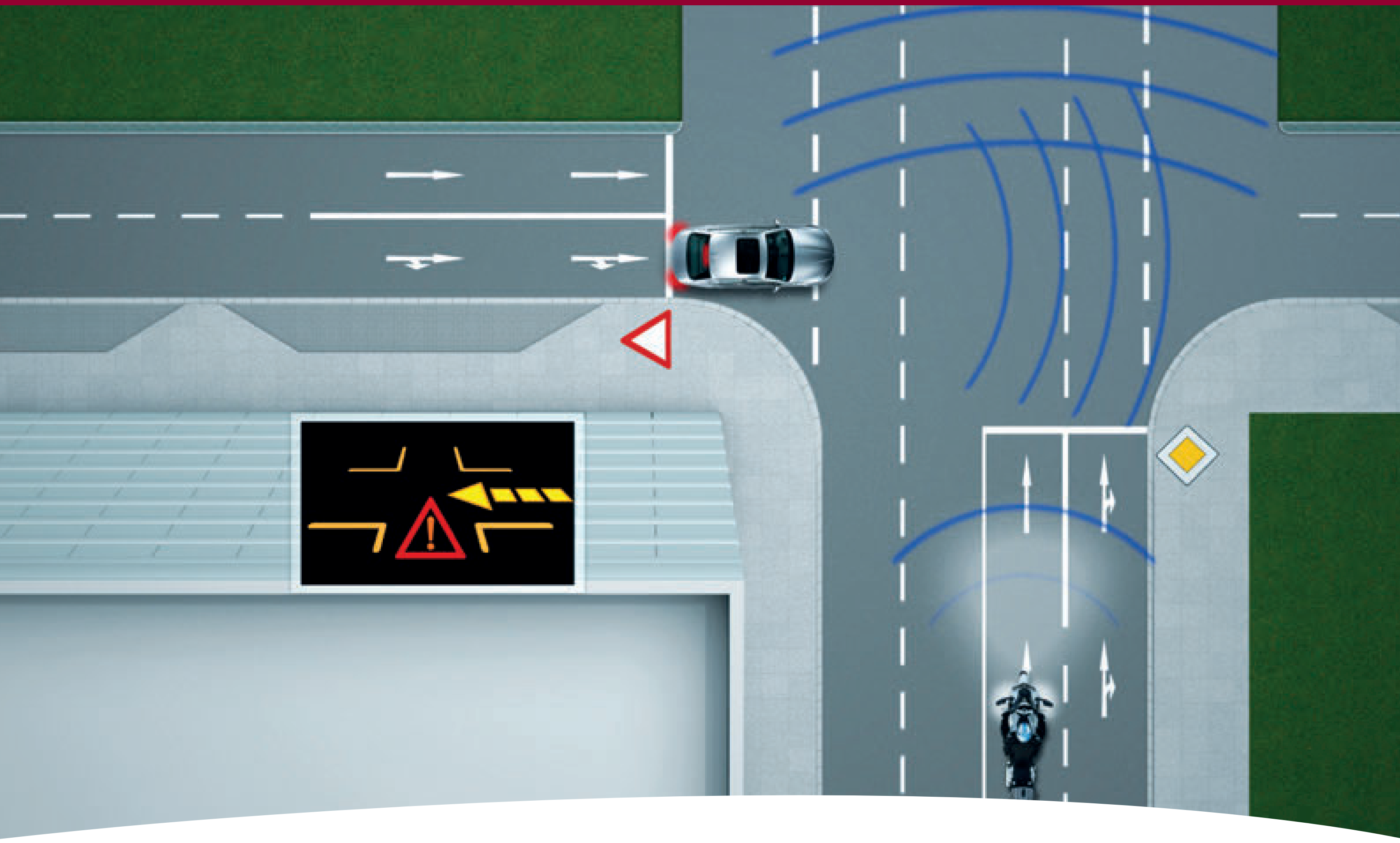


# Intelligent systems for improving motorcycle safety

## Compact accident research

Unfallforschung der Versicherer
GDV

# Contents

# Preliminary remarks

Riders of powered two wheel vehicles (PTWs) are at particular risk of having an accident on the roads. The German Insurers Accident Research (UDV) has investigated accidents involving PTWs in a number of projects and found that, as things stand, there is little technology available for preventing or mitigating the effects of accidents involving mopeds and motorcycles.

