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Supposedly unimportant? Accidents between cars and cyclists in driveways



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Introduction

In 2020, 426 cyclists were involved in fatal accidents [1]. In absolute terms, the number of cyclists killed has fallen over the last few years, despite a significant increase in the proportion of cyclists. However, the number of cyclist fatalities did not decrease as much as that of other road users. In relative terms, the share of cyclists killed in all traffic fatalities in Germany has actually risen from 8.1 percent in 1991 to 16 percent last year. Their primary opponent in road accidents is the passenger car.

Even though the focus in this paper is on vehicle technology measures. An interdisciplinary evaluation of various measures is also provided at the end.

In 2020, there were a total of 264,499 accidents with personal injury in Germany [1]. Around 7 percent of them (17,424) occurred at property access (in this paper the term driveway will be used). Most of those accidents occurred in built-up areas (16,055 accidents with personal injury; 92 percent of all accidents at driveways). 86 road users were killed, 62 of them in urban areas and 24 on roads outside built-up areas. Thus, one of eleven injured persons in road traffic in urban areas had an accident at driveways. Every 13th traffic related fatality in built-up areas is related to an accident at driveways.

For approaching the problem of accidents with cyclists at driveways, the accident data recorded by the police from several federal states in Germany for the year 2019 were first analyzed. This showed that a conspicuously large number of cyclists are involved in accidents with personal injury at driveways. While the share of cyclists in all accidents is 29 percent, their share at driveways is 45 percent (approximately higher than fifty percent).

The analysis further shows that 19 percent of bicycle accidents are single-vehicle accidents. The rest (81 % of bicycle accidents) had more than one involved road user. 75 percent of them are collisions between a car and a bicycle, 14 percent of these accidents occur at driveways (Table 1). In terms of accidents with personal injury at driveways, accidents between cars and cyclists have a share of 39 percent and represent the most frequent accident constellation for collisions at driveways.

10 percent of all bicycle accidents occur at driveways

Table 1 **· Bicycle accidents with personal injury recorded by the police in 2019 in Germany, several federal states included, own analysis**

Cyclist accidents with personal injury (in 2019)	Accidents with personal injury		Share of accidents at driveways
	Number	Share	
Total	53,568	100%	
Single-vehicle accidents (only cyclists)	9,928	19%	
Accidents involving more than one road user	43,640	81%	
of these, accidents at driveways	5,442	10%	12%
Accidents involving passenger cars and cyclists	32,601	61%	
of these, accidents at driveways	4,682	9%	14%

12 percent of the 4,682 accidents with personal injury involving cars and cyclists at driveways in this study were accidents with serious injuries. 9,470 road users were involved in these accidents, four of them were killed, 535 were seriously injured and 4,186 were slightly injured. This represents 4 percent of the fatalities, 12 percent of the serious injured and 15 percent of the slightly injured in all accidents involving passenger cars and cyclists that occur at driveways.

The most common causes of accidents in driveways are errors when mistakes made when entering the flow of traffic (32 %) or mistakes when turning (9 % to the left, 7 % to the right) followed by insufficient safe distance, mistakes made when making U-turn or reversing and unlawful use of the carriageway or of other parts of the road, e.g. footway, cycle-path (6 % each). The last cause mainly includes errors made by cyclists such as riding on sidewalks or riding against the direction of travel.

However, the accident data collected by the police are only suitable to a limited extent for in-depth investigations of the accident sequences and injury patterns. Therefore, more detailed data has been evaluated in the following chapters.

Description of the UDB case material

The further results presented here were compiled with the help of the German Insurers Accident Database (UDB). This contains a stratified random sample of all motor vehicle liability claims reported to the GDV and is representative of the claims experience of German insurers. On average, approximately 500 - 1,000 cases per year are recorded in the UDB. The data material only includes accidents with personal injury and a claims expenditure of at least €15,000.

A total of 619 accidents involving cars (including vans) and cyclists were used for the analysis of accidents at driveways. The case material examined covers the accident years 2002 to 2015 inclusive.

Case selection and relevance in the accident occurrence

In a first step, all accidents between a car and a cyclist in the UDB were preselected (n=615). These cases account for approximately 60 percent of all bicycle accidents in the UDB. From these, a total of n=114 accidents were identified in which the conflict between the passenger car and the bicyclist occurred in a driveway. The decisive factor was the conflict between the two opponents in the accident and not whether a collision actually occurred.

