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Single-vehicle accidents of cyclists



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1. Background and motivation

The majority of cycling accidents in Germany are collisions between two parties. However, single-vehicle accidents of cyclists without the involvement of a second party are becoming increasingly relevant. In 2023 27,394 single-vehicle accidents with personal injury were recorded, 147 cyclists (including passengers like children in child seats) were killed as well as 6,406 were seriously injured and 20,965 lightly injured [1]. Single-vehicle accidents are today responsible for 29 per cent of all cycling accidents with personal injury, 33 per cent of the killed cyclists and 44 per cent of the seriously injured cyclists [1]. The relevance of single-vehicle accidents for cycling accidents is made clear again in a comparison. In 2023, significantly more cyclists were seriously injured in single-vehicle accidents than in collisions with cars (5,112 seriously injured cyclists in such accidents involving two parties) [1].

In the case of single-vehicle accidents, a high number of unreported cases can be assumed as accidents with minor injuries are rarely recorded. Single-vehicle accidents and factors giving rise to them are therefore of high importance, the reduction can make an important contribution to improving road safety.

Against this backdrop, a detailed analysis of single-vehicle accidents of cyclists was carried out at the Institute of Transportation Engineering of the University of Kassel on behalf of the German Insurers Accident Research (UDV). The following findings are based on the project's research report.

2. Methodology

The aim of the study was to analyse single-vehicle accidents of cyclists with regard to characteristic aspects of the people involved, the accident causes and accident locations. Due to the high number of unreported cases, the study focussed not only on the analysis of accident data but also on a survey of cyclists involved in single-vehicle accidents. The following steps were carried out:

- a literature analysis of the current research state, including 33 German and 21 international studies,
- an exchange with experts from the fields of scientific research, infrastructure planning, police and medical care in a workshop,
- a comparative analysis of police-recorded accidents with personal injury (7,767 single-vehicle accidents of cyclists and 49,288 cycling accidents involving multiple parties) from 2018 to 2020 from the federal states of Berlin, Hamburg, Hesse, Saxony and Saxony-Anhalt,
- an in-depth analysis of police-documented accident descriptions (1,481 single-vehicle accidents with personal injury) to investigate the accident sequences and to identify factors giving rise to single-vehicle accidents that are not apparent from the tabularly coded accident data alone,
- an online-survey of cyclists (1,917 participants with 1,521 reported single-vehicle accidents and 366 near-accidents) to analyse typical situations of single-vehicle accidents and near-accidents,
- in-depth interviews with cyclists involved in accidents (157 single-vehicle accidents) and detailed analyses of written accident descriptions from cyclists (125 single-vehicle accidents) in combination with the analysis of accident locations (69 locations) to isolate accident-promoting driving manoeuvres at accident-prone features of the infrastructure.

3. Literature Analysis and Workshop

A particularly striking aspect of single-vehicle accidents of cyclists is the high number of unreported cases. In 2016 von Below referred to a proportion of unreported cases as high as 96 per cent [2]. The deficits associated with said underreporting make it difficult to analyse relevant characteristics of the accidents and, above all, to localise and counteract accident black spots in the road network.

Previous studies have been able to shed light on some factors influencing single-vehicle accidents of cyclists. Riders of pedelecs, for example, show a higher proportion of single-vehicle accidents (20 % in the age group between 18 and 64 years, 22 % in the age group over 64 years) than users of conventional bicycles (13 % and 18 % respectively) [3]. Furthermore, driving under the influence of alcohol is of great importance. In a study of 246 cycling accidents under the influence of alcohol, 152 (62 %) were single-vehicle accidents [4]. Regarding the infrastructure, previous studies already hinted towards the risks associated with tram tracks, slippery surfaces or surface irregularities [5, 6, 7].

In the workshop, the experts identified alcohol and drug consumption, distraction, misjudgement of the own abilities and driving at high speeds as accident-promoting aspects of the human behaviour. Age as well as experience in handling the own bicycle and the correct assessment of the characteristics of the bicycle are also relevant. The latter especially applies to pedelecs.

Regarding the infrastructure, the experts saw tram tracks in particular as a factor giving rise to single-vehicle accidents as tram tracks were mentioned most frequently in the workshop. Kerbs and ramps as well as poorly maintained, dirty or icy surfaces can also promote accidents. For kerbs and ramps, the design (e. g. the angle of ramps) is of importance. Furthermore, point objects like bollards or signposts come with an associated risk according to the experts, as these objects can be easily overlooked by cyclists if placed in unexpected locations.

