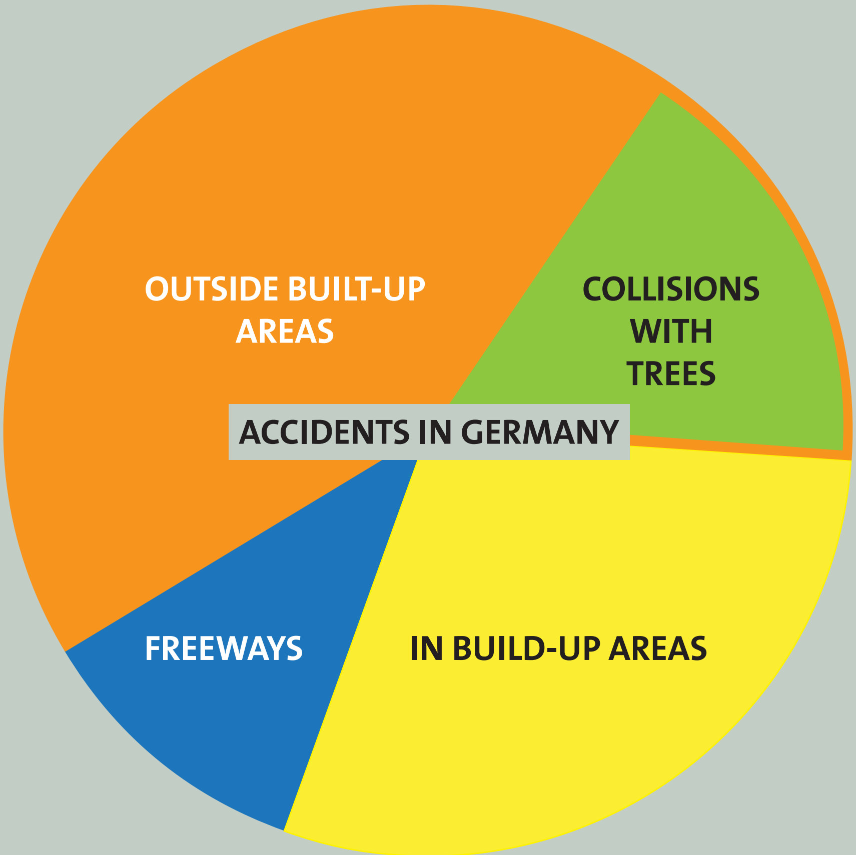

Compact accident research

Accident statistics and the potential of driver assistance systems

Unfallforschung der Versicherer
GDV

Imprint

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Insurers Accident Research

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Preliminary remarks

Before we make any statements about the effect of advanced driver assistance systems (ADASs) on road safety and their potential for the future, it is essential to know about and understand the accidents that happen. The accident patterns identified should then be addressed by the specific functions of the ADAS. In order to do this, a shift of focus is required from the general, representative view obtained from a country's accident statistics to detailed analysis of the accidents that happen. That, in turn, requires surveys of varying degrees of quality to collect accident data, resulting in accident statistics that provide specific information. This field extends from the representative surveys of the German Federal Statistical Office (Destatis), based on road accident reports, to the in-depth analyses of different accident researchers working on road safety. In Germany that means using, above all, the German In-Depth Accident Study (GIDAS) and the German Insurers' Accident Database (UDB).

GIDAS stands out in terms of its level of detail and the usefulness of its data. The data collected at accident locations for a representative selection of road accidents in a specific region is unrivalled. This joint research project of the German Federal Highway Research Institute (BASt) and the Forschungsgemeinschaft Automobiltechnik (FAT), a research alliance of all German car makers, is thus extremely useful for accident research. The UDB, on the other hand, is based on the claims data of insurers. The data is based on a representative selection of motor third-party liability claims involving damage costs of at least 15,000 Euros and at least one case of injury. However, the UDV (German Insurers Accident Research) does not investigate these cases at the accident locations. Consequently, certain kinds of statement cannot be made about the vehicle etc., or at least only with reservations. This dataset thus describes more severe claims and cannot be compared for all issues with the official road traffic accident statistics or GIDAS.

Content

1 Accident statistics in Germany

A glance at the accident statistics in Germany over recent decades tells you that the number of fatalities has declined almost continuously (see Figure 1).

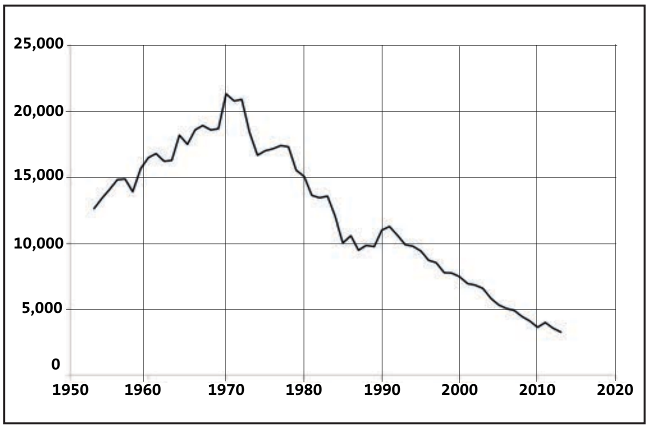


Figure 1:
Number of fatalities on the roads in Germany over time [1]

Whereas 21,332 people were killed on German roads (West Germany) in the year 1970, by 2012 this had fallen to 3,600. In 2013, 3,339 people were killed on the roads. The number of accidents involving injury fell from 377,610 in 1970 to 291,105 in 2013 [1]. When you also consider the increase in the distance traveled over the same period, the improvements in these figures are even more impressive. The number of motor vehicles in Germany increased from 16.8 million in 1970 to 53.8 million in 2012. And the distance traveled by motor vehicles almost trebled from just under 251bn km in the year 1970 to 719.3bn km in 2012. Most of these are passenger cars, of which around 43 million were registered in 2012, traveling a total distance of 610.1bn km and thus accounting for around 85% of the total distance traveled by all motor vehicles.