15 percent of all killed and seriously injured cyclists due to collisions with cars are related to driveways

Table 2 · Relevance of driveways to accidents and fatalities of cyclists with serious injuries in relation to car/bicycle accidents and all bicycle accidents

All accidents (including vans)	Accidents		Killed and seriously injured persons		Share related to all accidents involving cyclists (n=1,033)
	n	%	n	%	%
All car-to-bicycle accidents	619	100	407	100	60
of these, accidents at driveways	114	18	62	15	11

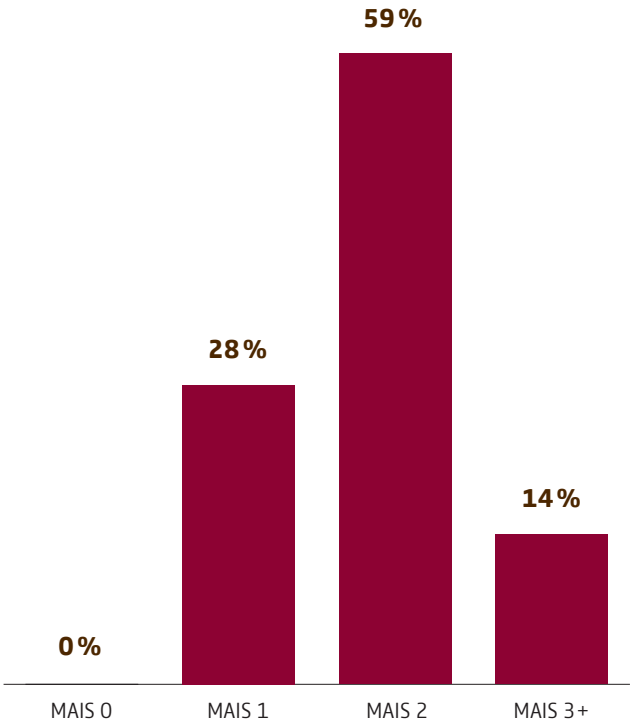
As can be seen in Tab.1, accidents in driveways account for 11 percent of all bicycle accidents (see Table 1: 12 %) and 18 percent of all car-wheel accidents (see Table 1: 14 %) in the UDB. This indicates an initial notable relevance in the insurers' claims experience and underscores how representative the UDB is compared to police-collected accident data (see Table 1).

Furthermore, the analyses show that cyclists were always injured in these accidents. With a share of approx. 15 percent of all - according to the official definition [1] - seriously injured and killed cyclists in the case material, these injuries were also frequently severe.

A look at the injury severity according to MAIS (Maximum Abbreviated Injury Scale) in Fig.1 also confirms this picture [3]. On the one hand, no MAIS 0 values occurred (MAIS 0 = uninjured). On the other hand, almost three quarters of the cyclists sustained at least one severe injury (MAIS 2+).

In collisions with cars at driveways, cyclists are always injured, and mostly seriously

Figure 1 · Distribution of the MAIS values for the injured cyclists in car-to-bicycle accidents in driveways



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Structure of accidents in driveways

In order to gain a better understanding of the accidents, they were first divided into rough categories (data pools). According to Fig.2, a distinction was made according to whether one of the parties involved was leaving or entering the property at the time of the accident and whether the car was moving forward or backward in the process. For the sake of clarity, all subsequent figures and those shown in Fig. 2 refer only to the basic population of n=114 car-to-bicycle accidents.

The first and largest data pool 1 (n=71; 62 %) is formed by "accidents in which the car exits a property" (Fig. 2). This in turn can be divided into two further subsets:

- Data pool 1 a: "Car exits property forward" (n=62; 54 %).
- Data pool 1 b: "Car exits property backward" (n=9; 8 %).