When it comes to bicycles, pedelecs and cargo bikes have the potential to promote single-vehicle accidents. Especially in combination with a lack of experience and practice (e. g. if such a bicycle is only rented) the weight and acceleration of these bicycle types can easily lead to falls.

According to the experts, a better database is needed above all. Knowledge of single-vehicle accidents that were not recorded by the police can support the creation of such a database. Local authorities can foot their efforts to counteract accident black spots in the road network on this basis.

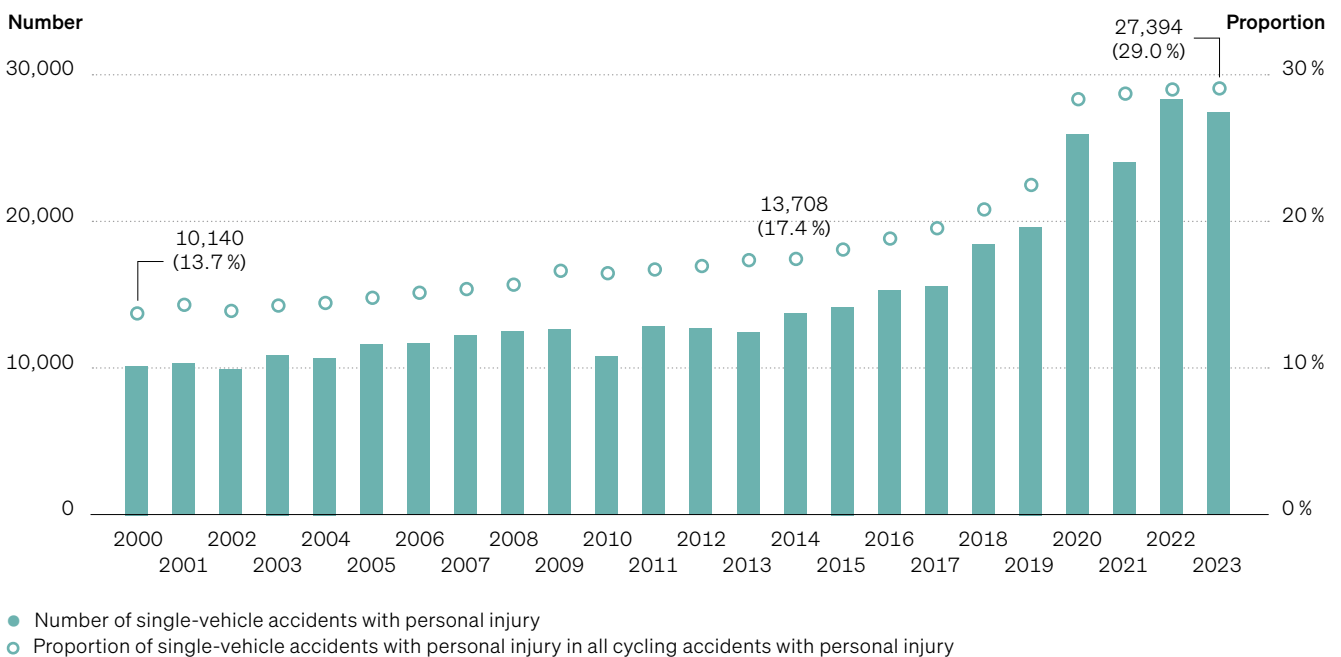
4. Accident data analysis and online-survey

4.1 Development of single-vehicle accidents since 2000

Single-vehicle accidents of cyclists with personal injury are accounting for a large proportion of the cycling accidents with personal injury today. The number of single-vehicle accidents has almost tripled since the turn of the millennium from 10,140 to 27,394 (figure 1). The proportion of single-vehicle accidents in all cycling accidents has also risen sharply from 13.7 per cent in 2000 to 29.0 per cent in 2023.

Single-vehicle accidents have increased significantly, especially in recent years

Figure 1 - Development of single-vehicle accidents with personal injury since 2000 (data basis: German Federal Statistical Office, Verkehrsunfälle [traffic accidents], annual reports of 2000 to 2023, table 2.8 und 3.1.2)



On the one hand, the increase is the result of a general rise in bicycle traffic. While 82 million passenger kilometres per day (around 51 million miles per day) were covered by bicycle in 2002, this figure had risen by a third to 112 million passenger kilometres per day (around 70 million miles per day) in 2017 [8]. On the other hand, the proliferation of pedelecs contributed significantly to the sharp increase since the mid-2010s. In the five federal states of the study, a similar doubling of single vehicle-accidents since 2014 as in the entirety of Germany can be observed. Single-vehicle accidents with conventional bicycles have thereby increased by nearly 80 per cent (from 1,872 to 3,354 cases) while those involving pedelecs increased more than twenty-fold (from 31 to 699 cases). The proportion of pedelecs in single-vehicle accidents rose from 1.6 per cent in 2014 to 17.2 per cent in 2023.

