CMC Basic Specification

Assessment of C-ITS application potential

Identify which accident scenarios are critical for the safety of powered two-wheeler and derive the resulting use cases for connectivity solutions.

Document Information

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Disclaimer

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1 Background

Road accidents kill someone every 24 seconds, with a total of 1.35 million traffic deaths around the world each year[1]. With a 28% share, riders and passengers of Powered Two Wheelers (PTWs) have established their second position in this group of fatally injured road users. A detailed analysis of accident statistics reveals that the decline in the rate of fatally injured persons on motorcycles has begun to stagnate in re-cent years.

The current technical possibilities that are available to address this challenge and improve the safety level of motorcycle riders are very limited. Technical systems like intelligent driving dynamic control and/or rider information systems mainly address single vehicle accidents. However, in most of the powered two-wheeler (PTW) accidents, other participants (often cars) are involved and these road users are often the main accident causer. According to the MAIDS report[2], 72% of collision accidents caused by other vehicles is due to perception failure.

Based on real traffic accidents from GIDAS (German In-Depth Accident Study), a study to evaluate the potential of future Cooperative Intelligent Transport Systems (C-ITS) for PTWs was made; these advanced safety systems could tackle the challenge of increasing the safety level of PTWs in the future.

2 Analysis of PTW accidents

PTW riders are categorized as Vulnerable Road Users (VRU), therefore deserving particular attention from other vehicle drivers. But PTWs are sharing the same roads with similar speeds to cars and are a special case as VRU when it comes to C-ITS technology.

The most common collision accident scenarios with a PTW and another vehicle (e.g. car / bus / truck), are at intersections and turns. One of the main causes for these accidents is perception failure.

Figure 1 shows an example of how difficult it is to recognize the presence of a small vehicle; they blend into the background and are overlooked easily. However, even if noticed, misjudgements in distance and speed are possible.

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[1] World Health Organization (December 2018). *Road accident deaths swell to 1.35 million each year: WHO* (https://www.enca.com/news/road-accident-deaths-swell-135-million-each-year-who, *accessed on 02.11.2020)*

[2] ACEM, In-Depth Investigation of Motorcycle Accidents, Version 2.0 of the MAIDS report (http://www.maids-study.eu/pdf/MAIDS2.pdf, accessed on 27.11.2020)

Figure 1: A PTW rider who is partially covered by a car driving in front

As stated before, the German national traffic accident statistics from 2017 indicates that the number of fatally injured persons on PTWs stagnates recently. The Figure 2 shows the change in numbers of fatally injured road users in Germany between 2000 and 2017 (basis 100% = year 2000).

Fatally injured road users in Germany 2000 - 2017
(relative figures / year 2000 = 100%)
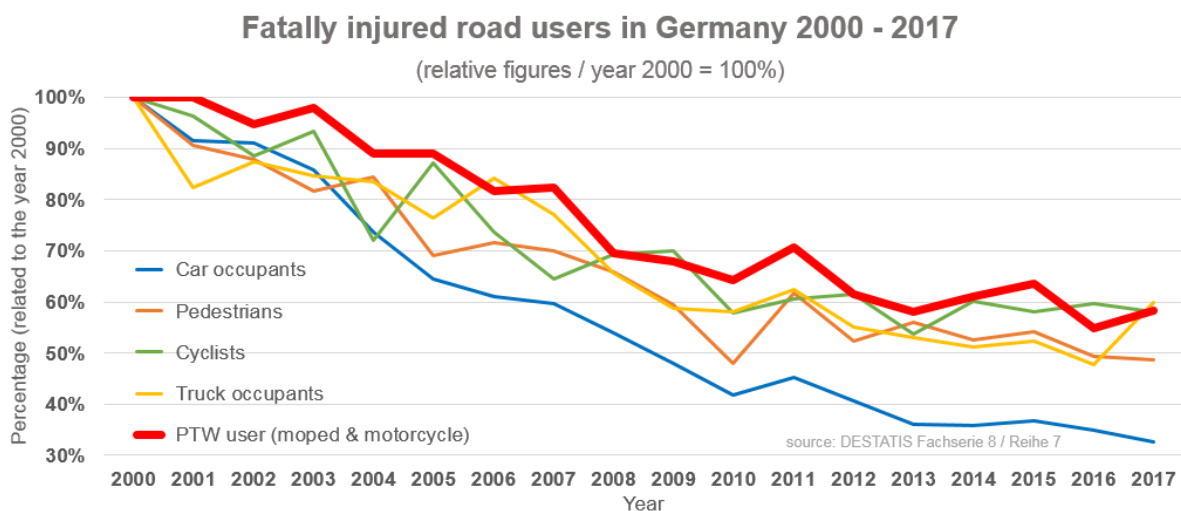
Figure 2: Development of the reduction of fatally injured road users in Germany [3]

The largest reduction of fatally injured road users was achieved for car occupants with -67% between 2000 and 2017. Fatally injured pedestrians show the second largest reduction with -51%. PTW users, cyclists and truck occupants have similar reduction rates with -40 to -42%. The group PTW user includes moped/motorcycle rider and passengers.

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[3] Christian Massong [BMW Motorrad], Marcus Petzold [VUFO GmbH] et.al. (October 2018). CMC-Roadmap: Motorcycles on Track to Connectivity & Evaluation of the Potential of C-ITS for Motorcycles on the Basis of Real Accidents (https://www.ifz.de/wordpress/wp-content/uploads/2018/10/ifz_Forschungsheft_18_Abstracts.pdf, accessed on 02.11.2020)

Table 1 shows the absolute numbers and the relative change of fatally injured road users in Germany from 2016 to 2017.

Table 1: Change of the fatally injured road users in Germany from 2016 to 2017

Road users	fatally injured road users		Change	
	2016	2017	absolute	Percentage
Car occupants	1.531	1.434	-97	- 6,3%
Motorcyclists	536	583	47	+ 8,8%
Pedestrians	490	483	-7	- 1,4%
Cyclists	393	382	-11	- 2,8%
Truck occupants	133	167	34	+ 25,6%
Moped users	68	59	-9	- 13,2%
PTW user (motorcycle & moped)	604	642	38	+ 6,3%

Source: DESTATIS Fachserie 8 / Reihe 7

Truck occupants showed the highest relative increase, however, based on low absolute numbers. The group of PTW users established their second position in the group of fatally injured road users with nearly 600 fatalities. Reasons for this development may be the increasing number of registered PTWs in Germany (+2%) as well as meteorological influences. The numbers of fatally injured car occupants, cyclists and pedestrians show slightly decreasing numbers between 1 and 2%. The highest declination could be found for moped riders/passengers with -13% (again based on low absolute numbers, which heavily affects the change in percentage).