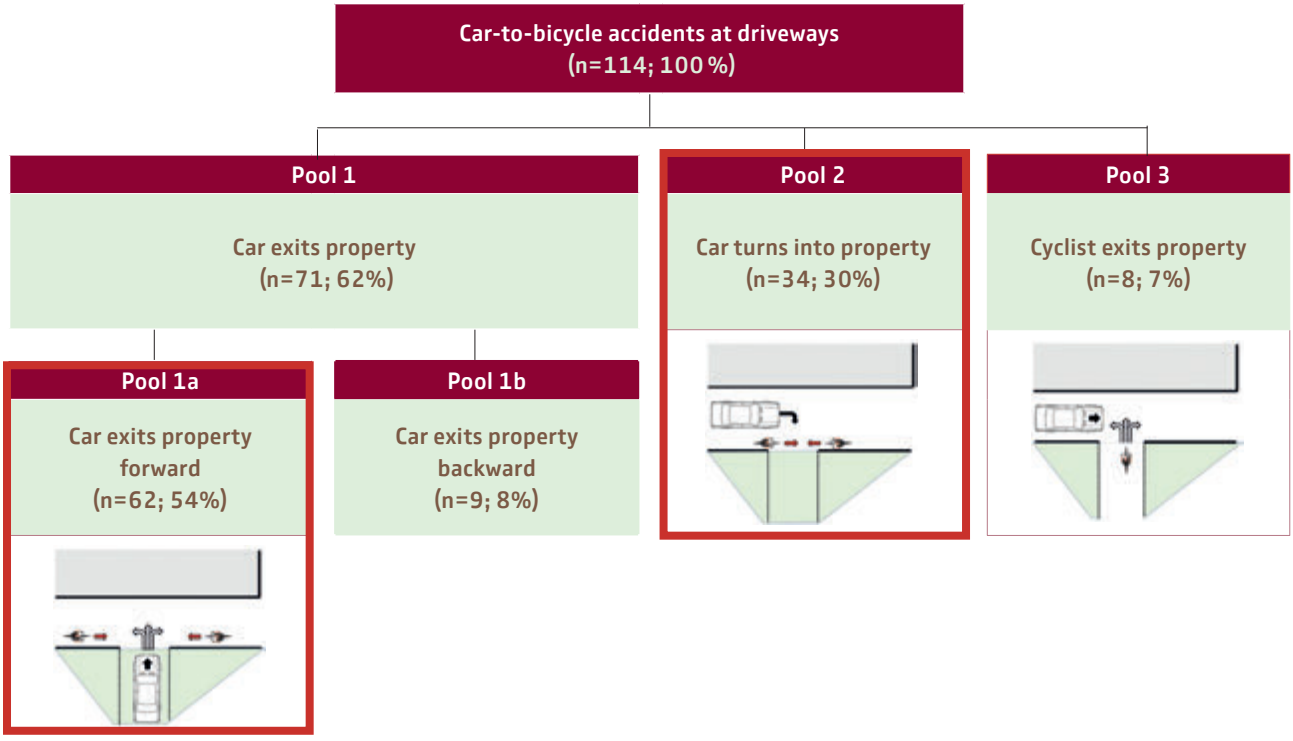
Another n=34 accidents (30 %) could be assigned to the category "car turns into property" (data pool 2). The remaining cases were assigned to data pool 3 "cyclist exits property" (n=8; 7 %).

The variety of possible accident constellations at driveways indicates that, from a vehicle technology perspective, different approaches are required in the subsequent identification of measures so that the accidents are also addressed, for example, with the appropriate driver assistance systems (e.g., emergency braking system with front/rear cross-traffic function, turn-off assistant).

In the following chapters, only the two largest data pools in the accident data are discussed: Data Pool 1a "Car exits property forward" (n=71; 62 %) and Pool 2 "Car turns into property" (n=34; 30 %).

In more than half of the cases, the car left the property forward

Figure 2 · **Subdivision of n=114 car-to-bicycle accidents in driveways into data pools**



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Accidents with cars that exit the property forward

For the data pool 1a (Fig. 2), the following vehicle and infrastructure aspects were analyzed:

- causes of accidents
- type of property
- view obstruction

In addition, typical accident scenarios were described. In a final step, safety benefits for suitable driver assistance systems were calculated.

Accident causes

Within the scope of an individual case analysis for data pool 1a "Car exits property forward (n=62; 54 %), the causes of accidents were determined.

In addition to driver inattention, two other aspects come into play at driveways:

- View obstruction in the driveway area and
- cyclists riding in the wrong direction.

Alcohol influence, darkness and the increased speed of the car had no relevance in these accidents.

Types of driveways

For n=57 of the accidents from data pool 1a (n=62), the type of driveway could be determined. The total of five types of driveways are listed in table 2 according to their frequency. It was found that the vans included in the data pool do have an impact on the ranking.

If vans are included in the analyses, then, as expected, accidents in the driveways of company sites occur somewhat more frequently than at other types of driveways (33 %). When excluding vans, gas stations and private parking lots come first in the ranking with a share of 26 % each, followed closely by supermarket parking lots and parking houses (14 % each).