The distribution of fatalities for the year 2012 (see Figure 2) gives an initial indication of where to focus efforts to further improve road safety in Germany.

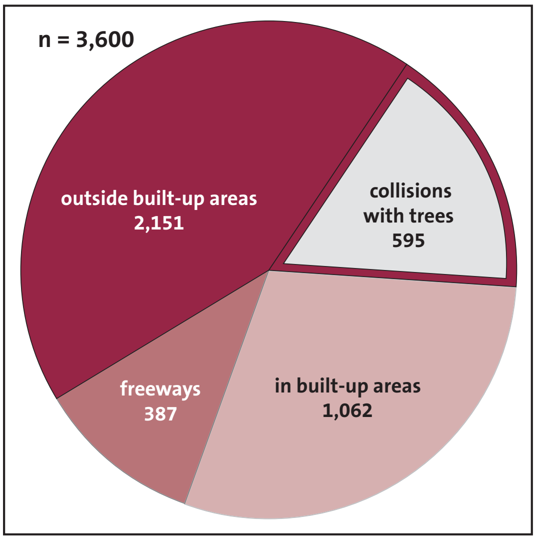


Figure 2:
Fatalities on German roads by location in 2012 [2]

It is clear from this that 60% of fatalities occurred on roads outside built-up areas. Over a quarter of these cases occurred as a result of collisions with trees. Just over 1,000 people were killed on the roads in built-up areas. These were primarily unprotected road users such as pedestrians and cyclists. The remaining 387 fatalities occurred on freeways (autobahns). If

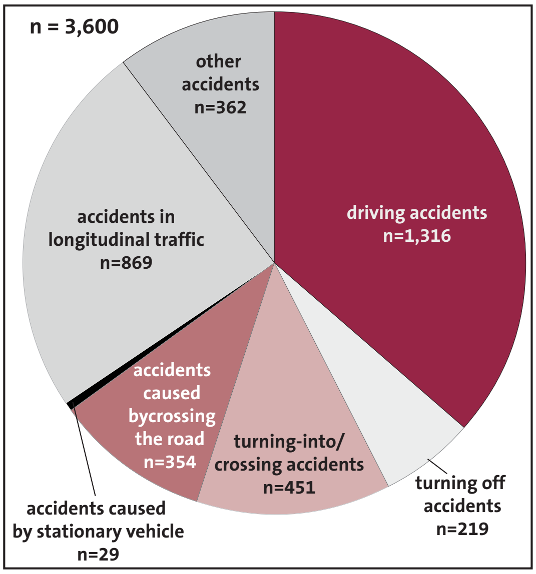


Figure 3:
Fatalities on German roads by accident type in 2012 [2]

the fatalities are analyzed by type of road user, we see that around half of the 3,600 fatalities in 2012 were car occupants (1,791), roughly 20% were on motorcycles (679), and around 25% were non-motorized, unprotected road users (520 pedestrians and 406 cyclists).

The distribution of fatalities by accident type in 2012 is shown in Figure 3. Driving accidents (where the driver loses control) are the most common type of accident resulting in fatalities, followed by accidents in longitudinal traffic and turning-into/crossing accidents.

In the case of driving accidents, in particular, which are categorized as such in police accident reports when the driver loses control of the vehicle as a result of driving at a speed that is inappropriate for the course, cross-section, inclination or condition of the road, it is possible to see the importance of speed as a factor contributing to accidents.

If you look at the situation in relation to serious injuries on the roads in 2012, the picture changes (see Figure 4). Over half of all seriously

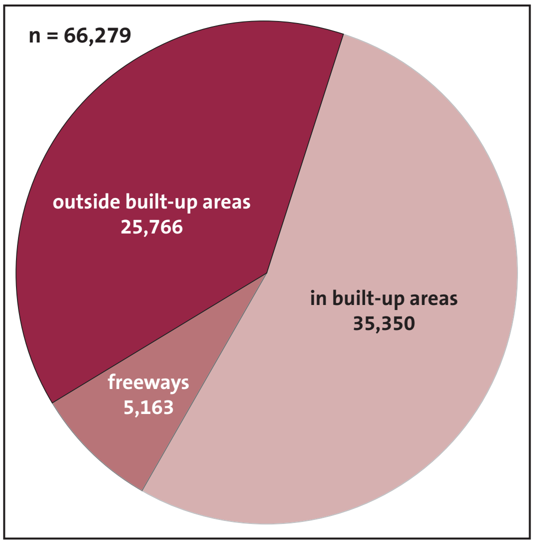


Figure 4:
Seriously injured accident victims in Germany by accident location in 2012 [2]