3 Estimation of motorcycle accidents with C-ITS system

3.1 Accident scenarios involving PTWs

In order to evaluate future C-ITS for PTWs, it is important to know the PTW accident scenario in detail. Therefore, the German PTW accident scenario was analysed on the basis of the in-depth accident database GIDAS and projected the results to the German national accident statistics by applying appropriate weighting procedures.

3.1.1 Scenario description

Figure 3 shows a vehicle (red car), making a left turn. The driver sees the construction vehicle (orange truck) and let it pass. The car driver probably also makes sure that the pedestrian has crossed the road. Nevertheless, the car driver overlooked the approaching PTW and an accident is likely to happen.

3.1.2 Powered Two Wheeler

With the assistance of C-ITS which a process runs in the background, the vehicles send automatically anonymous broadcasts, containing their position and other basic data. With this information, the vehicles are able to communicate. Automatic calculations accurately predict the probability of an accident.

Now, if the rider/driver (in this case the driver of the red car) chooses a path whereas the algorithm prognoses a high accident risk, the rider/driver will be informed/warned acoustically, visually and possibly also haptically, so that the person can take action and interfere to avoid the accident (C-ITS systems do not interfere automatically per se, at least the first generations will not).
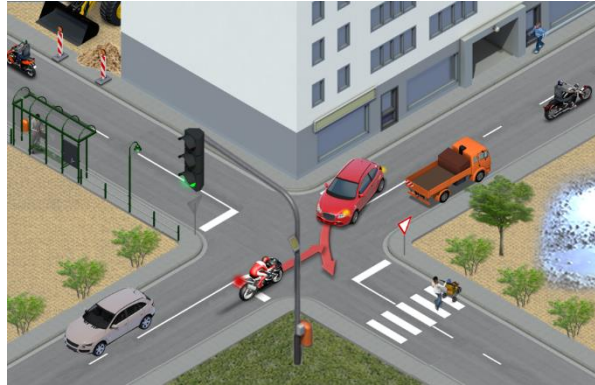
© This picture was created using the C2C-CC Illustration Toolkit, owned by the CAR 2 CAR Communication Consortium

Figure 3: Red car overlooks a PTW

© This picture was created using the C2C-CC Illustration Toolkit, owned by the CAR 2 CAR Communication Consortium

Figure 4: Red car gets a warning and stops safely

3.2 Construction of a dataset for the evaluation of C-ITS applications

The analysis is based on real accident data out of the GIDAS project (German In-Depth Accident Study). GIDAS is the largest in-depth accident study in Germany and collects data from all kinds of traffic accidents with personal damage. The advantages of this database are the extensive accident information collection (accident site, vehicle, participant, and injury), the accident reconstruction and the projected results to the German national accident statistics by applying appropriate weighting procedures. The project is funded by the Federal Highway Research Institute (BASt) and the German Research Association for Automotive Technology (FAT), a department of the VDA (German Association of the Automotive Industry).

Since 1999, the GIDAS project has collected data of more than 31.000 accidents in the areas of Dresden and Hannover. Due to the on-scene investigation and the full reconstruction of each accident, it gives a comprehensive view on the individual accident sequences and the

accident causation. In addition, representative statements with respect to the federal statistics are possible due to a well-defined sampling plan.

The used GIDAS dataset for the current analysis contains 31.634 reconstructed accidents.

3.2.1 First step in constructing the evaluation dataset

The first step for an up-to-date analysis of the PTW accident scenario in Germany was the creation of a dataset. For the dataset, the following filter criteria were used:

- Accidents must be completely reconstructed and coded
- only accidents since 2005
- Minimum one L3e[4] vehicle was involved (No moped)
- exclusion of unknown accident types

Finally, 1.964 accidents out of the GIDAS database are considered for the study.

3.2.2 Second step in constructing the evaluation dataset

To ensure representative statements for the German accident scenario the data was weighted towards the German traffic accident statistics of the year 2016. Therefore, a special analysis for L3e vehicles from the Federal Bureau of Statistics (DESTATIS) was commissioned. This step is substantial as the national German accident scenario is extremely dominated by cars. Without this special analysis from DESTATIS some data (e.g. injury severity, accident location) are biased due to external influences. As a result, the 1.964 GIDAS accidents were extrapolated to all 28.002 PTW accidents in Germany in 2016.

3.2.3 Third step in constructing the evaluation dataset

In the third step a scenario classification was done. In GIDAS, there are 295 different accident types available (according to the HUK classification of accidents), each type describes a critical situation / conflict that caused the accident. As the intended scenario classification is not feasible with 295 different accident types, an appropriate scenario classification was developed by clustering all 295 accident types into 11 main scenarios. Figure 5 shows the 11 scenarios that can be further aggregated into the two groups "Driving Accidents" and "Collision Accidents".
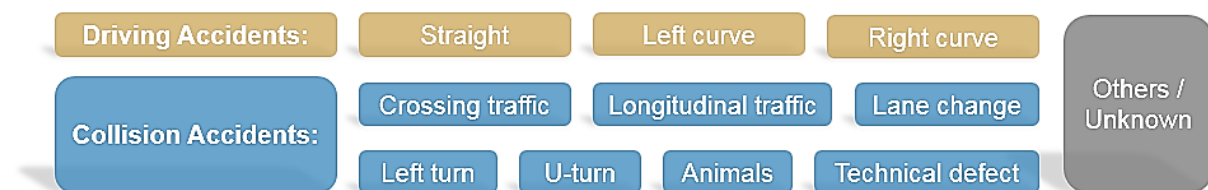
Figure 5: Accident Scenarios for PTW analysis[2]

"Driving accidents" are caused by riders that lost control of their vehicle (e.g. due to inappropriate speed, misjudgement of the course, adverse road conditions etc.). "Collision accident" means that the PTW had a conflict with another road user (e.g. a car, bus, truck or another PTW, train, etc.) mostly resulting in a collision between both.

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[4] Regulation (EU) No.168/2013

The reason why the category "Right turn" is missing is that the accident data underlies the German traffic regulation of right-hand drive. In countries where people drive on the left-hand side, the category "Right turn" would be relevant.

3.3 Evaluation dataset

After considering the around 3.500 single information per accident that are coded in the GIDAS database on average, and applying the already mentioned criteria, we obtained a dataset for the evaluation of C-ITS applications, some insights from this evaluation dataset are presented here.