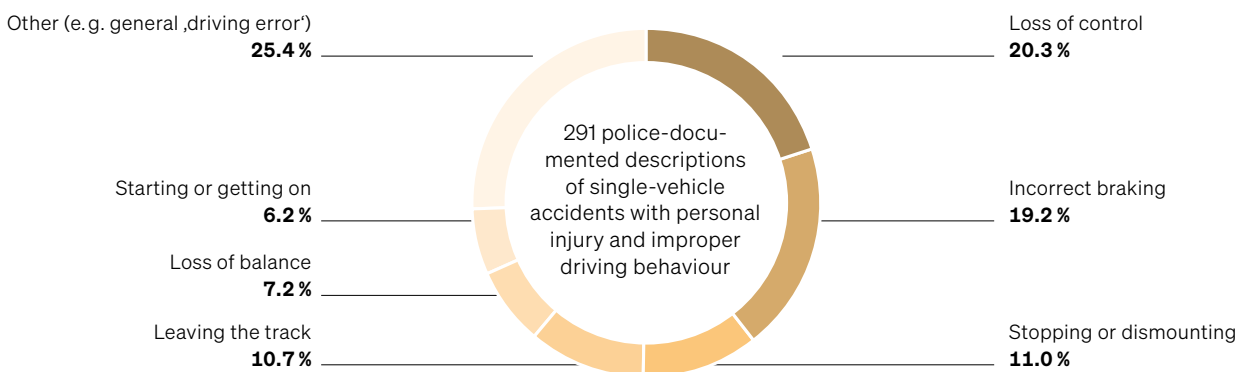
4.2 Accident-promoting aspects of the cycling behaviour

Single-vehicle accidents are very often caused by improper behaviour of the cyclists. Nearly a third (29.4 %) of the 7,767 analysed single-vehicle accidents recorded by the police was caused by inappropriate speed.

In addition, in almost one in five cases (19.6 %), the accident descriptions by the police document aspects of improper driving behaviour that cannot directly be taken in this detail from the tabularly coded accident data. The proportion of accidents caused by incorrect braking is particularly striking (figure 2). Around one in five accidents with improper driving behaviour involves either over-braking (most cases) or mistaking front and back brakes (a single case in the analysed data set).

Accidents as a result of improper driving behaviour often happen due to errors when braking, stopping or dismounting

Figure 2 · Improper driving behaviour documented in accident descriptions (data basis: police-documented accident descriptions)



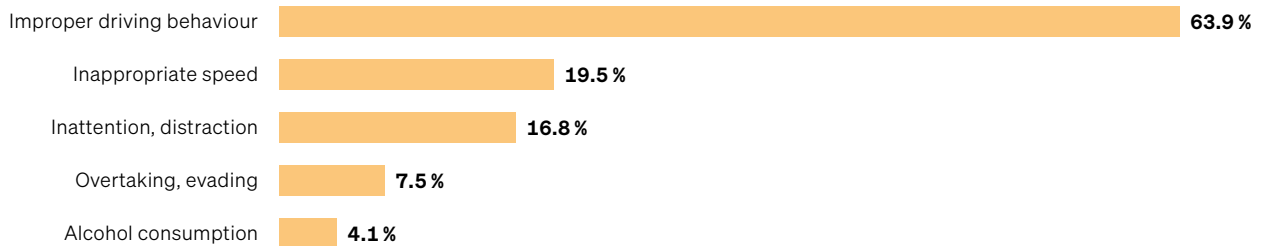
The consumption of alcohol also plays a major role in the cases recorded by the police, nearly every sixth (16.7 %) single-vehicle accident of a cyclist known to the police is an alcohol-related accident. It can be assumed, however, that these accidents involving alcohol are overrepresented in the police data of single-vehicle accidents. Firstly, the proportion of alcohol-related single-vehicle accidents is around three times as high as in cycling accidents involving multiple parties (5.6 %). Secondly, alcohol also plays a much smaller role according to the surveyed cyclists (4.1 % of the accidents in the online survey).