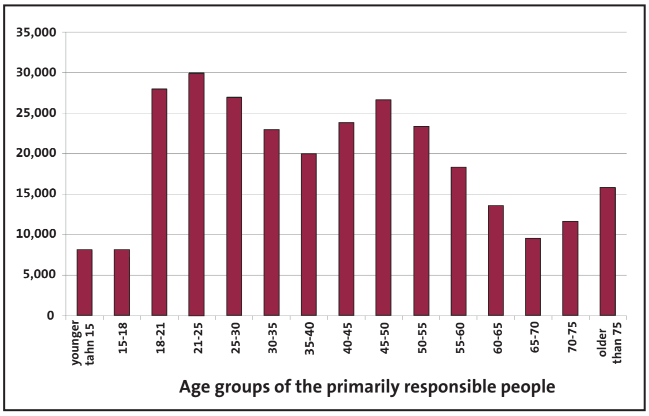


Figure 5:
People primarily responsible for accidents involving injury by age group in 2012 [2]

injured road users suffered their injuries in accidents in built-up areas, around two-fifths of injuries occurred in accidents outside built-up areas, and less than 10% happened on freeways.

In addition to the location, which is an accident-specific parameter, various participant-specific parameters can be analyzed. The age of the person responsible for the accident is an important parameter. The age distribution of the people primarily responsible for all accidents involving injury in 2012 is shown below (see Figure 5).

It is clear from this that the 18-25 age group is responsible for significantly more accidents than other age groups. The low proportion of older people primarily responsible for these accidents can also be partially explained by the fact that older people drive less. Age risk groups for causing road accidents thus cannot be specified accurately unless adjustments are made to take into account the distances trav-eled by these age groups. For example, the number of people responsible for an accident in each age group as a ratio of the number of people in that age group not responsible for an accident indicates the relative risk of someone in that age group

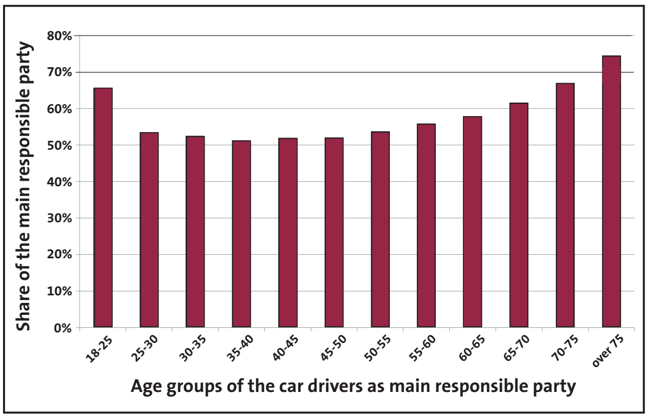


Figure. 6:
Percentage of car drivers by age group have been primarily responsible for an accident involving injury [9]

being responsible for an accident. Assuming that the distance traveled by those responsible for an accident does not differ from that of those not responsible for an accident in a specific age group, but that it does differ between the age groups, the effect of distance traveled can be eliminated. The age risk groups are then as shown in Figure 6.

1.2 Forecast

The major trends affecting individual motorized transport – driverless cars, electric vehicles and demographic change – will have a significant impact on the development of road safety in the future. Forecasts of accident figures for the years 2015 and 2020 assume a reduction in the number of accidents involving injury to 279,000 and then 234,000 [3]. On the basis of this forecast, 3,212 fatalities are expected in 2015 and 2,497 in 2020. A significant drop is thus expected in the number of car occupants and pedestrians involved in accidents in 2015 and 2020. The same applies to the number of fatalities and casualties with serious injuries. The number of pedestrians and car occupants suffering serious injuries is falling significantly as a proportion of all road users suffering serious injuries. On the other hand, the proportion of cyclists and, in particular, motorcyclists suffering serious injuries is rising. This is not due to an increase in the absolute numbers; instead, it is the result of differences in the rates at which casualties among different types of road users are declining.

In order to be able to understand accidents even better in the future and target measures more effectively, it is necessary to look at severely injured road users as well as fatalities. One consequence of improved vehicle technology and better rescue services is that, al-though the number of fatalities is falling, the number accident victims surviving with severe injuries is rising. Thus, the quality of road safety work cannot be measured by the reduction in the number of fatalities alone. The results of studies suggest that around 10% of the road users officially recorded as seriously injured had life-threatening injuries. For the year 2012 that amounts to 6,000 to 7,000 polytraumatiszed patients [4]. The current definition of seriously injured used in the official statistics is based solely on the criterion of whether a patient receives inpatient hospital treatment for at least 24 hours. This large group is thus very heterogeneous and does not permit any statements to be made about those with life-threatening injuries. Consequently, efforts are under way in Germany to introduce a subgroup for accident victims with very severe injuries based on the Maximum Abbreviated Injury Scale (MAIS). This would permit targeted accident analysis, the development of subgroup-specific preventative measures and more precise estimation of the economic costs of serious road accidents, for example. In a similar vein, the Europe-wide harmonization of the definition of seriously injured road accident vic-tims, also on the basis of MAIS [5], is expected in 2015.

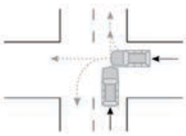
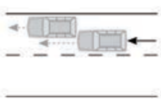
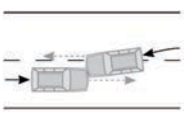
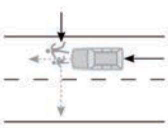
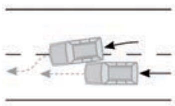
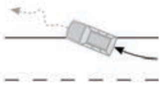
2 Accident statistics by vehicle type

To gain a better understanding of the accidents of the various vehicle types, it helps to shift the level of focus and make use of in-depth accident data. The insurers' accident database (UDB) was used to carry out in-depth analyses of the accidents involving different vehicle types. The UDB is based on motor third-party insurance damage claims and provides clearly more detailed information than the German federal statistics. It is comparable with GIDAS, although it is less useful in some respects because no analysis is carried out at the scene of the accident.