3.3.1 Distribution of the injury severity

Traffic accidents involving personal injury could be categorized into three injury severities. These categories are used to describe the most serious consequences of a traffic accident. This means that the accident is classified according to the maximum injury severity of a participant, regardless of the type of traffic participation. As an example, we consider an accident with two participants.
Participant 1 = car driver   = seriously injured.
Participant 2 = PTW rider   = slightly injured.
In this example the accident is classified and counted as an accident with seriously injured

In the present study, the injury severities are defined as follows:
• fatally injured: persons that die within 30 days after the accident
• seriously injured: persons that become in-patient treated for more than 24 hours in the hospital
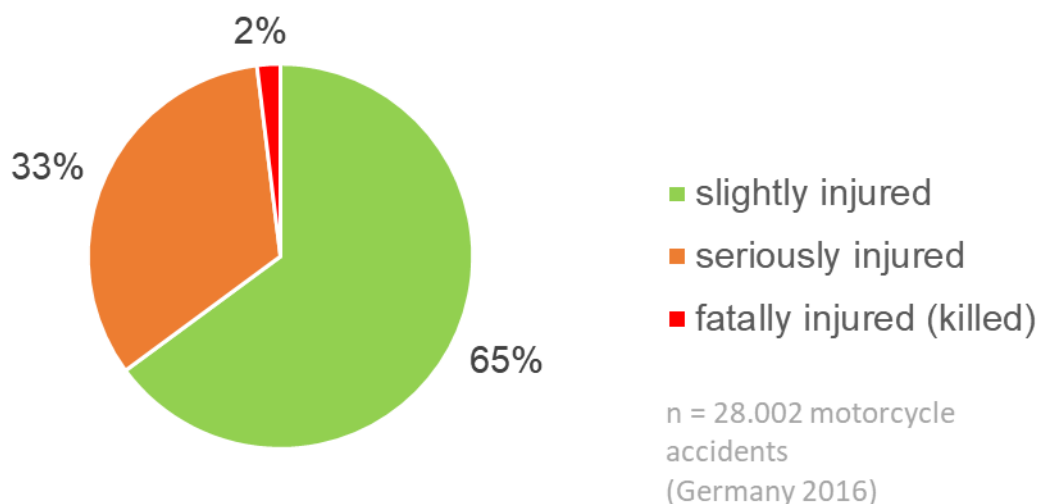• slightly injured: all other injured persons

Figure 6: Distribution of the injury severity

Figure 6 shows the distribution of the injury severity of 28.002 PTW accidents in Germany for the year 2016. The accident level was used for the analysis.

It can be seen that the majority (65%) are accidents with slightly injured persons. The second largest group, with 33%, are accidents with serious injured persons and the smallest share with 2% are accidents with fatally injured persons.

To provide a focus for the next steps in the implementation of C-ITS, the potential of C-ITS for accidents with serious injuries and fatalities has also been assessed separately (chapter 4.2 and 4.3).

3.3.2 Most frequent accident scenarios involving PTWs
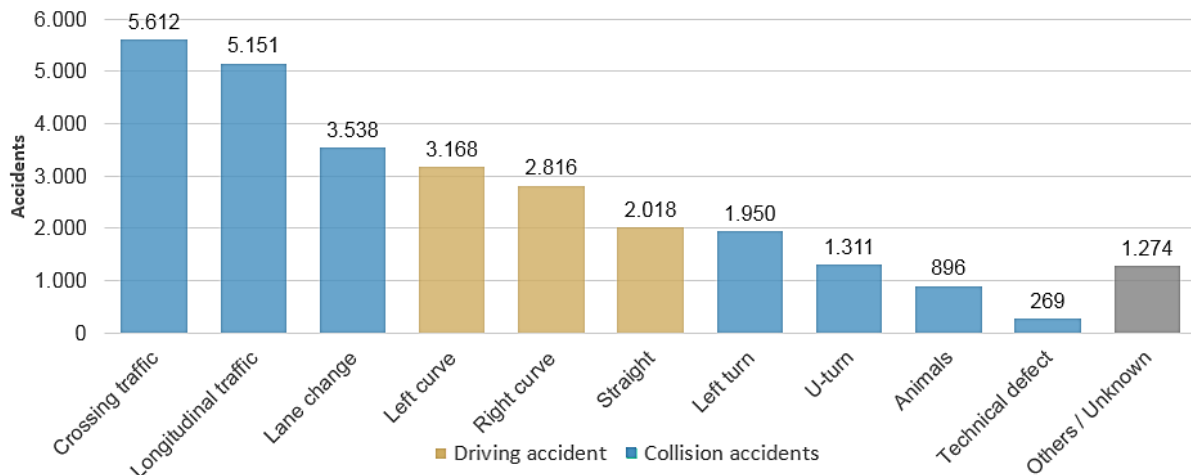

Figure 7: Frequency of PTW scenarios

Figure 7 shows that the three most frequent scenarios are collision accidents. The first, most common scenario, is **Crossing traffic** with 5.612 accidents; in this scenario the accident causer usually ignores / disregards a vehicle coming from the left or right at a junction or crossing. The second largest group is the scenario **Longitudinal traffic** with 5.151 accidents; in this type of accident, the accident causer (following vehicle) collides with a preceding vehicle or a collision between oncoming vehicles takes place (e.g. during overtaking on rural roads). **Lane change** is the third largest group with 3.538 accidents; this scenario includes cases where the accident causer changes the lane to another (parallel) lane, e.g. for overtaking a preceding vehicle on a motorway. Scenario number four to six are driving accidents. The scenario **Left curve** occurs slightly more often (3.168 accidents) than accidents in a **Right curve** (n=2.816). The reason for the lower number of accidents in the **Right curve** scenario is that PTW riders that left their lane due to a loss of control situation have some more space (on the oncoming lane) and time to correct their error before leaving the entire roadway.

The scenario **Straight** contains 2.018 accidents; these are often acceleration or deceleration manoeuvres that lead to a fall of the rider. Scenario number seven is **Left turn** with 1.950 accidents; in this scenario, the accident causer would like to turn left and overlooks the oncoming traffic. Scenario number eight with 1.311 accidents is the **U-turn** scenario; here, the accident causer wants to turn his vehicle on the road and fails to recognize a vehicle from behind. The scenario **Animals** (896 accidents) includes all accident types where a PTW rider had a collision with an animal. By definition, the main causer of accidents involving animals is always the road user. **Technical defect** (269 accidents) include all accident types where the PTW had a technical defect that caused the accident. Technical defect means malfunction and/or break-

age while riding due to unexpected trouble and/or damage. The last scenario is **Others / Unknown** with 1.274 accidents. This group contains accident types that do not fit into the other scenarios.