Accidents caused by distraction or inattention are rarely documented by the police (5.0 % of the 1,481 accident descriptions). This may be due to the difficulty proving the accident cause. According to the surveyed cyclists, distraction by technical devices does not play a significant role, but general inattention certainly does (16.8 % of the 1,521 accidents described).

Although the surveyed cyclists saw the infrastructure as the main cause of their accident more often than their own behaviour, many of them described accident-promoting behaviour when describing the circumstances of the accident. In particular, improper driving behaviour (riding inappropriately for the situation and slipping on the surface, loss of control or balance, over-braking etc.), inappropriate speed and the inattention already mentioned contribute significantly to the accidents (figure 3).

Almost two thirds of the single-vehicle accidents of the surveyed cyclists are (also) caused by improper driving behaviour

Figure 3 · Significant accident-promoting aspects of human behaviour according to the surveyed cyclists (data basis: online-survey, n = 1,521)



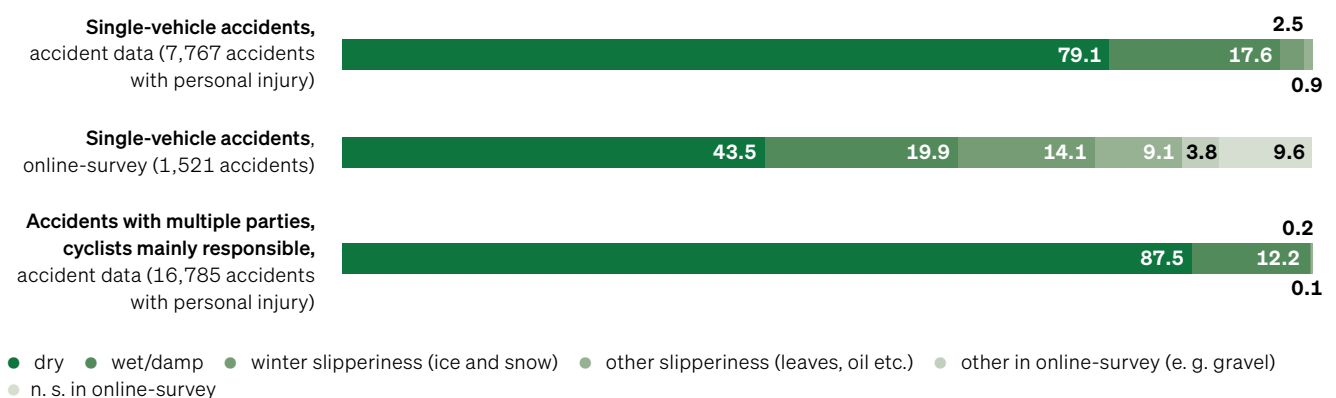
4.3 Accident-promoting aspects of the infrastructure

Single-vehicle accidents of cyclists occur mostly (51.9 % of the cases) on straight, level sections of roads between junctions and thereby on seemingly uncritical parts of the road network. Areas of junctions are also relevant but the proportion of single-vehicle accidents happening at junctions is significantly smaller than the one of cycling accident involving multiple parties (25.7 % of the cases opposed to 47.5 %). Downhill stretches that potentially favour high speeds are noteworthy, every sixth single-vehicle accident occurs here. Downhill stretches play a particularly important role outside of urban areas with 39,3 per cent of those cases. Only one in ten single-vehicle accidents of cyclists occurs outside of urban areas though.

The grip of the surface is of high importance for the occurrence or avoidability of single-vehicle accidents. In nearly half of all single-vehicle accidents of the surveyed cyclists, a surface with reduced grip contributed to the accident (figure 4). Especially winter slipperiness and slipperiness caused by other circumstances (e. g. due to leaves or oil) were stated significantly more often than in the accidents documented by the police (3.4 % of the single-vehicle accidents recorded by the police compared to 23.1 % of the accidents of the online survey). The survey also showed a smaller number of cases with conditions that the coding as dry by the police is incapable to cover. The surveyed cyclists reported other conditions such as loose surfaces due to gravel or sand in 3.8 per cent of the accidents.