UDV therefore investigated which future developments could have a positive impact on accident statistics. Experts talk about intelligent transport systems (ITSs) in this context. This term is used to refer to all information and communication technology systems in the road transport sector that make a significant contribution to reducing the impact of vehicles on the environment and improving efficiency and road safety. For the purpose of this study, they are considered as intelligent safety systems that can, for example, exchange information with the environment in order to improve the safety of PTWs. The vehicles range from mopeds limited to 25 km/h to high powered motorcycles. Taking the official accident statistics as a basis, the accidents were analyzed in detail using the insurers' accident database. In the next step, conceivable intelligent safety systems were specified and the best ones were selected for each accident. Finally, the most promising systems for PTWs were evaluated.

When the statistics for fatalities by modes of transport are compared for the years 1996 and 2016 (Figure 1), it can be seen that the percentage of fatalities among riders of PTWs has increased by nearly 70 percent. During the same period, the share of car occupants killed has fallen by around 15 percentage points. With regards to the absolute numbers of fatalities in both groups, fatalities among car occupants have fallen by 73 percent since 1996 while fatalities among riders of PTWs have only fallen by 38 percent.

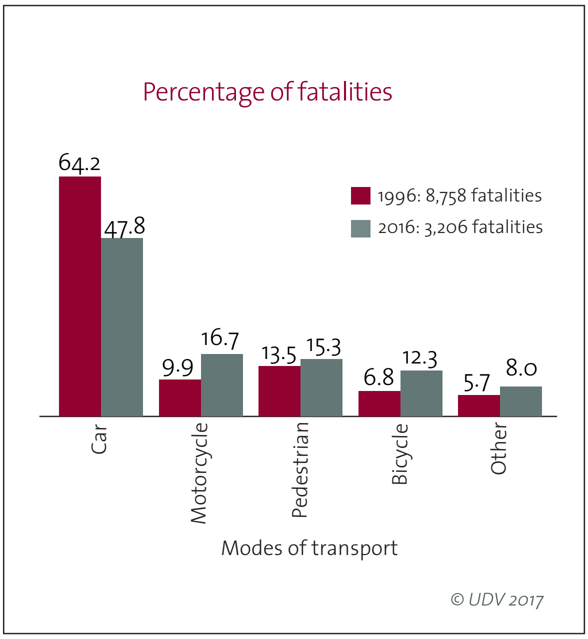



*Figure 1: Percentage of fatalities accounted by modes of transport 1996 and 2016; Source: German Federal Statistical Office (1997 and 2017)*

## Essential aspects of accidents involving PTWs

According to the official statistics for accidents involving powered two wheel vehicles (PTWs) in 2016 (shown in Figure 2), 28 percent of these accidents were single-vehicle accidents and 66 percent of them involved two road users. The rider of the PTW was the primary cause in one third of the accidents involving two road users.

If the single-vehicle accidents are taken together with the accidents involving two road users that were caused by the rider of the PTW, it can be stated that 54 percent of all accidents involving no more than two road users were primarily caused by the rider of the PTW. The official statistics for 2012 also show that 61 percent of all accidents in which the rider of the PTW was killed were caused by the rider.

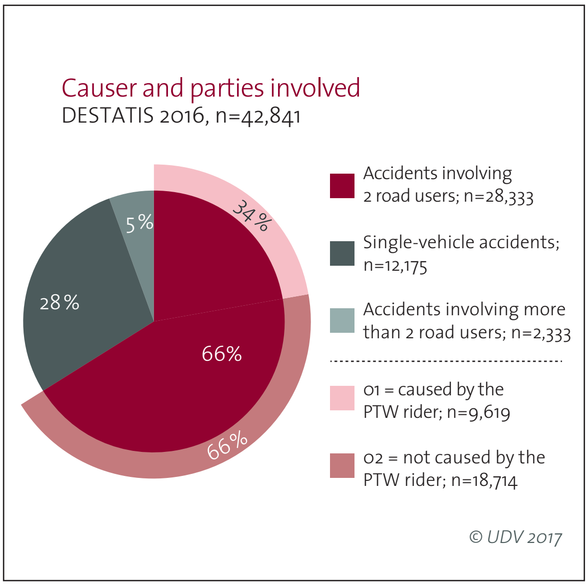



*Figure 2: Accidents involving PTWs and personal injury, subdivided on the basis of which road user primarily caused them, official statistics for 2016; Source: German Federal Statistical Office (2017)*