3.3.3 Most frequent accident scenarios including causation

To get a better understanding of typical conflict situations between PTW and other road users, the 11 accident scenarios are analysed regarding the accident causer (Figure 8).
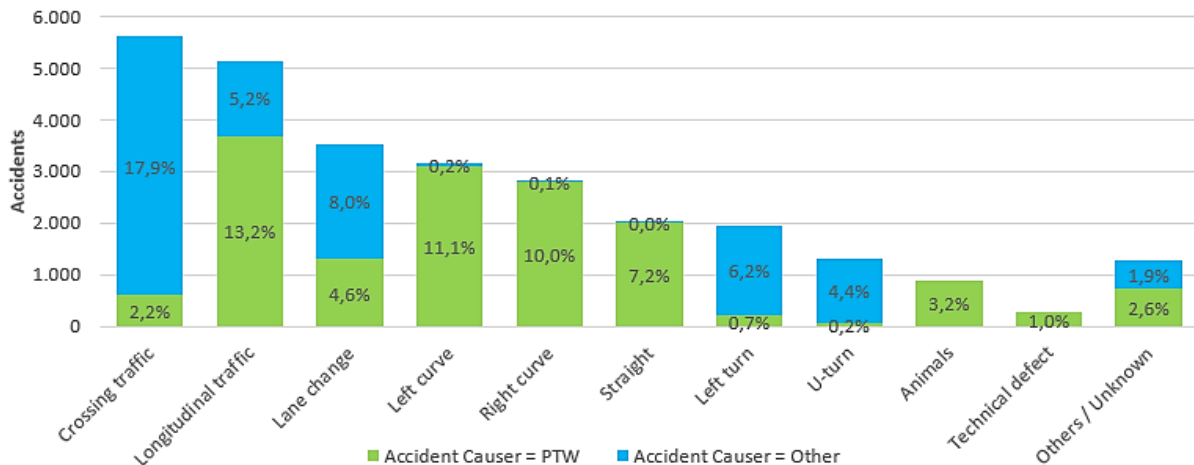

Figure 8: Accident causation in the PTW scenarios

It can be seen that in the **Crossing traffic** scenario mostly other road users are the accident causer. Mainly, the other vehicle driver overlooks the PTW rider or misinterprets the speed or distance of the PTW. The situation is similar to **Lane change**, **Left turn** and **U-turn**. Even in **Longitudinal traffic** scenarios nearly one third of the accidents were mainly caused by another road user. If these cases should be addressed or avoided by C-ITS, it is important to inform the other vehicle that a PTW is in its vicinity and will probably cross his way. However, in more than two thirds of the cases in **Longitudinal traffic** the PTW was the main accident causer. That indicates the importance of knowing about a preceding vehicle and its speed for PTW rider. In the scenarios **Left curve**, **Right curve** and **Straight** the PTW is by far the most frequent accident causer as these are mostly single vehicle accidents due to loss of control situations. To address these accidents it is important that the PTW rider is correctly informed about the course and road condition.

In the scenario **Lane Change** the PTW nearly causes every third accident. Here, the PTW rider should be supported in lane change situations, for example with a kind of blind spot detection (or Lane Change Assist). The scenario **Animals** are not easy to be address by C-ITS and may need other means of detection.

3.3.4 Most frequent accident scenarios with C-ITS potential

Figure 9 shows an alternative illustration of the scenarios, sorted by the combination of scenario and accident causation. The Top 10 cover 87,8% of all accidents and it becomes clearly visible which scenarios can be addressed by C-ITS and which road users should be equipped with the C-ITS functions.
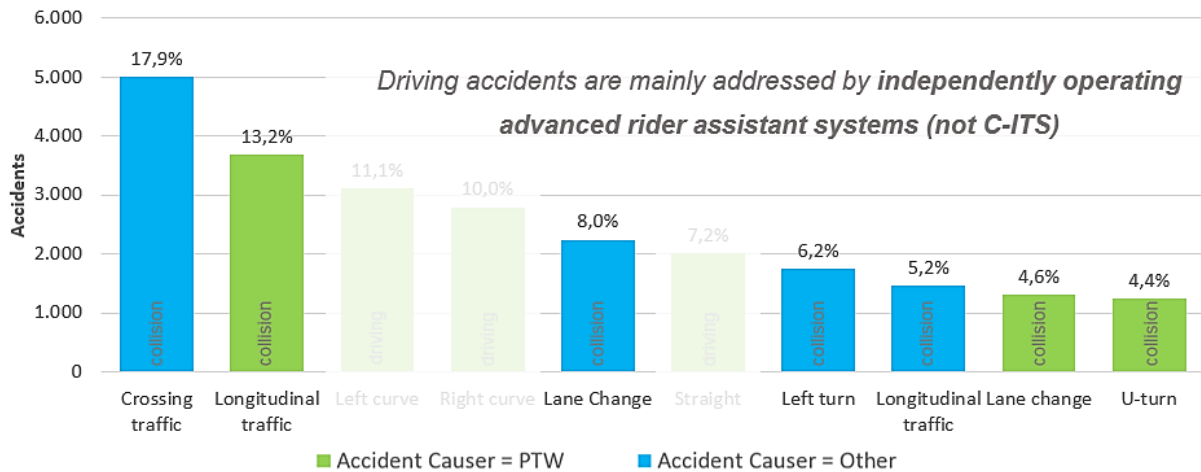

Figure 9: Top 10 - Accident causation in the PTW scenarios

The focus of C-ITS for PTW are collision accidents and amongst them, the majority was caused by other road users. Driving accidents like **Left curve**, **Right curve** and **Straight** are mainly addressed by independently operating advanced rider assistant systems. Therefore, these three scenarios are excluded from further analyses on C-ITS. Further information on the concepts to address those accidents is provided by the ifz paper *"Why automatization is the future of rider assistance systems – Intervene before a critical situation."* by Stefan Hans (BMW Motorrad) and Markus Köbe (Technische Universität Dresden).

The remaining scenarios still address around 60% of all PTW accidents. The figure shows on the one hand, that it is important to inform other road users that a PTW is in their vicinity and will probably cross their path. On the other hand, it is important for PTW rider to know about a preceding vehicle and its speed or a vehicle that changes his lane or makes a U-turn.