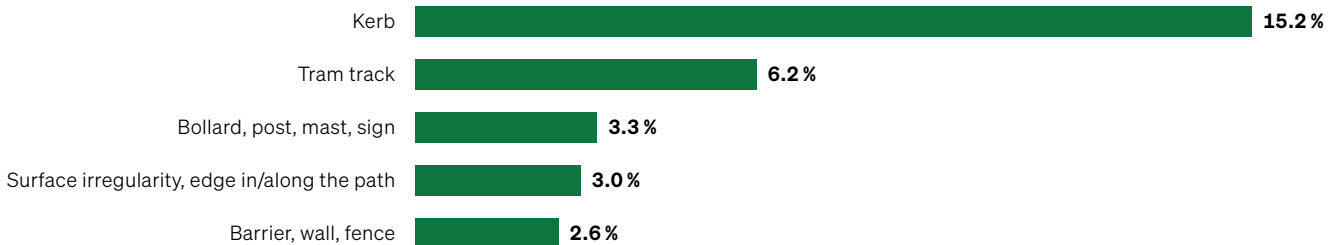
Almost half of the accidents of the surveyed cyclists happened on surfaces with reduced grip

Figure 4 · Road condition at the time of accident (data basis: single-vehicle accidents recorded by the police as well as online-survey)



Around one in 16 single-vehicle accidents is linked to tram tracks

Figure 5 · Top 5 features of the infrastructure giving rise to single-vehicle accidents according to the accident data (data basis: police-documented accident descriptions, n = 1,481)



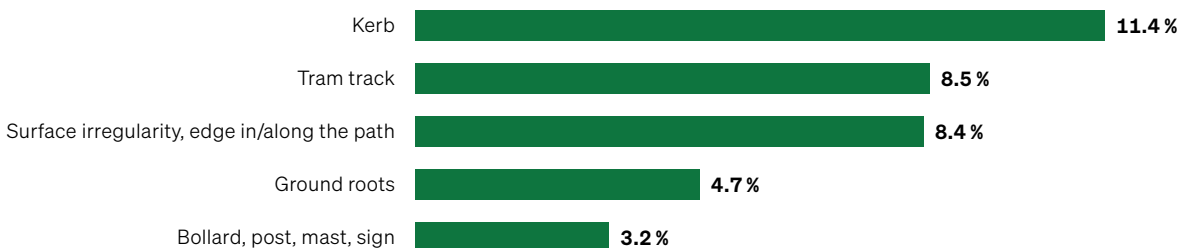
For roughly one in three accidents (36.3 %) the police-documented accident description revealed specific aspects of the infrastructure, that contributed to the accident. The diverse spectrum of documented infrastructural aspects ranges from frequently described kerbs through surface irregularities (e. g. potholes) to rarely contributing elements like ramps. Besides kerbs as the most frequently documented factor, tram tracks stand out (figure 5). Around every sixteenth single-vehicle accident of a cyclist occurs in conjunction with a tram track despite those being not as widespread in the road network. Point objects like bollards or signposts on the other hand are only of secondary importance. They are recorded much less frequently despite their widespread occurrence.

Single-vehicle accidents with kerbs mainly occur when transitioning from the carriageway to the sidewalk area (50.7 % of the kerb accidents) and when touching the kerb in longitudinal traffic (36.4 %). Accidents with tram tracks occur mainly along stretches of road between junctions (63.0 %) and less frequently (37.0 %) at junctions themselves.

The surveyed cyclists also stated kerbs and tram tracks as the main features of the infrastructure related to their single-vehicle accidents (figure 6). Surface irregularities play a greater role than in the police-recorded accidents, point objects are similarly inconspicuous.

According to the surveyed cyclists, surface irregularities also play a major role

Figure 6 · Top 5 features of the infrastructure giving rise to single-vehicle accidents according to the surveyed cyclists (data basis: online-survey, n = 1,521)



4.4 Accident-promoting aspects of the bicycle

On the side of the bicycle, pedelecs in particular and the handling of them have the potential to cause and aggravate accidents. The more frequent occurrence of serious injuries in single-vehicle accidents involving pedelecs is not only due to the increased use of pedelecs by senior citizens and the higher likelihood for more serious injuries at older age. A higher proportion of serious injuries among the riders of pedelecs can also be observed in younger age groups (figure 7). The fact that pedelecs place higher demands on the rider is reflected in some increased proportions of individual accident causes of improper driving behaviour (e. g. over-braking) in the sub-collective of single-vehicle accidents with pedelecs.