2.1 Cars

Using 1,641 damage claims in the UDB as a basis, accidents involving cars were subdivided by the parameter “kind of accident” (see Table 2).

Table 2:
The most common accident scenarios involving cars in the insurers' accident database (UDB) [6]

The most frequent accident scenarios $N_{\text{data pool}}$ = 136,954 [100 %]		Percentage share
(1) Collision with another vehicle that turns into or crosses a road		34.5
(2) Collision with another vehicle: - which starts, stops or is stationary - moving ahead or waiting		22.2
(3) Collision with another oncoming vehicle		15.5
(4) Collision between vehicle and pedestrian		12.1
(5) Collision with another vehicle moving laterally in the same direction		6.9
(6) Leaving the carriageway to the right or left		6.3
(7) Collision with an obstacle in the carriageway		0.1

Over 50% of the accidents involving cars are collisions with a vehicle that is turning into or crossing a road or collisions with a vehicle which starts, stops or is stationary.

Figure 7 shows the most common mistakes made by car drivers that lead to accidents. Turning, U-turn, reversing and starting is the most common category, just ahead of ignoring the right-of-way. Not too far behind these come unadapted speed and insufficient safety distance from the vehicle in front. The category "other mistakes made by driver" features prominently for all vehicle types. It is clear from this both that the picture would be different

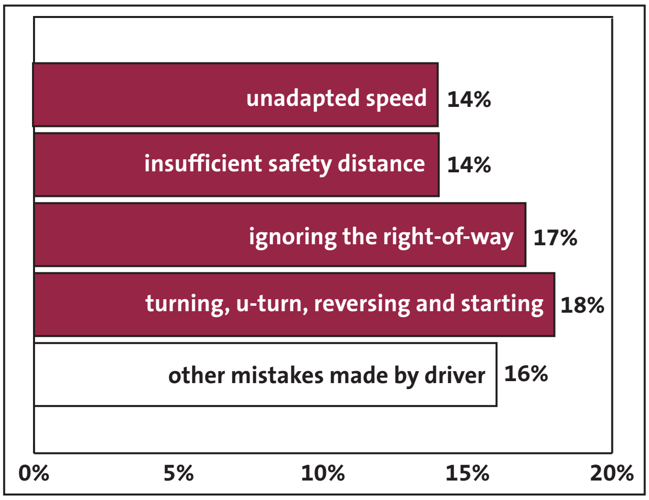


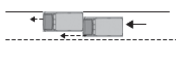
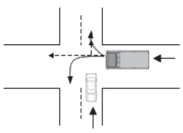
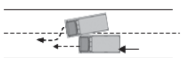
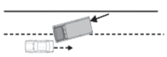
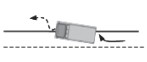
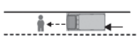
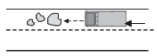
Figure 7:
The most common causes of car accidents involving injury [2]

if these causes were known and that there are limits to the usefulness of the national road accident statistics if you want to find out the causes of accidents. The information on unadapted speed, for example, is also worthy of further critical analysis here.

2.2. Trucks

Table 3 shows the most common accident scenarios involving trucks.

Table 3:
shows the most common accident scenarios involving trucks

The most frequent accident scenarios $N_{data\ pool}$ = 18,467 [100 %]		Percentage share
(1) Collision with another vehicle that is: -moving ahead or is waiting -starts, stops, or is stationary		31.6
(2) Collision with another vehicle that turns into or crosses a road		22.3
(3) Collision with another vehicle moving laterally in the same direction		18.5
(4) Collision with another oncoming vehicle		14.3
(5) Leaving the carriageway to the right or left		5.1
(6) Collision between a vehicle and pedestrian		4.4
(7) Collision with an obstacle in the carriageway		0.4

The analyses show that around 50% of the accidents are collisions with a vehicle traveling in the same direction next to or in front of the truck. Accidents involving vehicles that are turning into or crossing a road are the second most common accident type. 443 claims cases involving trucks were analyzed in detail here [6]. The most common accident causes were failure to drive at a safe distance from the vehicle in front and mistakes when turning, making a u-turn, reversing and starting (see Figure 8).

2.3 Buses

The analysis of accidents involving buses revealed that around 30% of them were accidents in longitudinal traffic, 18% were turning-off accidents and 17% were driving accidents, in which the driver lost control of the vehicle. When turning-into/crossing accidents are taken into consideration as well, which accounted for around 15% of all accidents, it

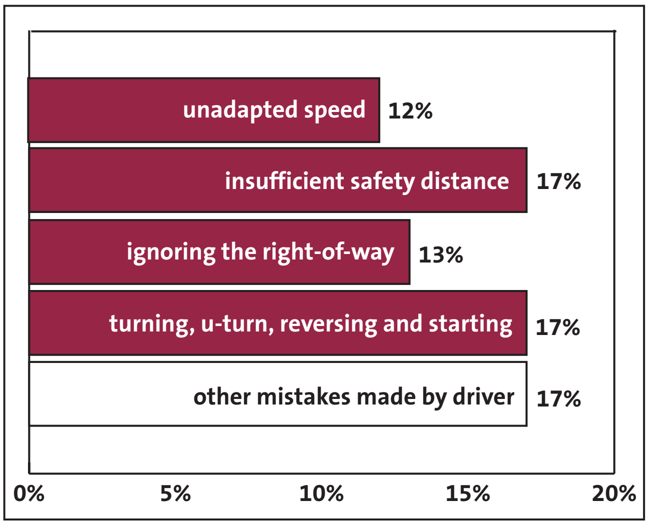


Figure 8:
The most common causes of truck accidents involving injury [2]

is clear that around 33% of all accidents took place at junctions and intersections [11]

The most common causes of accidents are shown in Figure 9. As already mentioned, knowledge of the causes of the accidents in the largest group, the "other mistakes by driver" category, could change the picture and have a significant impact on the measures required.