To identify the most frequent scenarios, single-vehicle accidents and accidents involving two road users were analyzed, subdivided on the basis of who primarily caused them, as recorded in the insurers' accident database (UDB). The analysis is based on the results presented in research report FS03 on driver assistance systems published in 2011 [1] and the compact accident research No. 45 from 2014 [2] and was updated in 2017.

The underlying accident data material from the years 2002 to 2012 consists of 1,179 accidents involving PTWs, 69 percent of which were motorcycles, 20 percent mopeds and 11 percent light motorcycles of 50cc to 125cc. From these accidents the main accident scenarios for PTWs were obtained.

The UDB accident material contains third-party motor insurance claims involving personal injury and damage costs of at least 15,000 euros. This underestimates the number of single-vehicle accidents, since these only appear in the accident material when a third party (such as a pillion passenger) has been injured.

There were 116 accidents available in the UDB for the analysis of **single-vehicle accidents**. It became clear (Figure 3) that 47 percent of all single-vehicle accidents happened as a result of a fall onto the road. A typical example would be loss of control of the motorcycle on an uneven, wet or contaminated road surface.

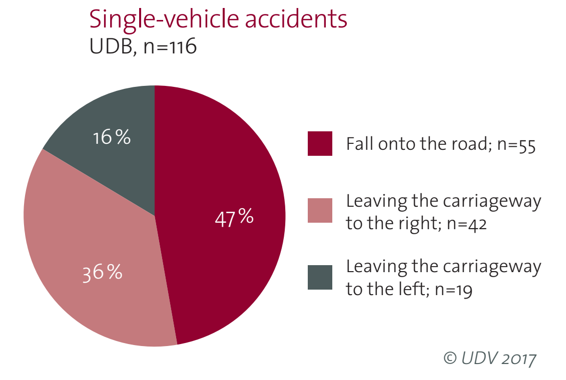



*Figure 3: Most common accident scenarios in the UDB for single-vehicle accidents involving PTWs, based on UDB-analyses*

Leaving the carriageway to the right (36 %) and left (16 %) were the second and third most common scenarios. These two scenarios were characterized by inappropriate speed in bends and unfavorable weather conditions.

There were **420 accidents involving two road users and caused primarily by the rider of the PTW** available in the UDB (Figure 4). The most frequent scenario was a collision with an oncoming vehicle (41 %), followed by a collision with a vehicle traveling in the same direction (22 %) and a collision with a vehicle coming from the right (14 %). Further scenarios were a collision with a vehicle that was stationary, parking or stopping for traffic (10 %) and a collision with a vehicle coming from the left (8 %).

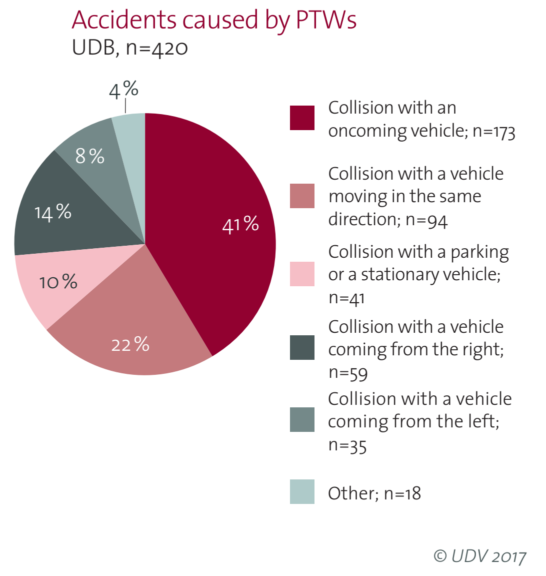



*Figure 4: Most common accident scenarios in the UDB for accidents caused by PTWs, based on UDB-analyses*