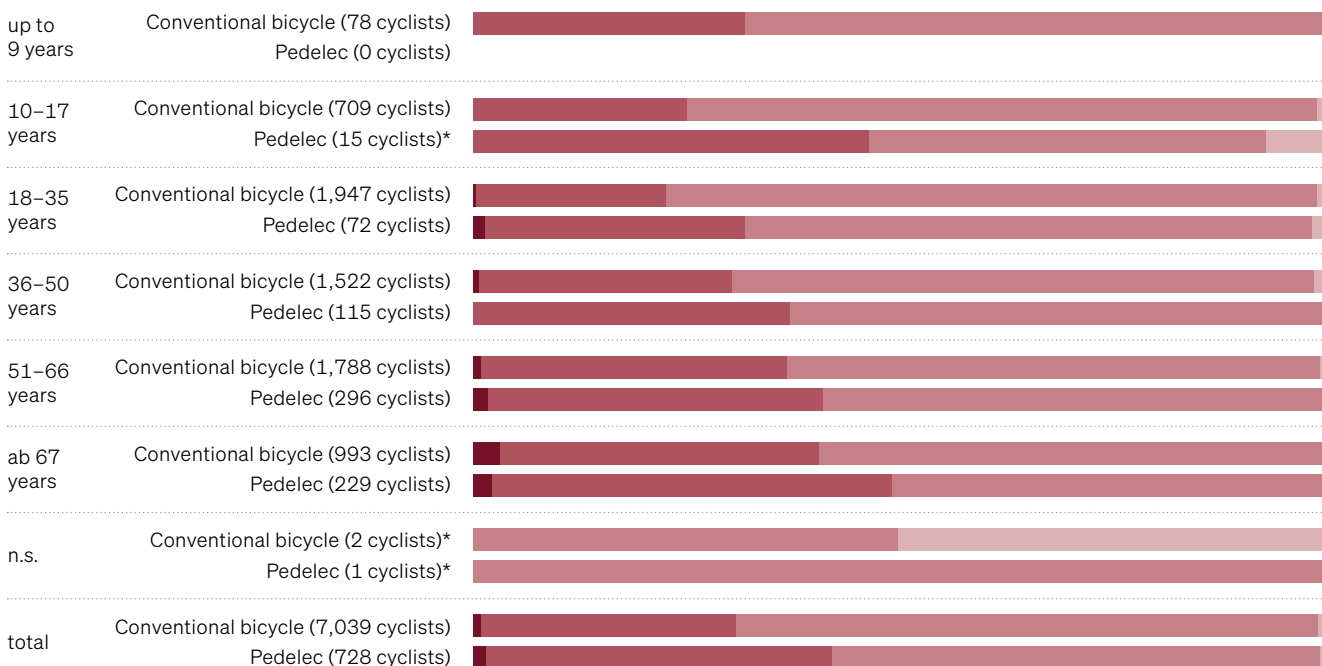
The surveyed cyclists who experienced a single-vehicle accident with a pedelec consider the higher weight and the higher speed to be potentially accident-promoting. The higher acceleration as well as the more demanding braking, steering and driving behaviour are also seen as factors that may contribute to a fall with a pedelec.

Technical defects are only of minor relevance. Only in 3.1 per cent of the 7,767 single-vehicle accidents recorded by the police did defective brakes, tyres or other components play a role. The police-documented accident descriptions speak of defects similarly rarely (3.6 % of the 1,481 accident descriptions) and the surveyed cyclists also only reported defective component on the bicycle in 4.4 per cent of their accidents.

Single-vehicle accidents involving pedelecs also lead to more serious injuries in younger age groups

Figure 7 · Degree of injury in single-vehicle accidents with conventional bicycles and pedelecs in comparison (data basis: single-vehicle accidents recorded by the police)

Age group and type of bicycle



● killed ● seriously injured ● lightly injured ● uninjured**

* Resilience limited due to low number of cases ** Injury of passenger defines the accident as an accident with personal injury