Driveways at gas stations and private parking lots were often represented

Table 3 · **Ranking of the five types of driveways in the data pool 1a (see also picture 2)**

Type of driveway	Data including vans (n=57)	Data excluding vans (n=42)
Company site	33 %	19 %
Gas station	23 %	26 %
Private parking lot	21 %	26 %
Supermarket parking lot	12 %	14 %
Parking house	11 %	14 %

View obstructions

In almost half of the cases from data pool 1 a "Car exits property forward", a view obstruction was documented (n=29; 46 %). In these cases, the driver's view of the road and the cyclist path running directly in front of the driveway was partially or completely obstructed when exiting the property. The identified sight obstructions from data pool 1a account for one-quarter of all n=114 crashes at property access points. Because visibility restrictions can theoretically also occur in the other data pools from Figure 2 (not quantified here), their total proportion is probably higher.



Figure 3 · Examples of selected driveways with obstructed view (Source: UDV)

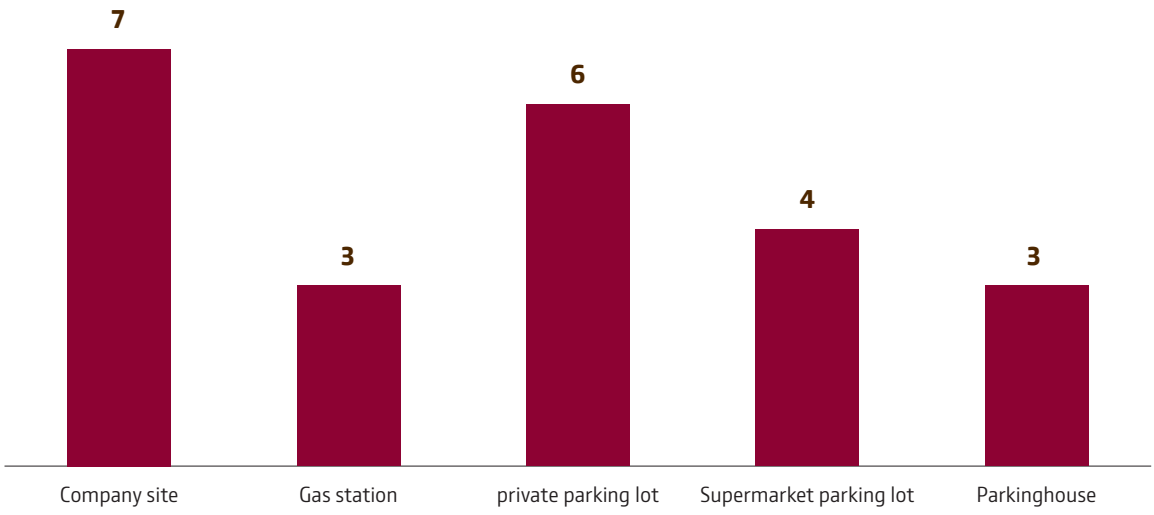
Hedge and shrubbery (n=18; 29 % of Data Pool 1a) were cited as the most common type of view obstruction. Figure 3 shows some examples of property driveways for this purpose. The analyses showed that car drivers often had to "inch their way" when exiting the property. As documented in at least two cases, this can already lead to an accident - even if the driver stops and does not proceed - because the approaching cyclist can fall by over-braking when the protruding front of the car is detected.

Parked vehicles (n=2), parts of buildings (n=3) and posters/signs (2 cases) are also among the documented view obstructions. In principle, all types of driveways can be affected by view obstructions (Fig. 4).

The importance of visibility restrictions in these accidents was also addressed by Baier et al [4].

View obstructions are a problem with all types of property driveways

Figure 4 · **Distribution of the feature "view obstruction" among the different types of driveways**