There were 643 **accidents involving two road users not caused primarily by the rider of the PTW** available for analysis in the UDB (Figure 5). From the perspective of the road user who primarily caused the accident, the two most common scenarios were a collision with a PTW coming from the left (30 %) and a collision with an oncoming PTW (also 30 %). These scenarios were followed by a collision with a PTW traveling in the same direction (21 %) and a collision with a PTW coming from the right (16 %)

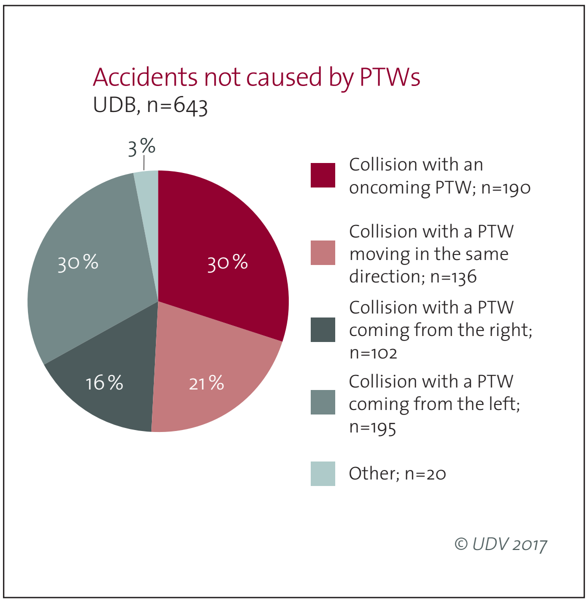



*Figure 5: Most common accident scenarios in the UDB for accidents not caused by PTWs, based on UDB-analyses*

## Comprehensive analysis of the measures

The measures for increasing the safety of PTWs can be subdivided into the categories of active and passive safety and into the sub-areas of vehicle, rider and road (Table 1 on page 8).

The use of new vehicle concepts such as the three-wheel chassis could help the rider by reducing the risk of falling and increasing the braking forces that can be be applied.

The anti-lock braking system (ABS), which has been mandatory since 2016/2017 for motorcycles of 125cc or over, is only available at leading manufacturers for light motorcycles of 50cc to 125cc [3]. ABS is not available for mopeds, at all. Motorcycles have been increasingly equipped with the system since the mid-2000s. However, an ABS that was suitable for cornering did not enter the market until 2014: the motorcycle stability control (MSC) from Bosch [4].


*Figure 6: Example of a new vehicle concept: the BMW Advanced Safety Concept motorcycle [5]*
*Source: BMW*

**Comprehensive analysis of the measures**

*Table 1: Options for improving safety, taking into account vehicles, riders and roads*

| | Active safety | Passive safety |
|---|---|---|
| **Vehicle** | **Chassis, brakes, lighting, ADAS, ITS collision warning systems, HMI**<br><br>• New chassis concepts (e.g. three-wheeled Piaggio MP3)<br>• Dynamic traction control with tilt recognition<br>• ABS with braking in bends<br>• Improved lighting systems (xenon light, daytime running light)<br>• Speed limit information<br>• Assistance systems in longitudinal traffic (overtaking assistant, collision warning system, curve assistant, left-turn assistant)<br>• Assistance systems for traffic coming from the side (intersection assistent)<br>• Vehicle-to-vehicle communication (simTD)<br>• Human-machine interface (HMI) | **Restraint systems, ITS**<br><br>• Safety cell and belt (see BMW C1)<br>• Airbag<br>• Automatic fall recognition and emergency calling |
| **Rider** | **Training**<br><br>• E-learning<br>• GermanSafetyTour (in real traffic)<br>• New findings from naturalistic riding studies | **Protective clothing**<br><br>• Active protective clothing and helmet |
| **Road** | **Improvement of accident black spots through road layout and ITS**<br><br>• Leaflet on the improvement of road safety on motorcycle routes (MVMot)<br>• Vehicle-to-infrastructure communication (simTD) | **Improvement of the space at the side of the road with motorcycle-friendly safety features**<br><br>• Crash barriers with underrun protection (MVMot)<br>• Alternatively earth walls |

The example of a new vehicle concept shown in Figure 6 on page 7 includes pioneering ITS systems that improve vehicle safety.