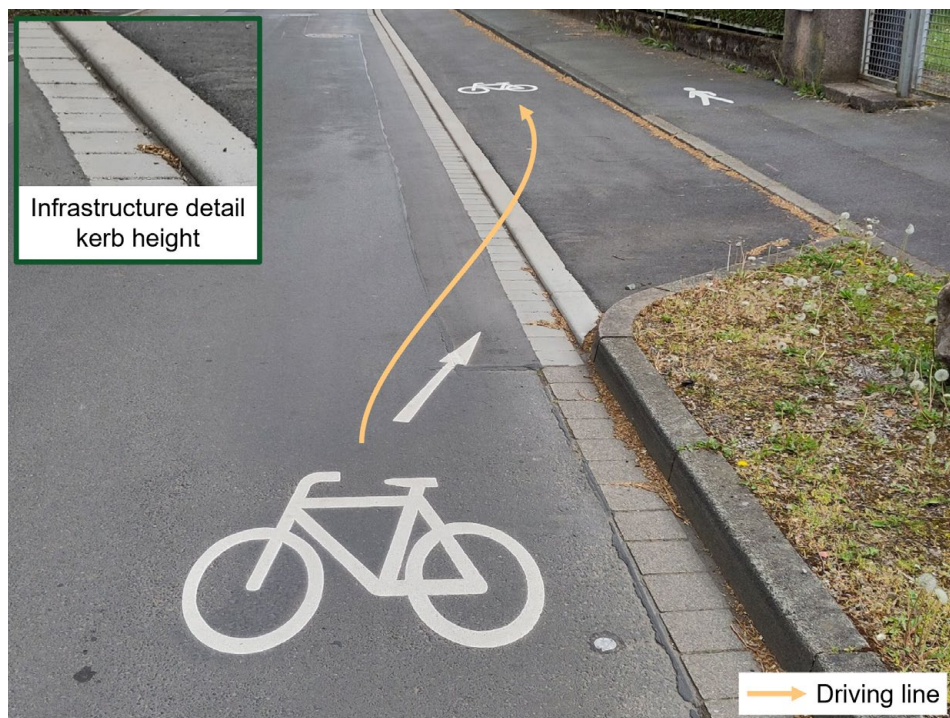
5. In-depth interviews and analysis of accident locations

The in-depth interviews of cyclists and the analysis of accident locations made it possible to derive typical situations leading up to a single-vehicle accident at noteworthy features of the infrastructure. Typical situations at kerbs and tram tracks, which were repeatedly described, are briefly illustrated below using an example.

Single-vehicle accidents at kerbs often result from a combination of small remaining kerb height and an acute approach angle of the cyclist. Occasionally reduced grip (e. g. due to wet conditions) plays an additional role. This kind of situation arises, for example, when a small remaining height difference must be crossed when changing from the carriageway to a cycle path at transition points or at drive-ways (figure 8). If cyclists ride closely along the kerb, a steep and safer approach angle of the flat kerb is hardly possible. Similarly problematic are situations with slowly rising kerbs after a reduction to zero height at a transition point. Changing to the cycle path at the transition point itself is uncritical because of the zero height, but a slightly delayed change (e. g. after overtaking a slower cyclist) can lead to another acute-angled approach of an again already existing small height difference.

Even low kerb heights pose a risk if approached at an acute angle

Figure 8 · Routing of bicycle traffic over poorly recognisable, flat kerbs



Two of three single-vehicle accidents involving tram tracks occur along stretches of road between junctions. The typical accident situation is primarily a result of narrow cross sections with vehicles parked at the edge of the carriageway and the routing of the bicycle traffic in mixed traffic (figure 9). Cyclists can ride between the tram tracks or between the outer tram track and the parked vehicles. If the cyclists decide to use the area between the tracks in favour of a safer distance to the parked vehicles, the outer tram track must be crossed. The crossing in a steeper and safer angle is a challenging task and particularly difficult at higher speeds. Contact is easily made at an acute angle, the front or rear wheel can slip into the tram track and a fall occurs. If the cyclists try to avoid the change, they ride between the outer tram track and the parked vehicles. In case of vehicle doors suddenly opening, pedestrians emerging between parked vehicles or vehicles emerging at driveways, cyclists attempt to avoid a collision by swerving into the area between the tracks. Due to the time-critical reaction required the risk of crossing the outer tram track at an acute angle is especially high. At junctions, a risk of crossing over tram tracks in an acute angle is also present, especially when turning left directly instead of indirectly and when turning in from side roads.

Tram tracks are particularly problematic in narrow cross-sections

Figure 9 - Riding between the tracks to avoid the dooring zone and crossing over the tracks at an acute angle repeatedly leads to falls.



A surface with reduced grip can also quickly lead to a single-vehicle accident. Particularly in autumn and winter cyclists fall more frequently on otherwise safe sections of the infrastructure because the front or rear wheel slips on wet leaves or at slippery spots. Slippery patches due to ice are often tightly confined spots in the shade. Here, freezing wetness occurs more quickly, the icy patch is unexpected and noticed too late by the cyclists, especially at higher speed.

6. Conclusions and recommendations

The results of the study show the increasing relevance of single-vehicle accidents of cyclists and the need for action. Since the mid-2010s in particular, the number of single-vehicle accidents with personal injury has increased considerably and those accidents are today responsible for a significant proportion of cycling accidents in the federal accident statistic. Because of the high number of unreported cases the federal accident statistic only records a fraction of the accidents. The importance of single-vehicle accidents is therefore even greater than it might seem according to the already conspicuous numbers in the federal statistic.