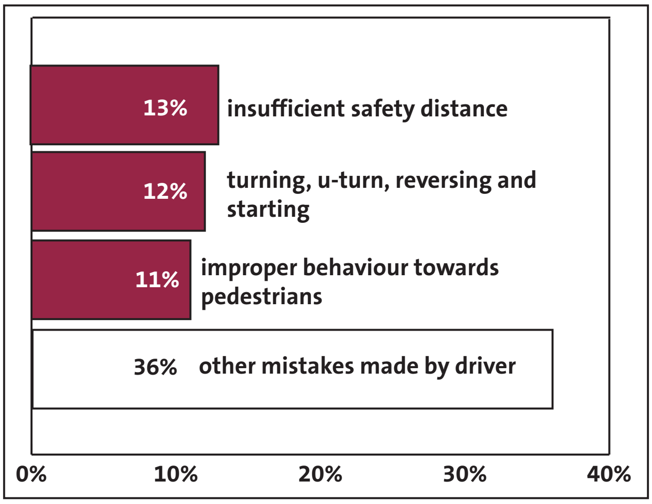


Figure 9:
The most common causes of bus accidents involving injury [2]

2.4 Powered two-wheelers (PTWs)

As road users, motorcyclists are extremely vulnerable. Motorcycle accidents, which often result in serious or fatal injuries for the rider, are caused by acceleration, speed, the narrowness of the motorcycle's silhouette and errors of judgment on the part of both motorcyclists and other road users. It therefore makes sense to examine the accident data by looking more closely at who causes the accidents and who is involved (see Figure 10). If the single-vehicle accidents and the accidents involving two road users caused by the rider of the powered two-wheeler are grouped together, it is clear that 51% of all accidents involving no more than two road users were caused by the rider of the powered two-wheeler.

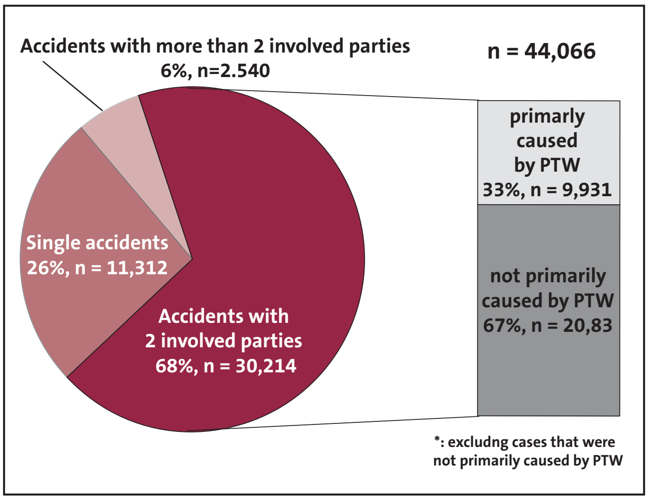


Figure 10:
Involvement in accidents of powered two-wheelers in Germany in 2012 [2]

To identify the typical accident scenarios, we analyzed single-vehicle accidents and accidents involving two road users, subdivided on the basis of who primarily caused them, as recorded in the insurers' accident database (UDB) [6]. The underlying accident material consists of 880 accidents involving powered two-wheelers.

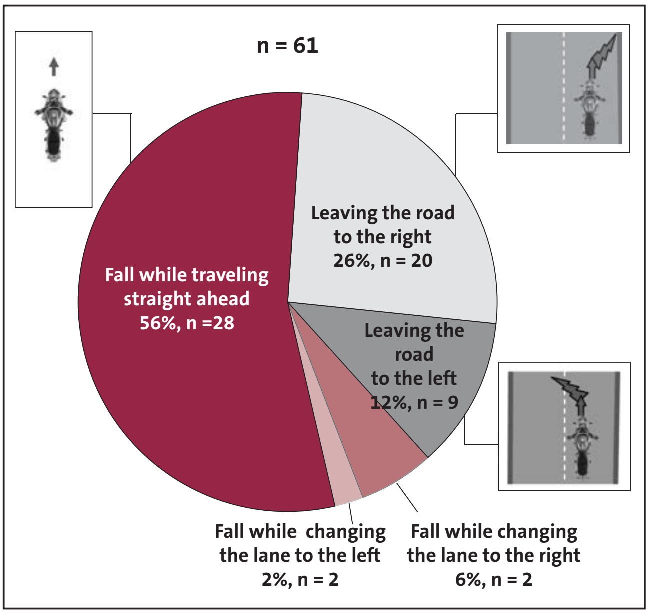


Figure 11:
Accident scenarios for single-vehicle accidents involving powered two-wheelers [6]