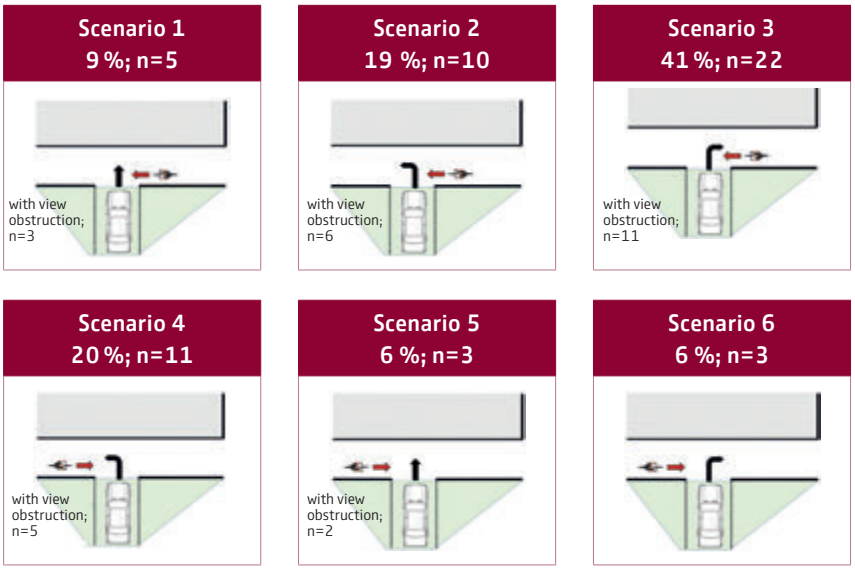
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Accident scenarios

For n=54 sufficiently documented cases, a total of six typical accident scenarios could be derived. These are determined by the characteristics "direction of travel of the two opponents in the accident" - in the case of passenger cars, however, only the intended direction of travel – and "view obstruction" (Fig. 5). Vans had no influence on the frequency of the accident scenarios.

Conflicts with cyclists coming from the right are an accident black spot

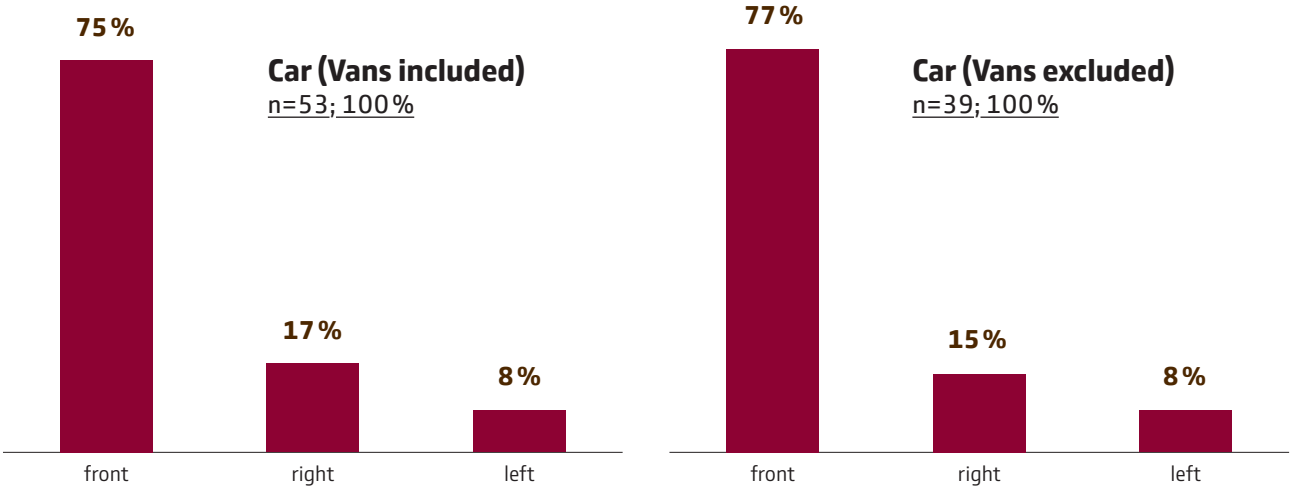
Figure 5 · **Accident scenarios for the data pool 1a "Car exits the property forward"**



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Most of the cyclists collided with the front of the car

Figure 6 · **First impact at the vehicle when it exits the property forward (data pool 1a, fig. 2) subdivided by the feature "van included" and "van excluded".**



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With a share of 41 percent, scenario 3 dominates in which the passenger car exits the property to the right and collides with a cyclist approaching from the right. This scenario also has the most documented view obstructions in absolute terms (11 out of 22 cases). Another indication of the poor visibility of bicyclists is that in this scenario, except for one case, there was no braking by the passenger car. The total percentage of cases in which the passenger car had braked was only 18 percent in the entire data pool 1a.