The study was able to identify aspects of the human behaviour, the infrastructure as well as the bicycles that are giving rise to the increasing number of single-vehicle accidents. In the case of the infrastructure, an accident-promoting effect of certain features of the infrastructure also results from a combination with the behaviour of cyclists and the way they use the infrastructure.

The single-vehicle accidents recorded by the police are primarily caused by the behaviour of the cyclists. Driving with inappropriate speed or improper driving behaviour (e. g. over-braking) are important accident causes. Driving under the influence of alcohol as the accident cause is particularly noticeable in the police data, with around one in six recorded single-vehicle accidents being an alcohol-related accident. According to the surveyed cyclists, however, alcohol consumption as the cause for the accident is of less relevance (every twenty-fifth accident). Accidents due to distraction or inattention are rare in the cases recorded by the police. Based on the survey, general inattention is definitely relevant, whereas distraction by technical devices is of lesser importance. Although the surveyed cyclists refer more frequently to the infrastructure than their own behaviour as the main cause for their accident, they often describe improper behaviour in connection with the accident such as riding at inappropriate speeds or general inattention.

However, in roughly one in three cases recorded by the police the single-vehicle accident is at least also partly caused by infrastructural features. Kerbs and tram tracks are the most prominent features documented. With kerbs, approaching it in an acute angle when changing from the carriageway to a cycle path or the sidewalk area is particularly dangerous – even with low kerb heights. For tram tracks, crossing them in an acute angle is also the main problem, both along stretches of road between junctions and at junctions themselves. The statements from the surveyed cyclists confirm kerbs and tram tracks as the most relevant features of the infrastructure that are giving rise to single-vehicle accidents. Point objects like bollards or signposts rarely play a role in the accidents, they are seldomly documented by the police or stated by the surveyed cyclists. A surface with reduced grip contributed to the accident in about half of the cases in the online survey.

Pedelecs show some specific anomalies. The proportion of serious injuries is higher in single-vehicle accidents with pedelecs than in those with conventional bicycles. This is not only the case for older but younger cyclists as well. In addition to that, single-vehicle accidents with pedelecs show a slightly higher proportion in causes related to the more demanding handling of the bicycle. The technical condition of the bicycles is rarely relevant for single-vehicle accidents, defects only have an accident-promoting effect in small number of cases.

The following measures are recommended to counteract single-vehicle accident of cyclists and a further steep increase.

- Cyclists must be guided with clear and easy to understand solutions so they can recognise without doubt where drivability is given and where this is not the case. This applies in particular to transition points between carriageway and a cycle path or the sidewalk area and at junctions.
- At transition points between carriageway and cycle paths or the sidewalk area the kerb height should be reduced to zero, even a small remaining height differences should be avoided.
- Cyclists should be guided as right-angled as possible across tram tracks and not in immediate vicinity of them along stretches of road between junctions. At junctions indirectly turning left lends itself allowing for safer crossing angles. Along stretches of road between junctions the distance between cyclists and the tram tracks should be sufficiently large so the tracks don't have to be crossed, not even to avoid potential dangers along the side of the road. This may necessitate a reduction in parked vehicles along the road.
- The maintenance and cleaning of the infrastructure as well as winter services are of vital importance. The cleaning is especially relevant in autumn to counteract effects associated with lying leaves like the concealment of small height differences or of damage and reduced grip. The maintenance of the cycling infrastructure should focus on maintaining an even and grippy surface and fixing damage (e. g. due to roots).
- The awareness regarding the correct and safe infrastructure use as well as the consequences of improper behaviour should be raised through suitable campaigns. The former applies in particular with regard to the approach of height differences and the crossing of tram tracks in steep angles. The latter in particular with regard to speeding or inattentive driving as well as driving under the influence of alcohol. This kind of awareness raising measures is especially important for novice cyclists.
- When purchasing a pedelec, it is advisable to take a course on safe driving to familiarise oneself with the heavier bicycle and stronger acceleration in a safe and controlled environment.
- It would be desirable to fit heavier and faster bicycles like pedelecs with an anti-lock braking system (ABS) to prevent over-braking and improve the controllability of these bicycle models. This is especially important for inexperienced cyclists.
- To counteract accident black spots of single-vehicle accidents, those black spots in the road network must be known. It would therefore be desirable to, in particular, document accidents with serious injuries in the context of medical treatment in hospitals and to hand over collected data to local authorities.

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