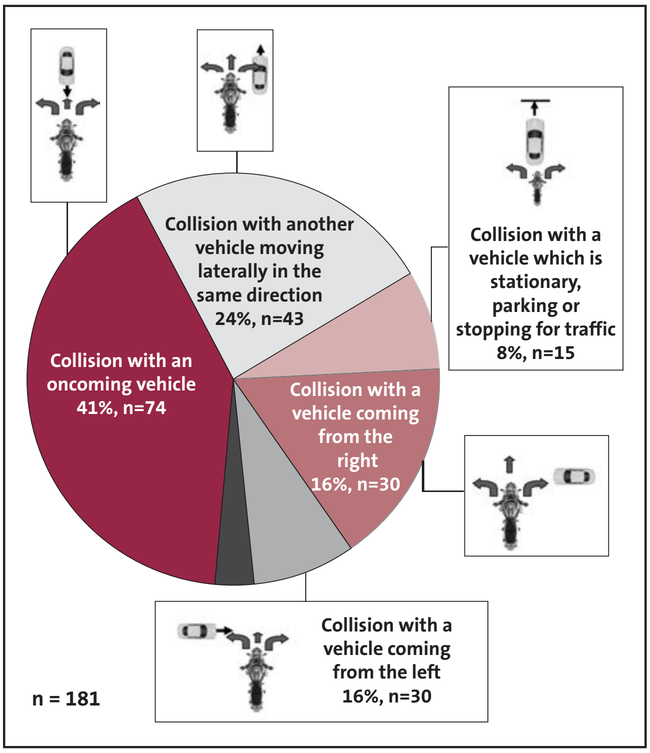


Figure 12:
Accident scenarios of accidents involving two road users and primarily caused by the powered two-wheeler rider [6]

The analyses of the single-vehicle accidents show that 56% of them involved crashes when traveling straight ahead. Leaving the carriageway to the right (26%) and left (12%) were the second and third most common scenarios. These two scenarios were characterized by inappropriate speeds in bends and unfavorable weather conditions.

In accidents involving two road users and primarily caused by the powered two-wheeler rider, the most frequent scenario was a collision with an oncoming vehicle (41%), followed by a collision with a vehicle traveling in the same direction (24%) and a collision with a vehicle coming from the right (16%). Further scenarios were a collision with a vehicle that was stationary, parking or stopping for traffic (8%) and a collision with a vehicle coming from the left (also 8%).

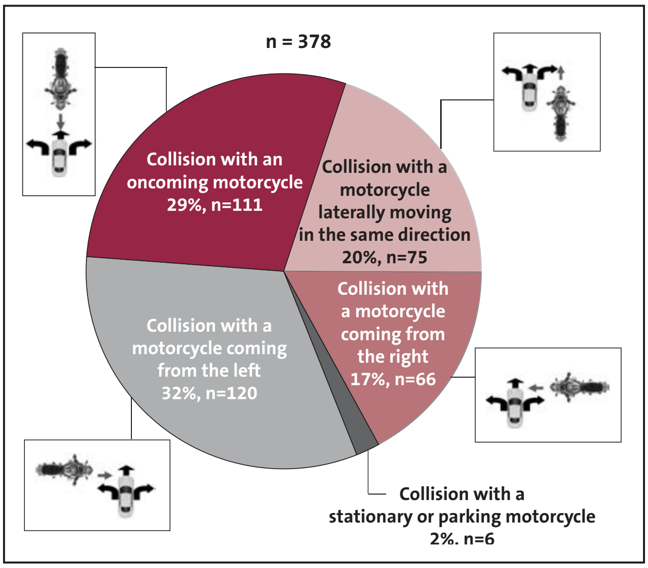


Figure 13:
Accident scenarios of accidents involving two road users and not primarily caused by the powered two-wheeler rider [6]

The analysis of the accidents involving two road users that were not primarily caused by the powered two-wheeler rider revealed that the most common accident scenarios were a collision with a powered two-wheeler coming from the left (32%) and a collision with an oncoming powered two-wheeler (29%). These were followed by a collision with a powered two-wheeler traveling in the same direction (20%) and a collision with a powered two-wheeler coming from the right (17%).

3 Safety potential of advanced driver assistance systems

Advanced driver assistance systems are electronic systems in the vehicle that are designed to help the driver to drive. The aim is often to make driving easier and improve safety or economy. This section focuses exclusively on the safety aspect.

There are direct links between the safety of vehicles and accident situations. The figure below shows the phases involved in an accident (see Figure 14). It was produced by the European Automobile Manufacturers Association (ACEA). The idea is that every accident goes through the different phases, beginning with a "normal driving" phase in which the accident is not yet foreseeable for the driver but in which certain conditions, such as the length of time for which the driver has been driving, are already having an effect on the driver. This phase ends with the accident-triggering critical situation that precedes every accident. For example, the driver may be too late in noticing that the driver in front has braked or that a child has run onto the road. This situation is followed by the danger phase. These three phases occur relatively frequently in everyday traffic and do not always result in an accident. The critical threshold of an accident is passed when the "point of no return" is reached and an accident becomes unavoidable. This is followed by the pre-collision phase, which may be relatively short, depending on the accident. The impact is followed by the "during collision" phase and ends with all road users involved coming to a standstill in the final situation of the accident. The greatest stresses – and thus the injuries of those involved – usually occur in this phase. The phase following the collision involves any rescue measures taken, such as the making of an emergency call.