If all cases that can be characterized by the direction of movement of the bicyclist "coming from the right" are combined (scenarios 1,2,3), they account for almost 70 percent (n=37) of the cases. In over half of these cases, there was also a view obstruction.

For the accidents in which the passenger car collided with a bicyclist coming from the right, the analyses also showed that in n=20 cases the cyclist was proved to have been riding against the permitted direction of travel. Cyclists traveling in the wrong direction accounted for half of all scenarios in data pool 1 overall and 19 percent of all accidents in driveways.

A closer look at the area of the first impact at the car confirms the high relevance of accidents in which the cyclist approaching from the right (Fig. 6). The right side of the vehicle was hit twice as often as the left side.

In line with earlier UDV studies on the subject car to cyclist accidents [5], however, overall the passenger car had its first impact predominantly with the front of the vehicle. This again shows the importance of an emergency braking system as a possible accident-preventing measure.

Furthermore, the traffic area from the cyclist's point of view could also be determined for n= 21 cases in scenario 3. It was shown that only two cyclists were using the sidewalk instead of the cyclist lane at the time of the accident, whereby in one case the cyclist had dismounted from the bicycle beforehand.

Accidents with cars turning into a property

In the following, results from the analyses of data pool 2 are described. These are those accidents in which the passenger car had a conflict with the cyclist while the car was turning into the property (see also Fig. 2). Due to the lower level of documentation in some cases, these accidents cannot be described in the same level of detail as the accidents from data pool 1a. It was also not possible to estimate the potential benefits of driver assistance systems in terms of accidents that could actually be avoided. Here, only the positive influence of suitable ADAS (Advanced Driver Assistance Systems) is shown. An initial finding from the analyses was that these do not differ in principle in their sequence from the other turning accidents at intersections. Thus, 29 of the n=34 accidents contained in this data pool can be well represented with the help of the three-digit accident type (Fig. 7).

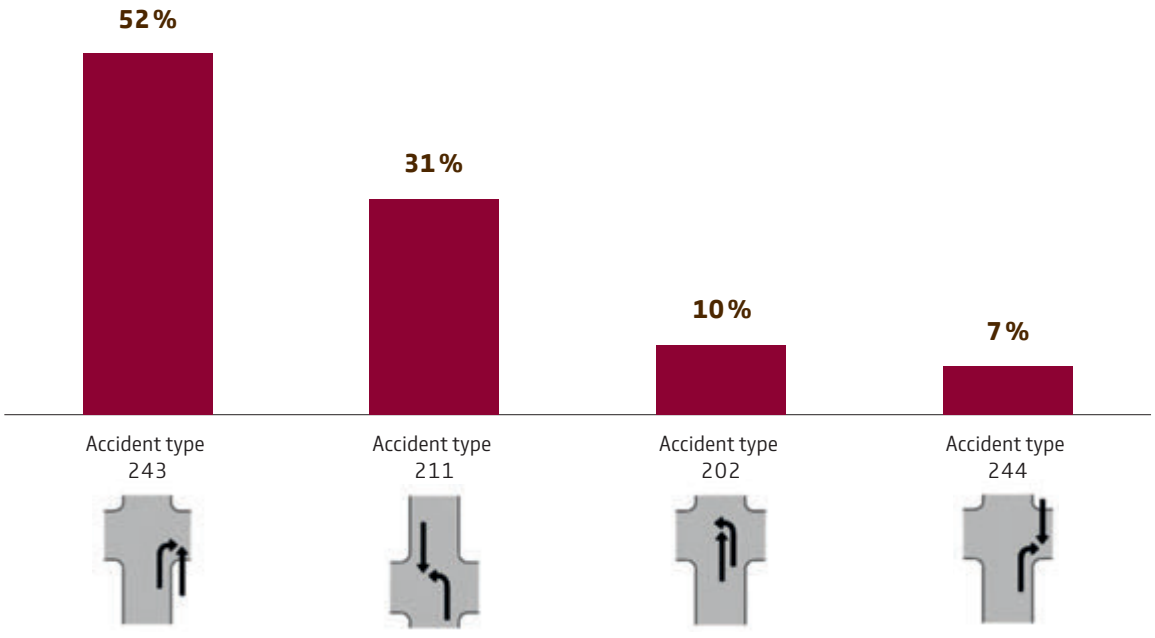
More than half of these accidents are addressed by the accident type 243 (52 %; n=15). These are accidents in which the passenger car turns right into the property and collides with the cyclist riding to its right in the same direction. These accidents can be further described as follows:

- In 11 out of 15 cases, the accident took place during daylight.
- In 4 out of 10 cases, the passenger car driver had braked.
- The speed of the car immediately before the accident (initial speed) was 10 km/h on average.
- View obstruction by parked vehicles was present in only two of 15 cases.
- In 12 out of 15 cases, a system with the functionality of a turn-off assistant in the form of a blind spot warning function would have had a positive influence on the accident.