Active protective clothing, in the form of airbag jackets and airbag helmets, has been available since about the year 2000. However, the level of market penetration of this smart protective clothing is still low.

The leaflet on the improvement of road safety on motorcycle routes (MVMot) [6] is worth reading for insights into how road-related safety aspects could be improved. In the future, safety could also be improved by vehicle-to-infrastructure communication.

## Fundamentals for the evaluation of the ITS technologies

The following generic safety systems were defined for the assessment of ITS technologies:

- **Dynamic stability control** – consists of an advanced ABS and stability programs that are suitable for cornering and that also permit braking and acceleration when the vehicle is tilted at an angle.
- **Curve warning assistant** – warns the rider of the PTW when approaching a bend if the speed is too high to negotiate the bend safely and suggests a safe speed.
- **Overtaking assistant** – when the rider intends to make a lane change or to turn left, the assistant issues a warning if there is another road user traveling in the same direction and currently in the process of overtaking.
- **Oncoming traffic assistant** – warns the rider about any oncoming vehicles when overtaking.
- **Turning assistant** – warns the rider about any overtaking or oncoming vehicles when turning.
- **Collision warning system** – warns the rider about a possible collision with a vehicle traveling in the same direction on the road ahead when the rider is approaching.
- **Intersection assistant** – warns the rider at an intersection/junction/entrance about a vehicle on collision course that may not yet be visible.
- **Left-turn assistant** – warns the rider about any oncoming vehicles on collision course when turning left.

To evaluate the relevance of the safety systems, the 1,179 individual accidents described in Chapter 1 were analyzed. Since several systems may be effective in any one case, it was decided that only one system could be used per accident, even if a number of systems would address the accident. Only the system that promised to be most effective was selected for the assessment. The influence of the driver's behavior was not investigated.

The most promising systems were then evaluated based on the frequency with which they were selected for the different accident scenarios. Since single-vehicle accidents are underrepresented in the UDB because the insurance company is only notified if there is injury or damage to a third party, this also affects the evaluation of the systems. It means that the ITS systems that are effective in single-vehicle accidents are also underrepresented.

The benefits of ITS technology have already been demonstrated in a number of projects:

In the **SAFERIDER** project, for example, the effectiveness of ITS technology in the form of assistance systems for PTWs for both active and passive safety was clearly shown (e.g. a curve warning assistant and the eCall automatic emergency call system) [7].

In the national research project **simTD**, it was demonstrated in a large-scale field trial, and taking into account the infrastructure and a wide variety of vehicles including motorcycles, that vehicle-to-X communication is practical (e.g. an intersection assistant). The left-turn assistant for motorcyclists was found to have the potential to prevent large a number of accidents [8].

Fall recognition with automatic emergency calling was found to be of great benefit in the **MOSAFIM** project [9].

## Evaluation of the ITS technologies

The accidents described in Chapter 1 were examined by analyzing individual cases to ascertain whether the specified generic ITS systems would have had a positive effect on them. A system was regarded as effective in the specific scenario if it would have been able to prevent the accident or mitigate the consequences of the accident.

It was found that 59 percent of all **single-vehicle accidents** (Figure 7) could have been addressed by a curve warning assistant. The dynamic stability control came second with 18 percent. None of the systems specified in Chapter 3 was considered to be reliably effective for the remaining 23 percent of the accidents.