Active safety and advanced driver assistance systems are relevant in the pre-collision phases, 1 to 3, but no longer once the first impact takes place. Depending on how the system takes effect, it may be able to prevent the critical situation from arising (for example, a navigation system minimizes the extent to which the driver is distracted from driving, and adaptive cruise control ensures that a sufficient distance to the car in front is maintained). Alternatively, it may defuse a critical situation (like an ESC system, for example) or reduce the force of the impact once the point of no return is passed (like a brake assist system). As a result of this diversity and the range of different ways in which advanced driver assistance systems take effect, special methods are required in order to ascertain the safety potential.

3.1 Methods of assessing the safety potential of ADASs

The safety potential of advanced driver assistance systems (ADASs) can be ascertained in a variety of ways. For example, a retrospective

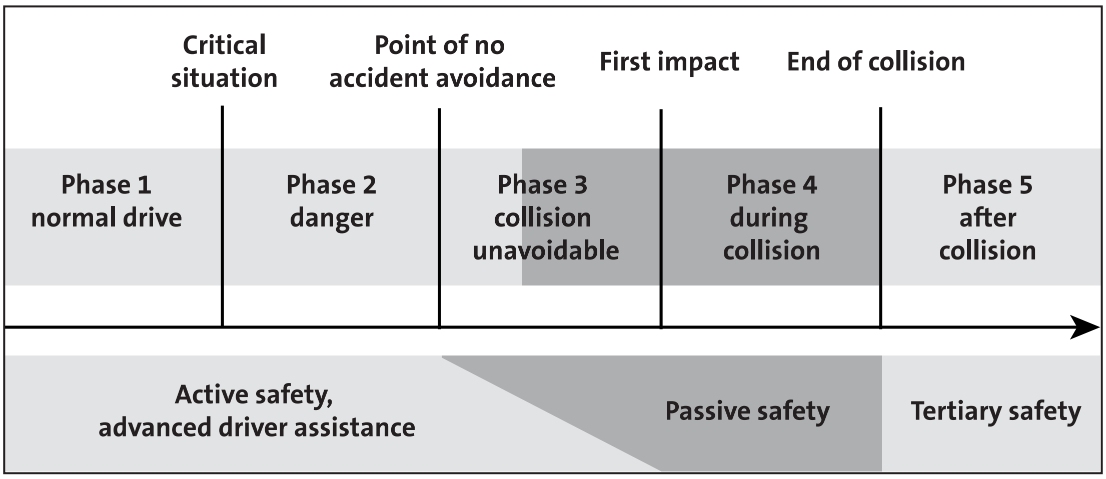


Figure 14:
Accident phases in the ACEA model and relevance of active safety and advanced driver assistance systems and passive and tertiary safety measures

comparison of two accident groups can be carried out: vehicles with ADASs and vehicles without them. Lie et al used this approach to prove the effectiveness of electronic stability control (ESC) on the basis of Swedish accident data [7].

For the results shown below, an alternative, "what if" method was used [6]. In this approach, the course of an accident as it happened in reality is examined and contrasted with what would have happened with a generic advanced driver assistance system. Generic in this context means a system with a number of selected features rather than a product that is actually available on the market. This makes it possible to determine the effect a particular type of advanced driver assistance system would have on the accident statistics if all cars were fitted with the system. In order to use this method, both the accident circumstances and the features (functionality) of the system to be examined or a generic system must be known. In the multi-stage procedure adopted in this method, the following distinction was drawn: whether the accident would have been preventable or whether its effects could only have been mitigated. An accident is considered to be theoretically preventable if it would not have happened with an ADAS. However, if the analysis shows that the accident would still have happened but that its consequences may have been less serious, the system is still considered to be capable of having a positive effect.

This can be illustrated with significantly greater precision by means of a simulation. In this case, too, the accidents are examined on a "what if" basis. Now that the accident situation can be portrayed with such detail and precision in the simulation environment, systems with significantly more complex functionality can be assessed with regard to their benefits. In addition, for warning and notification systems, human reactions have to be taken into account in the form of a driver model. The definition of this driver model is a great challenge, since it cannot always be assumed that the reactions of the driver will be suitable. In the study "Equal Effectiveness for Pedestrian Safety", for example, the benefits of a brake assist system were examined in terms of its effect on all pedestrian accidents in GIDAS. In all accident scenarios involving cars, it was examined what positive effects on the pedestrian an emergency braking system would have as a result of the lower speed of impact that would be expected. Following this case-based analysis of over 700 real pedestrian accident scenarios, the reductions in the numbers of seriously injured and killed pedestrians were compared with the known potential of other measures to protect pedestrians [10]

As an alternative, a field operational test (FOT) can also be considered in order to analyze the safety potential. Field operational tests are used primarily to evaluate new technologies such as ADASs [8]. To this end, the vehicle is equipped with extensive measurement equipment. The driver is then instructed, for example, to drive for a period with the ADAS switched on or off. This type of behavioral observation has become possible as a result of the rapid technical progress made in the collection, storage and analysis of large quantities of data and the development of measurement equipment that takes up less and less space. Everything required to explain and describe the driver's driving and the functionality of the ADAS is recorded: from the vehicle's movement (e.g. acceleration, speed, direction, vehicle status, etc.) to eye, head and hand movements and pedal operation. This data provides information about the interactions between driver, vehicle, road, weather and traffic not just in normal conditions but also in critical situations and even accident situations. The biggest challenge here is analyzing the very large quantities of data.