3.4 Method for the evaluation of potential of C-ITS applications

The Connected Motorcycle Consortium (CMC) created a document that describes relevant C-ITS for PTWs including "Application specification". This document is the basis for this analysis. In CMC more than 30 applications were considered, from which 19 applications were selected for the accident analysis, at the beginning of year 2018. These are mainly applications that could have an impact on the accident scenario and other comfort applications were not analysed. Figure 9 shows a rough overview about the evaluation steps.
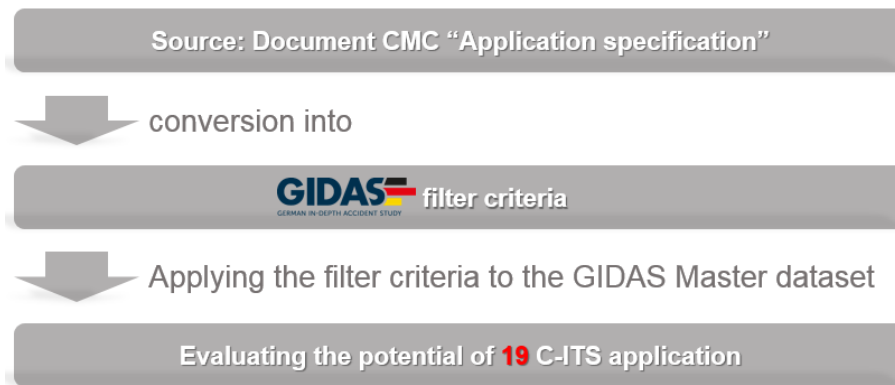
Figure 10: Method for the Evaluation of the potential of C-ITS for PTWs

The main tasks were the checks to the application specification from an accident research point of view and, on the other hand, the conversion of all application specifications (limitations, scenarios, speed ranges etc.) into GIDAS filter criteria.

The following questions can be answered with the "**Application specification".**

- On which road types the system should work?
- Which road users are addressed with the system?
- Which direction of travel did both accident participants have?
- Which further restrictions does the system have?

The workflow is described exemplarily for the **Left Turning Assist (LTA)**. Figure 11 shows information from the "Application specification" for LTA.
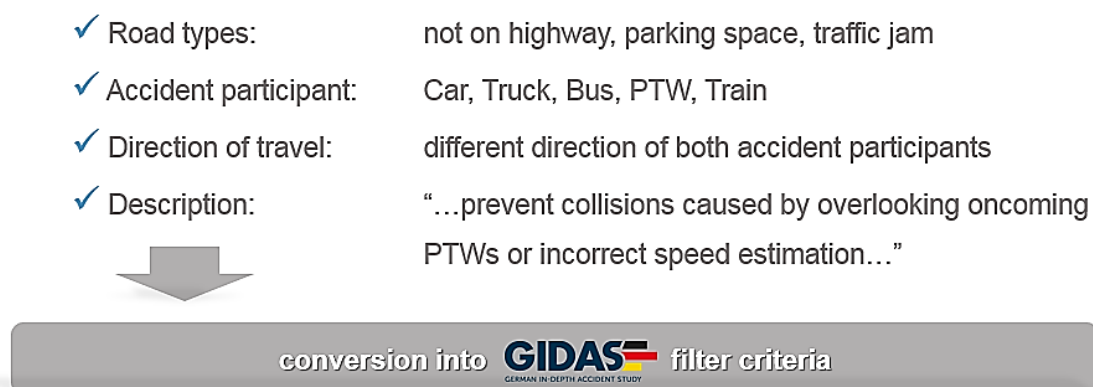

Figure 11: Information from the "Application specification" for LTA

Note: Definition of LTA in this document is not exactly matching with the definition of Application Specification, but the most important use case is covered by both definitions.

3.5 Results of the evaluation for an example C-ITS application (LTA)

With the information obtained, it is possible to create queries within the GIDAS database. All queries are done twice to distinguish between the two accident causing parties (either PTW or other road user). Table 2 shows the results in the case the accident causer was the PTW.

Table 2: Result – Example LTA – Accident causer = **PTW**

Accident scenarios			Addressed cases with LTA	
Scenario	no. of accidents	%	no. of accidents	%
Crossing traffic	604	2,2%	0	0%
Longitudinal traffic	3.689	13,2%	0	0%
Lane change	1.300	4,6%	0	0%
Left curve	3.116	11,1%	0	0%
Right curve	2.789	10,0%	0	0%
Straight	2.005	7,2%	0	0%
Left turn	206	0,7%	123	60%
U-turn	65	0,2%	0	0%
Others / Unknown	732	2,6%	0	0%
Animals	896	3,2%	0	0%
Technical defect	269	1,0%	0	0%
total	15.671	56,0%	123	1%

The first column shows the 11 accident scenarios described before. The second and third column gives the number as well as the percentage of these scenarios. The columns five and six show the number and percentage of accidents that can be addressed by the LTA.

It can be seen that the LTA only addresses accidents in the Left turn scenario (as from the name of the application already suggests). In all other scenarios the application has no effect. It can be seen from Figure 7 that the scenario **Left turn** includes nearly 2.000 accidents. However, in only 10% of these cases the PTW was the accident causer. If an LTA would be available on every PTW, nearly 60% of these accidents could be addressed and thus, potentially be avoided or at least mitigated.

In the next step, the results are shown for accidents that were caused by another road user (Table 3).

Table 3: Result – Example LTA – Accident causer = **Other**

Accident scenarios				Addressed cases with LTA	
Scenario	**no. of accidents**	**%**		**no. of accidents**	**%**
Crossing traffic	5.008	17,9%		0	0%
Longitudinal traffic	1.463	5,2%		0	0%
Lane change	2.238	8,0%		0	0%
Left curve	52	0,2%		0	0%
Right curve	26	0,1%		0	0%
Straight	12	0,0%		0	0%
Left turn	1.744	6,2%		1.244	71%
U-turn	1.245	4,4%		0	0%
Others / Unknown	542	1,9%		0	0%
Animals	0	0,0%		0	0%
Technical defect	0	0,0%		0	0%
total	**12.330**	**44,0%**		**1.244**	**10%**

Here, the remaining 90% of the accidents in the Left turn scenario are included and 71% of these accidents can be addressed by LTA. This figure is the potential field of operation for such an application if 100% of all other road users (car, truck, bus, tram, other PTW) would be equipped with LTA.

Table 4 shows the overall potential of an LTA in the German PTW accident scenario. Assuming that a 100% market penetration would address every 20th PTW accident with personal damage in Germany (4,9%). However, this figure is the maximum possible benefit and does not consider additional aspects like actual usage rate, (de)activation, HMI, appropriate rider/driver reaction, false-positives etc.