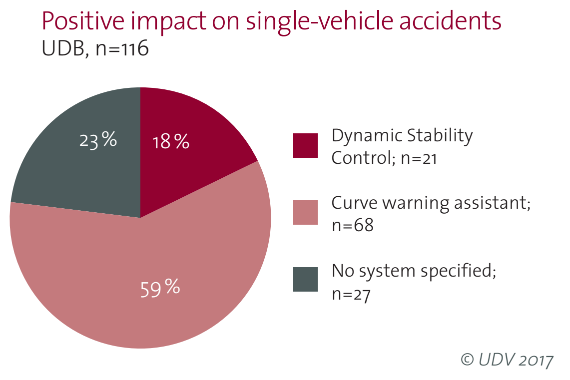
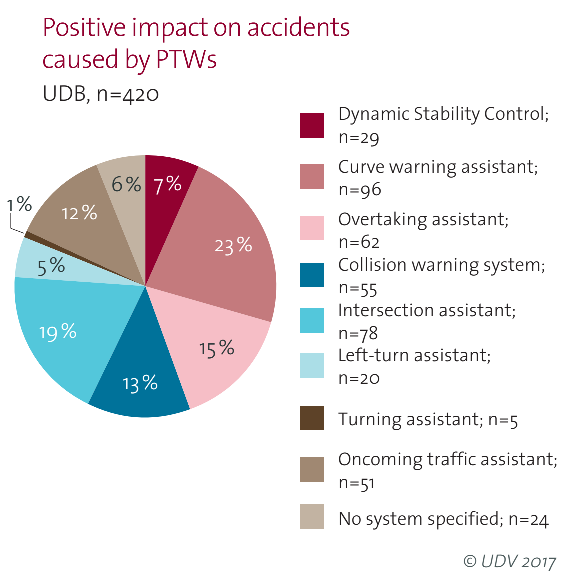



*Figure 7: Positive impact of ITS systems on single-vehicle accidents involving PTWs*

A further ITS system, the **eCall** automatic emergency calling system for motorcycles, is currently under discussion [10]. This helps to reduce the response time for the police or rescue services when riders are not able to make an emergency call themselves. This system could be helpful for single-vehicle accidents, in particular. However, the system can only be assumed to be of direct benefit if there is no other road user at the scene who is able to make an emergency call. In this connection, a UDV study of motorcycle accidents in the German federal state of Saarland found that eCall would have been effective in 15 percent of crashes with MAIS 3+ injuries, and up to 35 percent of crashes with minor injuries of all single-vehicle accidents [11]. Based on the figures shown in Figure 2 on page 5, this would mean that automatic emergency calls would have had a positive effect on around 4 percent up to 10 percent of all accidents involving personal injury in 2016 in Germany. These figures match with 310 relevant accidents out of 4,052 (7.7 %), found in the EU project I_HeERO [12].

**In accidents involving two users caused primarily by the rider of the PTW** (Figure 8), the curve warning assistant was found to have the greatest potential and would have been effective in 23 percent of the cases. This was followed by the intersection assistant (19 %), the overtaking assistant (15 %), the collision warning system (13 %) and the oncoming traffic assistant (12 %). The dynamic stability control was the most effective option in 7 % of the cases. The left-turn assistant (5 %) and turning assistant (1 %) were also found to have potential. None of the ITS systems analyzed were deemed to be effective for the remaining 6 percent of the accidents.

► *Figure 8: Positive impact of ITS systems on accidents caused by PTWs*



The assessment of **accidents involving two road users that were not caused by the rider of the PTW** (Figure 9) indicated a positive effect on 37 percent of the accidents for the intersection assistant. The left-turn assistant would have had a positive effect on 23 percent of the accidents, followed by the overtaking assistant (15 %). Further positive effects would have been obtained with the turning assistant (5 %), the collision warning system (also 5 %), the oncoming traffic assistant (3 %), the dynamic stability control (also 3 %) and the curve warning assistant (1 %).

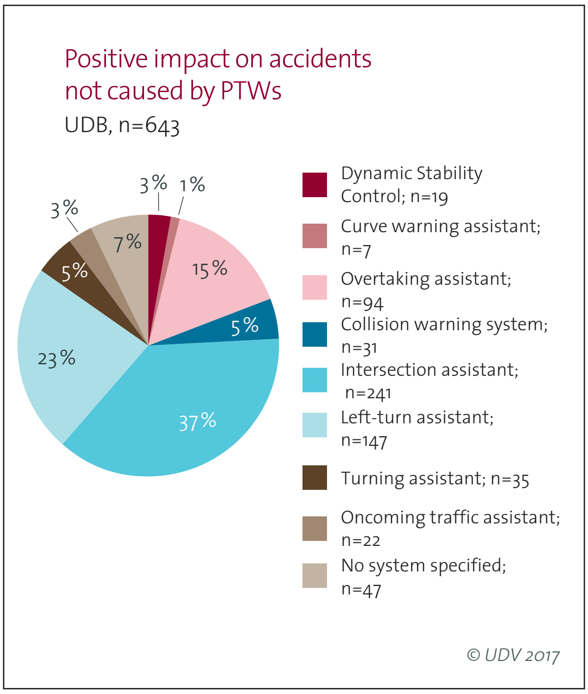



*Figure 9: Positive impact of ITS systems on accidents not caused by PTWs*

## Ranking of the most promising systems

The specified systems are ranked below on the basis of the frequency with which they are selected for the 1,179 UDB accidents investigated. The ITS systems mirror the accident scenarios.