3.2 Cars

The most promising advanced driver assistance system for cars is the emergency braking system, followed by the lane departure warning system or lane-keeping assist system and the blind spot warning system (see Table 4). The emergency braking system becomes even more effective if it is also able to address accidents with pedestrians and cyclists. Up to 43.4% of all car accidents in the database then become preventable [6].

Table 4:
Safety potential of ADASs for cars based on all accidents involving cars [6]

ADAS	Theoretical safety potential
Emergency braking system (does not react to stationary vehicles)	17.8% p
Lane departure warning system	4.4% p
Blind spot warning system	1.7% p
p = preventable	

3.3 Trucks

Using the method described above, it was found that an emergency braking system was the advanced driver assistance system with the greatest safety potential for trucks as well [6]. The potential doubled when the system was also able to detect stationary vehicles in front of the truck. The emergency braking system was followed by the blind spot warning system and the turning assistant with cyclist detection when all truck accidents were taken into account (see Table 5). If you look only at accidents between trucks and unprotected road users, the safety potential of a turning assistant with cyclist and pedestrian detection is very high. In order to analyze the cases, a system was assumed that monitors the areas in front of and to the right of the truck and warns the truck driver if there is a pedestrian or cyclist in the critical zone when the vehicle is pulling away or during turning. It was assumed that the driver would make the ideal response to the warning.

It was found that around 43% of all truck accidents involving cyclists and pedestrians could be prevented if this turning assistant were used, and that around 31% of the cyclists and pedestrians killed in collisions with trucks would not be killed.

Table 5:
Safety potential of ADASs for trucks based on all accidents involving trucks [6]

ADAS	Theoretical safety potential
Emergency braking system	6.1% p
Emergency braking system (reacts to stationary vehicles)	12.0% p
Turning assistant for pedestrians	0.9% p
Turning assistant for cyclists	3.5% p
Lane departure warning system	1.8% p
Blind spot warning system	7.9% a
p = preventable, a = addressable	

There is significant variation in the safety potential of the different advanced driver assistance systems depending on the configuration/type of the truck they are used with (see Table 6).

Table 6:
Safety potential of ADASs for trucks depending on truck type/configuration [6]

ADAS	Theoretical safety potential for		
	Box truck (no trailer)	Truck with trailer	Semi-trailer truck
Emergency braking system (p)	2.2%	6.1%	5.1%
Emergency braking system (reacts to stationary vehicles) (p)	7.9%	10.7%	9.5%
Turning assistant for cyclists (p)	4.2%	0.6%	2.9%
Turning assistant for pedestrians (p)	0.5%	0.9%	0.8%
Blind spot warning system	6.8%	5.2%	6.4%
Lane departure warning system (p)	1.6%	1.8%	1.3%
p = preventable, a = addressable			

3.4 Buses

The emergency braking system is the system with the greatest safety potential for buses (see Table 7). It is followed by the blind spot warning system and the turning assistant with pedestrian and cyclist detection. There is also a clear increase in safety potential if the emergency braking system can detect stationary vehicles.

Table 7:
Safety potential of ADASs for buses based on all accidents involving buses [6]

ADAS	Theoretical safety potential
Emergency braking system (a)	8.9%
Emergency braking system (reacts to stationary vehicles) (a)	15.1%
Turning assistant for cyclists and pedestrians (p)	2.3%
Lane departure warning system (p)	0.5%
Blind spot warning system (a)	3.8%
p = preventable, a = addressable	

Here, too, the potential of the ADAS varies depending on the type of bus or the purpose for which it is used (see Table 8). Intercity buses benefit significantly more from a blind spot warning system, for example, while a turning assistant is more beneficial for a city bus.

Table 8:
Safety potential of ADASs for buses depending on bus type/ purpose [6]

ADAS	Theoretical safety potential	
	City bus	Intercity bus
Emergency braking system (a)	11.9%	4.5%
Emergency braking system (reacts to stationary vehicles) (a)	16.6%	17.3%
Turning assistant (p)	3.4%	-
Land departure warning system (p)	0.3%	1.5%
Blind spot warning system (a)	0.2%	14.6%
p = preventable, a = addressable		

4 Outlook

Across all the vehicle types analyzed, the emergency braking system emerges as the most promising ADAS. It will be found in different forms and with different functionality in all vehicle categories in the future – with justification, as the figures show. The addition of cyclist and pedestrian detection to the functionality of emergency braking systems will increase their safety potential. The turning assistant is particularly effective in trucks for the protection of cyclists and pedestrians. The increasing numbers of cyclists on the roads can only increase its importance. A next step in the development of these systems could be automatic evasion in emergency situations. This could increase the effectiveness of pure emergency braking systems in certain accident-critical situations, since, in terms of pure driving dynamics, evasion can take place at a later point than braking. This functionality has not yet been evaluated in terms of its influence on improving road safety, so that is essential. However, it would place even greater demands on the quality of the methods of analysis and the accident data.

The development of ADASs will benefit from the major trend toward highly automated driving, and the systems found in vehicles in future will blur the boundaries between systems that make driving easier and pure safety systems as well as between different ADAS functions. Road safety will benefit when it is no longer necessary for drivers to develop an understanding of the various ADAS functions in order to be able to interpret warnings etc. correctly. Instead, it would make sense to have a fluid protection zone around the vehicle that supports the natural responses of the driver in critical situations. This goes hand in hand with the further development of the human-machine interface in order to adjust warnings or interventions so that they cannot be misinterpreted by the driver. The accident analyses show that today's systems still have clear shortcomings in this respect.

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