Table 4: Result – Example LTA – Total potential

Accident scenarios				Addressed cases with LTA	
Scenario	**no. of accidents**	**%**		**no. of accidents**	**%**
Crossing traffic	5.612	20,0%		0	0%
Longitudinal traffic	5.151	18,4%		0	0%
Lane change	3.538	12,6%		0	0%
Left curve	3.168	11,3%		0	0%
Right curve	2.816	10,1%		0	0%
Straight	2.018	7,2%		0	0%
Left turn	1.950	7,0%		1.367	70%
U-turn	1.311	4,7%		0	0%
Others / Unknown	1.274	4,6%		0	0%
Animals	896	3,2%		0	0%
Technical defect	269	1,0%		0	0%
total	**28.002**	**100%**		**1.367**	**5%**

4 Potential of C-ITS applications

4.1 Overall potential independent of the injury severity

The presented method from chapter 3.4 was used for the evaluation of the potential of 19 C-ITS applications for PTWs. Figure 12 shows the calculated potential of several C-ITS applications for PTW depending on the accident scenarios.
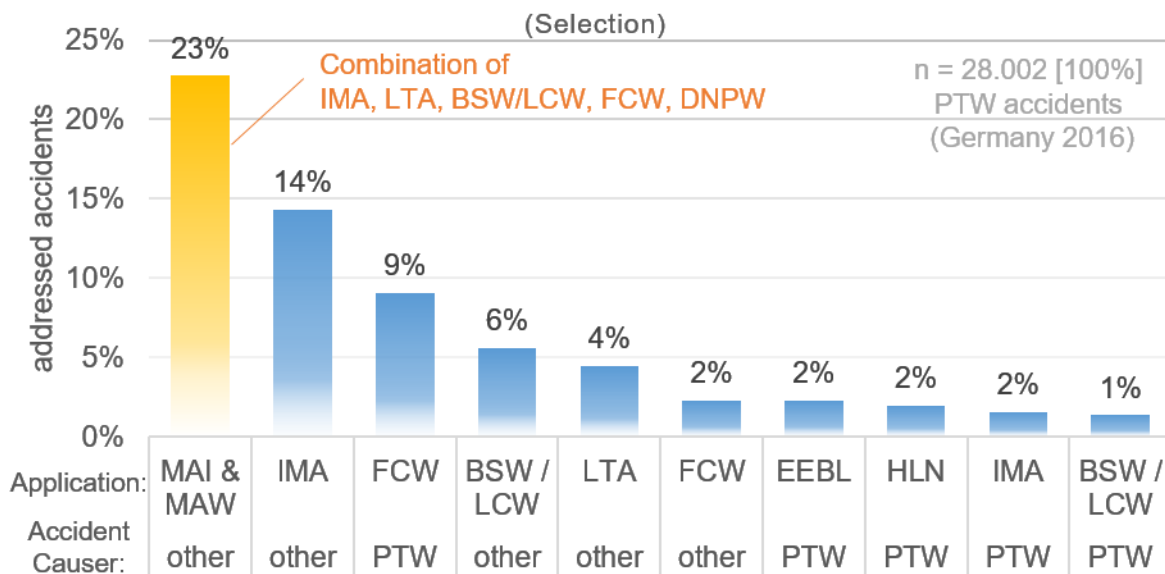

Figure 12: Potential of C-ITS for PTW

The Figure shows that the future safety applications can contribute substantially to the safety of PTWs. This is true for most of the relevant accident scenarios and many C-ITS applications achieve remarkable potentials within their dedicated scenarios.

The highest potential was obtained with the **Motorcycle Approach Indication / Warning** (MAI/MAW) as a set of applications is able to address 23% of all 28.002 PTW accidents. The second highest potential was obtained with the **Intersection Movement Assist** (IMA) with 14%. However, all of these three applications can only affect the scenarios positively by informing and warning the driver of the other vehicle, because they are the main accident causer in the scenarios. The **Forward Collision Warning** (FCW) can possibly address 9% of all accidents and has the highest potential when focusing on warning the rider of the PTW.
A **Blind Spot Warning** (BSW) & **Lane Change Warning** (LCW) can possibly address 6% and a **Left Turn Assist** (LTA) can possibly address 4% of the accidents, if implemented on the other vehicle. Other applications such as Electronic Emergency Brake Light (EEBL), Hazardous Location Notification (HLN) and so on, from CMC Basic Specification "Application specification", show slight or moderate effects on PTW accidents.

4.2 Accidents with serious injuries

Figure 13 shows the calculated potential of several C-ITS applications for PTW depending on the accident scenarios and for accidents with serious injuries.
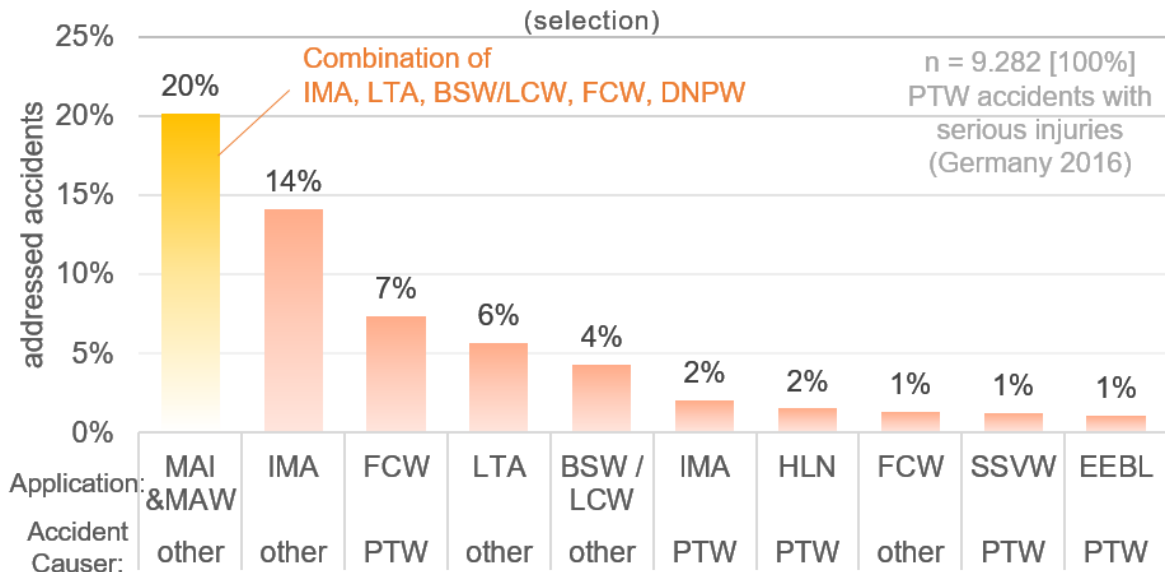
Figure 13: Potential of C-ITS applications for PTW for accidents with serious injuries

The Top 3 most important C-ITS applications are in line with the assessment in chapter 4.1. The C-ITS applications that ranked 4th and 5th have changed their position. Stationary Vehicle Warning (SVW) is now in the Top 10 of accidents with serious injuries.