Figure 10 on page 12 shows that systems that warn about crossing traffic can have a positive impact on more of the accidents examined than any other kind of system. The curve warning assistant is most effective in the case of single-vehicle accidents and accidents involving two road users caused by a PTW. Since single-vehicle accidents are underrepresented in this study, the systems identified as effective would be even more effective in reality. The left-turn assistant, which was implemented as a prototype in simTD, and the overtaking assistant are also highly relevant. These four systems should therefore be implemented as soon as possible.

The dynamic stability control would certainly have a positive impact on most scenarios. However, due to the selection of only the most effective system for each accident, the benefits cannot be clearly highlighted.

The four ITS systems discussed above are of equal relevance for PTWs above 125cc, as the differentiation between PTWs up to 125cc (mopeds+light motorcycles) and PTWs above 125cc (motorcycles) shows. The oncoming traffic assistant is an important system, as well (Figure 11 on page 12). For PTWs up to 125cc, the intersection assistant excels all other systems. With fewer than half of the positive effected accidents, the overtaking assistant ranks second. This mirrors the different usage and thus the different accident scenarios of the two PTW classes.

**Ranking of the most promising systems**

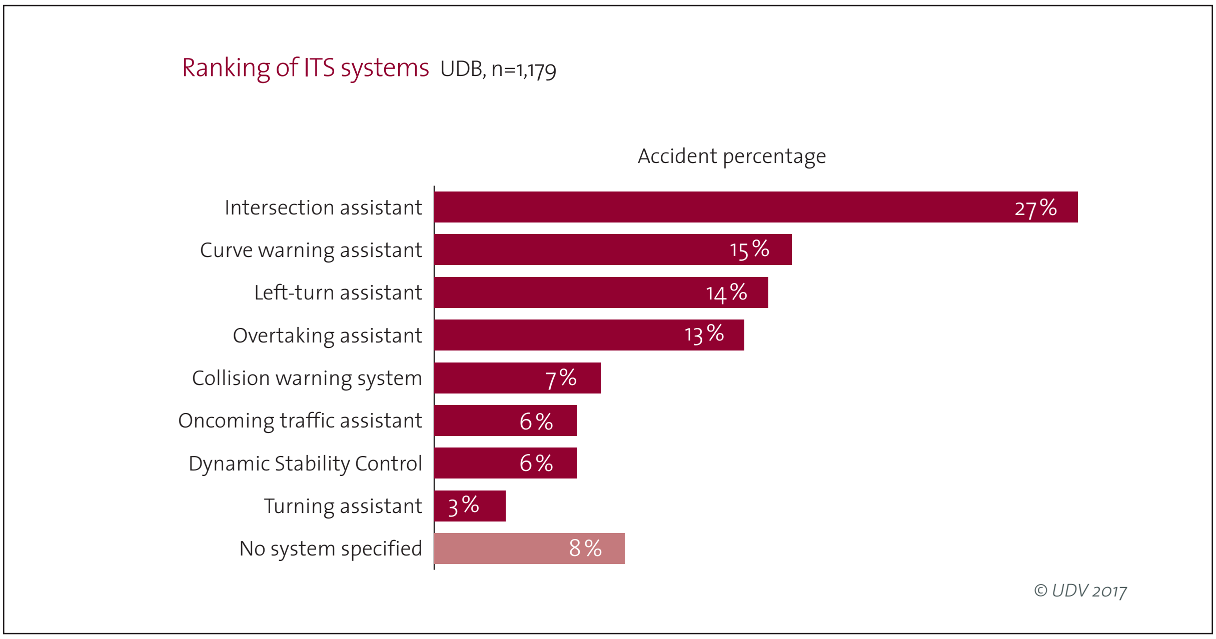