The second place in the ranking is taken by accident type 211 with 31 percent (n=9), i.e. those accidents in which the passenger car makes a left turn in order to

Collisions with cars turning right dominate

Figurge 7 **· Categorization of accidents where the car turns into a property based on the three-digit accident type (data pool 2, see also fig. 2)**



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enter the property and overlooks the oncoming cyclist. The following applies to these accidents:

- In seven out of nine cases, the accident took place in daylight.
- In two out of nine cases, the car driver had braked.
- The average speed immediately before the accident was 20 km/h.
- View obstruction due to parked vehicles could not be seen in any of the cases.
- In eight out of nine cases, a system with the functionality of a conventional emergency braking system with cyclist detection would have had a positive influence on the accident.

For the remaining five cases from data pool 2 - accident type 202 and 244 - the description is omitted due to the small number of cases. It should only be noted that in both cases from the category of accident type 244 ("car turns right and collides with oncoming cyclist") a positive influence by an emergency braking system with cyclist detection would be expected. In contrast, for the n=3 cases of accident type 202 ("Accidents with passenger car turning left and colliding with cyclist coming from behind"), a benefit can only be expected with full all-round visibility. The lateral distance between the car and the cyclist was considered to be too large for a turn-off assistant, so that these accidents could not be addressed by such a system.

Counter-measures

In the following, vehicle-specific, infrastructure and behavior-based measures are identified. On the vehicle side, the potential benefits for emergency braking systems are quantified.

Interdisciplinary coutermeasures

Measures that could have a positive impact on this accident scenario are listed below.

Infrastructure:

- **Creating and maintaining a clear view**
  A good view for all road users is essential for improving road safety at driveways. This required that geometric sight triangles must be kept free of obstructions to visibility (such as parked vehicles, planting or trees, other road equipment or extensions).

- **Signage/Marking**
  In order to improve the recognizability of bicycle traffic guidance at driveways, a clear and easily recognizable priority signs ("Give right-of-way" or "Stop", possibly with reference to bicycle traffic for both directions), clear “ford markings” with bicycle symbols and, if necessary, in red colored “ford markings” are recommended.

- **Pavement / thresholds**
  Slower speeds contribute to greater awareness and if an accident occurs, this contributes to a lower accident severity. Paving (bumps),ramps or thresholds can be used to reduce speeds by entering and exiting driveways.

- **Traffic light controlled entrances and exits**
  At driveways (or intersection arms) with a high traffic volume, vehicles entering/exiting the driveway can be separated from crossing pedestrian and cyclists through the traffic signals. This avoids conflicts that end up in accidents.

- **Traffic mirrors**
  At intersection arms with a low traffic volume, especially in private access, traffic mirrors can contribute to a better visibility of crossing bicycle traffic if the visibility conditions can’t be improved by any other measures.

Behavior:

- Raise awareness among car drivers that cyclists can approach from both directions.
- Raise awareness among bicyclists regarding the presence of driveways and the resulting danger.

Vehicle:

- Emergency braking system with cross-traffic function (front/rear)
- Turning assistant
- All-round vision (camera)
- Car-to-bike

Safety benefits of emergency braking systems

Vehicle technology systems are divided into informing, warning and actively intervening systems. For the accidents in driveways considered here, however, only an actively intervening system makes sense, since the local and temporal circumstances of the accident do not allow the driver to react.

For n=47 sufficiently documented cases from data pool 1a (see Fig. 2), a benefit potential estimation in terms of avoidable accidents was performed. For this purpose, two emergency braking systems, hereinafter referred to as AEB/AEB+ (AEB: Automatic Emergency Braking), were considered:

- conventional emergency braking system with detection of cyclists (AEB), as already available on the market today [2].

- improved emergency braking system (AEB+), which is based on AEB and whose sensors are not disturbed by view obstructing structures (generic system, see example Fig. 8).

Each accident was analyzed according to the "what-if method" and examined to determine whether the accident would still have occurred if the AEB/AEB+ system had functioned correctly.