4.3 Accidents with fatal injuries

Figure 14 shows the calculated potential of several C-ITS applications for PTW depending on the accident scenarios for accidents with fatal injuries.
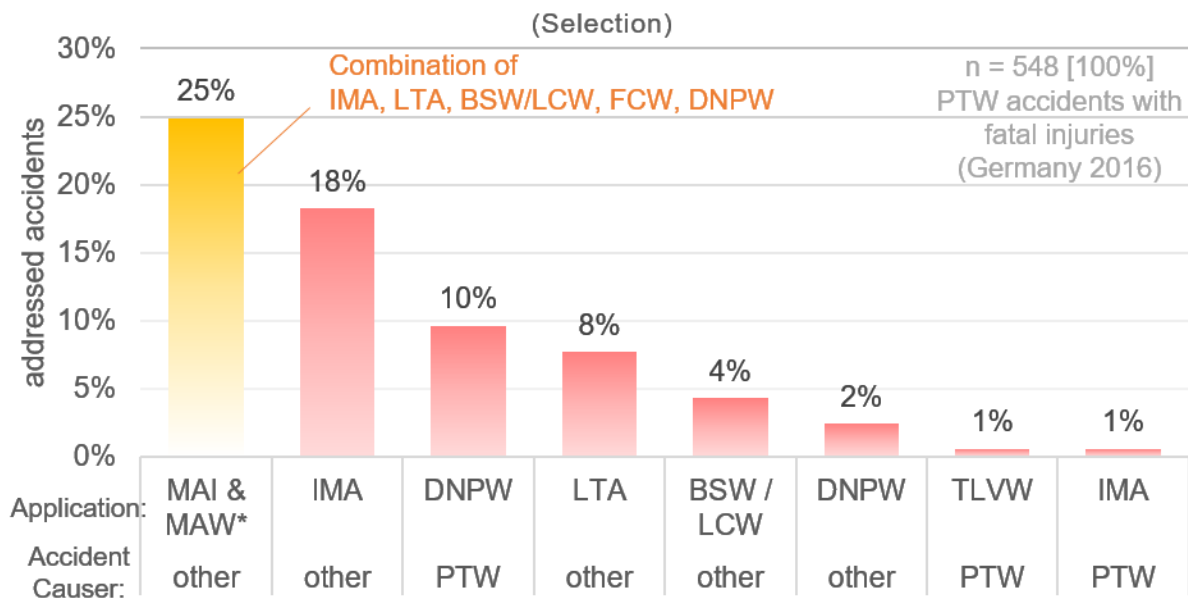

Figure 14: Potential of C-ITS applications for PTW for accidents with fatal injuries

The Top 2 of the C-ITS applications correspond to the assessment in chapter 4. Do Not Pass Warning (DNPW) shows the third highest potential for fatal injuries. DNPW and Traffic Light Violation Warning (TLVW) are new in the Top 8 of accidents with fatal injuries.

4.4 Detail analysis MAI & MAW

MAI & MAW (Motorcycle Approach Indication & Motorcycle Approach Warning) is a combination of different C-ITS applications as follows:
*   LTA   - Left Turning Assist
*   IMA   - Intersection Movement Assist
*   BSW / LCW   - Blind Spot Warning / Lane Change Warning
*   FCW   - Forward Collision Warning
*   DNPW   - Do Not Pass Warning

In the present study, the same properties were assumed for MAI/MAW. The differences of the systems (time-dependent criticality) could be analysed in principle with simulative studies where exact C-ITS specifications are available. This was not performed within the project.
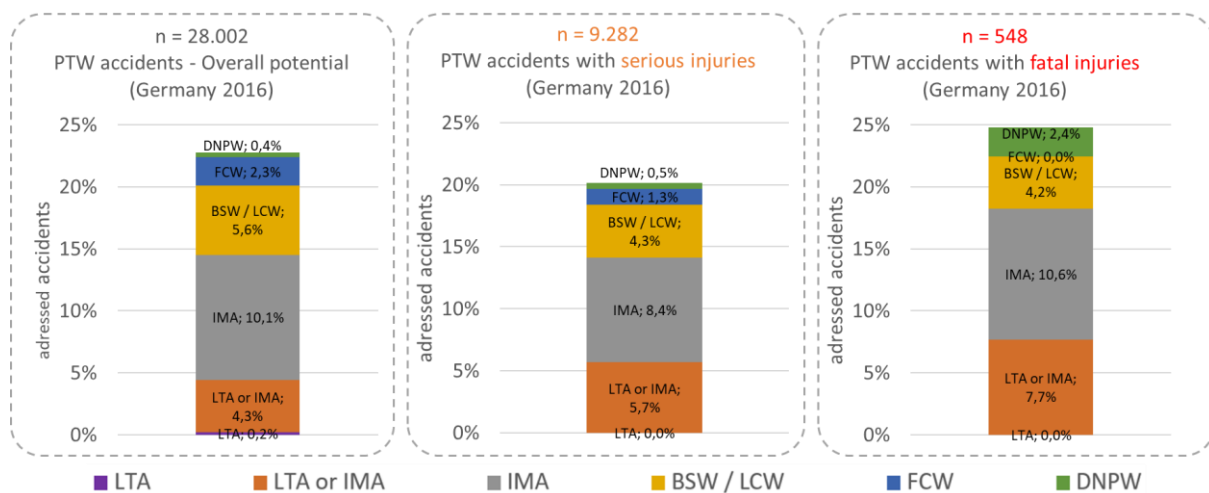In Figure 15 the findings of the detailed potential analyses to MAI & MAW are shown.

Figure 15: Detail analysis MAI & MAW*

A summation of the individual potentials was not possible because LTA and IMA address partly the same accidents. This applies to the bars in orange, which represent an overlapping of the accidents of LTA and IMA. The graph illustrates that IMA, BSW/LCW can address a very large proportion of accidents. It is noticeable that FCW does not address the accidents with fatalities. In contrast, DNPW has an increased potential in accidents with fatalities, compared to non-fatal accidents.

4.5 Challenge towards high market penetration of C-ITS technology

Although the study suggests it was proven that there is high potential to C-ITS technology, the assumption is that the market penetration is 100%. Therefore, it is also important for riders to understand the value of C-ITS and apply it to their PTWs. The following is an evaluation of rider attitudes towards rider assistance systems and C-ITS based assistance systems from a German study with 3.805 participants from 2018[5] . Even though the majority of the study results refer to rider assistance systems, a certain part of the knowledge may be transferred to C-ITS applications.

In general, riders are very aware of the risks they run in road traffic, whereby the awareness increases with age. Almost all study participants (85,2%) have suffered a critical situation in the last 12 months. Most of them (53,1%) were being overlooked by other road users followed by braking in inclined positions (38,4%) and incorrect curve estimation (35,7%). Otherwise, 34,8% have already gained positive experience (increasing with the rider's age) with rider assistance systems.