*Figure 10: Ranking of the most promising systems*

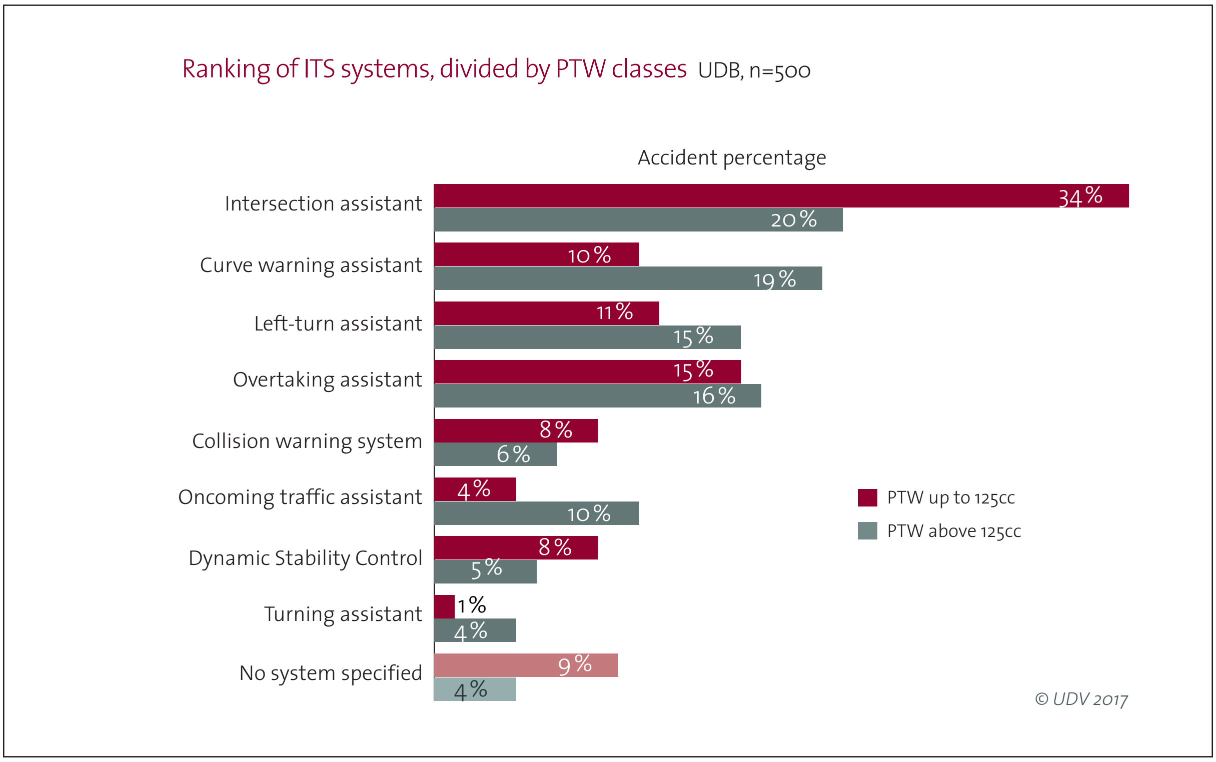



*Figure 11: Ranking of the most promising systems, divided by PTW classes*

## Summary of results

An analysis was carried out on a theoretical level to ascertain whether the use of ITS systems would have a positive impact on accidents involving powered two wheel vehicles and thus improve safety on the roads.

It was found that the specified ITS systems for powered two wheel vehicles are capable of having a positive effect on safety. The four most highly ranked systems address over two-thirds of all accidents. These are the intersection assistant, the curve warning assistant, the left-turn assistant and the overtaking assistant. In order to put more precise figures on the improvements in safety brought by these highly promising systems, in-depth studies are required. This applies, in particular, to single-vehicle accidents, which are underrepresented in this study.

When developing ITS systems for powered two wheel vehicles, it is crucial to devote particular attention to the human-machine interface in order, for example, to avoid distracting riders and to increase the degree to which these systems are accepted by riders. The distinctive nature of riding powered two wheel vehicles has to be taken into account, since riding a single-track vehicle is very different from driving a car.

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