It should be mentioned at this point that none of the vehicles involved in the case material were equipped with an emergency braking system. Cases in which the cyclist was startled or fell due to an incorrect reaction and without colliding with the passenger car were also classified as unavoidable for both systems.

This results in the safety benefits listed in Table 3. A conventional system with detection of cyclists (AEB)



Figure 8 · Schematic picture of an advanced emergency braking assistant with detection of cyclists at driveways (AEB+).

could prevent just under a quarter of these cases. A generic system (AEB+) would be able to prevent more than 90 percent of the n=47 relevant cases from data pool 1a, if its sensor technology detects the cyclist at an early stage despite restricted visibility and prevents the vehicle from continuing its journey (Fig. 8).

Based on all n=114 accidents at driveways, this translates to approximately 10 percent preventable accidents from a conventional system (AEB) and 39 percent preventable accidents from an improved system (AEB+).

30 percent more accidents could be avoided by an improved emergency braking system in addition to the conventional system

Tabelle 4 · **Potential benefits of AEB and AEB+ related to the subset from data pool 1a (n=47) and to all accidents in driveways (n=114).**

All cars (including vans)	Data pool 1 a "car exits driveway forward" (n=47; 100 %)		All accidents in driveways (n=114; 100 %)	
	n	%	n	%
Avoidable by AEB	11	23	11	10
Aditionally avoidable by AEB+	+33	+70	+33	+29
In total avoidable by AEB+	44	93	44	39

Summary and outlook

In this study, n=114 accidents between cars and cyclists in driveways (property access points) were investigated. The aim was to show the characteristics of these accidents and to derive reasonable avoidance strategies. Accidents in driveways account for 18 percent of all accidents between cars and bicyclists and 15 percent of the bicyclists killed and seriously injured in these accidents. In relation to all bicyclist accidents in the UDB, their share is 11 percent. The consequences of these accidents are often severe for the cyclists involved (70 % MAIS 2+ injured).

The focus of the analyses was on those accidents in which the passenger car left the property in a forward direction. These accounted for 54 percent of all driveway-related accidents between passenger cars and bicyclists.

The analyses showed that structural view obstructions - mostly in the form of hedges and shrubbery - play a notable role in causing accidents; these account for about half of the cases involving passenger cars exiting forward, or a quarter of all accidents at driveways.

In 19 percent of the cases, the cyclist coming from the right was proved to have been riding against the permitted direction. Both structural view obstructions and cyclists riding the wrong way additionally increase the complexity of the situation at driveways and thus the probability of an accident. The analyses also showed that the use of the sidewalk instead of a cyclist lane had hardly any relevance here. Only two of 21 cyclists coming from the right and for whom the traffic area could be determined had used the sidewalk.

From a vehicle technology point of view, emergency braking systems with detection of cyclists are primarily considered as an accident-avoiding measure. With a system already available today, only 10 percent of all accidents at driveways can actually be avoided due to the aforementioned problem of restricted visibility. Only with an improved emergency braking system can a higher benefit potential be achieved in the form of 29 percent avoidable accidents, provided that the sensors of the system are not disturbed by structural view obstructions.

In addition, infrastructure and behavior-influencing measures can be particularly effective. The advantage of these measures over vehicle-related measures is that they have a positive effect more quickly, since they do not have to be incorporated into the vehicle fleet over a period of several years. The selective use at danger points also reduces the expense of equipping the infrastructure across the board.

Literature

[1] DESTATIS: Fachserie 8, Reihe 7. Statistisches Bundesamt, Wiesbaden 2020

[2] EuroNCAP: Test Protocol - AEB VRU systems, Version 3.0.4, April 2021

[3] Association for the Advancement of Automotive Medicine: Course Training Manual, A specialized Course on: Injury Scaling: Uses and Techniques, Introducing The Abbre-viated Injury Scale - 2005 Update 2008, Version January 2011. Barrington, Ill.: 2011

[4] Baier, Michael et al.: Interdisziplinärer Ansatz zur Analyse und Bewertung von Radverkehrsunfällen. FE 82.0658/2016 im Auftrag der Bundesanstalt für Straßenwesen, Kurzbericht, Aachen, Dezember 2020.

[5] Kühn, M., Bende, J., Lang, A.: Pkw Heck- und Seitenkollisionen mit Fußgängern und Radfahrern. Unfallforschung kompakt Nr. 71,

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