The consequence is that 94,6% of all participants see a safety enhancement through rider assistance systems up to now. Furthermore, 61,8% of the participants anticipate also an improvement in future accident statistics. Although 56,6% of the participants believe that they will contribute more to reducing the number of accidents in the future through improved rider skills than rider assistance systems, over 53% say that safety-related PTW aspects have a major influence on their next purchase decision. This proportion is even higher for riders who have already had positive rider assistance systems experience. For 93,6% of them, rider assistance systems are a must-have item for their next choice of PTW.

About rider assistance systems operation, it should be noted that these should be self-explanatory for the majority of riders (64,5%). This means, that the systems have to function in such a way that they do not require any explanation to the rider in their handling. However, 37,8% can also imagine an explanation via the vehicle display. Nevertheless, systems with different operating modes are difficult to implement in a self-explanatory manner.

The idea of "connectivity" with C-ITS is still relatively unknown to the majority of the participants. Only 47,4% could explain "connectivity" in general. It is interesting to note that only 47% of the participants understood connectivity to have positive influence on PTW safety in the future. 12,8% even see a deterioration of safety by C-ITS in the future (Figure 16 left). With regard to pure V2V communication, only 35,8% of all participants believe that this will reduce the number of accidents in the future (Figure 16 right). This is surprising in the sense that rider assistance systems are already considered to have a high positive influence on future PTW safety, whereas this is not automatically the case for C-ITS. The study authors attribute these answers less to mistrust than to a large portion of "uncertainty", because many study participants still have a low level of knowledge about connectivity.

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[5] Haasper, M., et al. (August 2020). Motorcycle Safety in Germany: Attitudes And Behavior With Special View on Advanced Rider Assistance Systems for Powered Two Wheelers. Institut für Zweiradsicherheit (ifz), Germany.
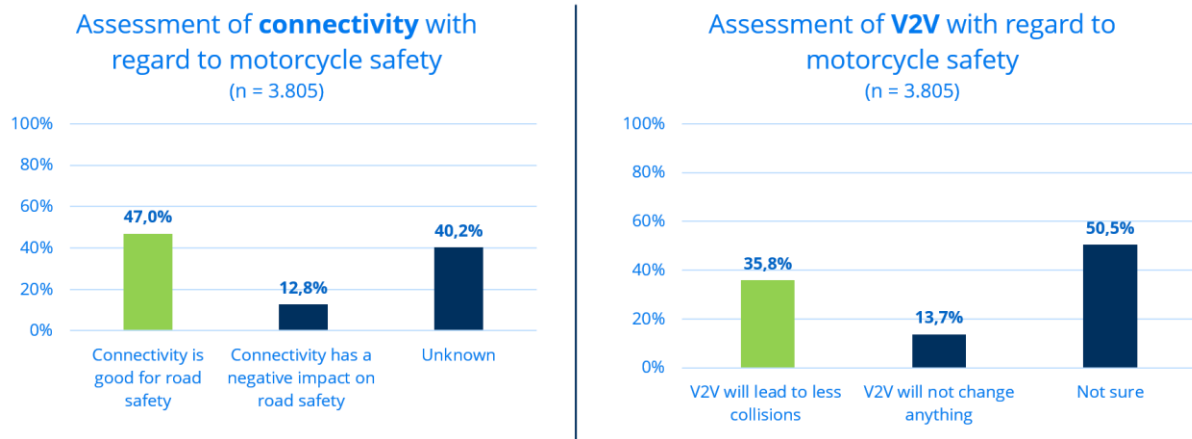
Figure 16: Assessment of connectivity and V2V by study participants

It should be emphasised that the first rider assistance systems (introduction of ABS in 1988) have been on the market for a long time and their acceptance depends above all on the learning process "learning by doing". For example, 38,7% of all participants gained their rider assistance systems knowledge through trial and error, 29% through professional journals and 14,4% through social networks. Thus, in the case of a C-ITS introduction, a targeted rapid market penetration or the enabling of practical testing for broad acceptance must be promoted. If the safety advantage can be credibly communicated, this can be a very important reason for a purchase decision.

5 Summary

One of the main causes for PTW accidents is perception failure of other vehicle drivers. By employing C-ITS, vehicles will be able to exchange location information and therefore will be able to identify accident relevant situations. Where necessary, vehicles can generate information to the riders/drivers to inform that a PTW is approaching and that caution needs to be taken. Next to safety relevant applications, various comforting features can be deployed. For example, optimizations in traffic flow by controlled traffic light changes reduce emissions and stress in urban areas. Therefore, the use of cooperative safety systems for PTWs will help to enhance safety for PTW rider but also riding pleasure. To understand and address traffic safety topics, numbers of researches and surveys are being executed. The results of the study done by CMC indicate that PTW accidents at intersections cover a large proportion of injuries. Furthermore, these studies also reveal that perception failure is one of the major factors. For this, technical systems such as "Motorcycle Approach Indication / Warning" relying on connectivity between PTWs and other vehicles on the road have significant potential to address the typical 'sorry mate, I did not see you' phenomena.

The obtained results show that collision accidents can be mainly addressed by Intersection IMA, LTA, FCW, and BSW/LCW; grouped as MAI/MAW, these are covering a large proportion of all possible collision accidents involving PTWs.

To address Driving accidents, it is important that the PTW rider is correctly informed about the course and road conditions.

In conclusion, all considered C-ITS applications could have a positive influence in critical traffic situations. However, the actual success of these safety systems for PTWs and the expected reduction of accident numbers depend on penetration rate and additional aspects such as the acceptance of these systems, the design of the human machine interface, the avoidance of negative effects (e.g. distraction) and more.

Abbreviations

ABS	Anti-lock Braking System
AWW	Adverse Weather Warning
BASt	Federal Highway Research Institute
BSW	Blind Spot Warning
C-ITS	Cooperative Intelligent Transport Systems
CMC	Connected Motorcycle Consortium
CSW	Curve Speed Warning
DESTATIS	Federal Bureau of Statistics
DNPW	Do Not Pass Warning
EEBL	Electronic Emergency Brake Light
FAT	German Research Association for Automotive Technology
FCW	Forward Collision Warning
GIDAS	German In-Depth Accident Study
HLN	Hazardous Location Notification
HMI	Human Machine Interface
IMA	Intersection Movement Assist
LCW	Lane Change Warning
LMA	Lane Merge Assist
LTA	Left Turn Assist
MAI	Motorcycle Approach Indication
MAW	Motorcycle Approach Warning
PTW	Powered Two Wheeler
SSVW	Stop Sign Violation Warning
SVW	Stationary Vehicle Warning
TCS	Traction Control System
TLVW	Traffic Light Violation Warning
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VDA	German Association of the Automotive Industry
VRU	Vulnerable Road User
VUFO	Verkehrsunfallforschung an der TU Dresden