CMC

Lane Change

CMC has developed specifications related to the incorporation of powered two-wheelers in Cooperative Intelligent Transport Systems, with the ultimate goal of enhancing rider safety. The CMC Specifications consist of multiple documents, and this document represents the use case description.

Document Information

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Disclaimer

Index

1. Preamble

Powered Two Wheelers (PTWs) have different characteristics compared to other road users. Significant characteristics of PTWs are a basically smaller size and different driving dynamics compared to other types of vehicles, which may end up in a variety of dangerous situations as described below:

- Hidden behind another participant or object
- Delay of detection by other road users such as car drivers
- Hidden in the blind spot
- Speed and distance are easily misjudged
- Filtering through narrow space

This document describes important lane change use cases with collision potential.
Both for Advanced Driver Assistance Systems (ADAS) based on on-board sensor system such as camera or radar, as for Cooperative Intelligent Transport Systems (C-ITS) technologies, taking PTW-specific characteristics into consideration.
The basic criterion to decide whether a conflict situation is arising or not, is the Time-To-Collision (TTC). TTC defines what time is left before the conflict emerges. For the TTC calculation a path prediction is used assuming constant speed and trajectory for each participant at every point in time. If these paths cross and would lead to a collision, a TTC can be calculated. For the following analyses, the German In-Depth Accident Study (GIDAS) was used and weighted to the German motorcycle accident statistics 2019.[1,2]

[1] GIDAS dataset from 30.06.20 weighted to Germany 2019, https://www.gidas.org/start.html
[2] The methodology for the creating of the dataset can be found in chapter 3.3 of the document "CMC Basic Specification Assessment of C-ITS application potential", https://www.cmc-info.net/assessment.html

2. Lane Change

2.1 Summary

Lane change accident types according to the German In-Depth Accident Study (GIDAS) database is described as a conflict between a road user (Participant A) who is changing lanes to the left or turning left and a road user (Participant B) who is following / overtaking Participant A. In this report, the 3 most frequent types of lane change accident (type 202, 631 and 551) are featured. Those accident types are illustrated in *Figure 1*.

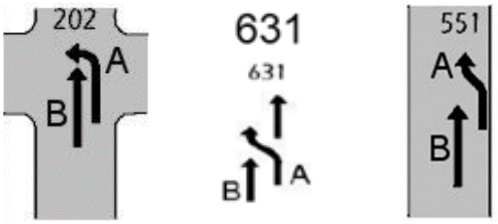

Figure 1: Lane change – Accident type 202, 631 and 551[3]

Accident type 202:
The accident type 202 occurred most frequently on urban roads (58.8%), especially at junctions, crossings and property exits. In comparison, the average accident location for all PTW accidents is also on urban roads in 56.9% of cases. Participant A is an M1/N1 vehicle (passenger car / light commercial vehicle) in 67.7% of cases and a motorcycle in 20.9% of cases. Participant B is a motorcycle in 90% of cases.

Accident type 631 and 551:
The accident types 631 and 551 were evaluated together in the detailed analyses due to their similarity. Both accident types occurred most frequently on urban roads (65.4%), especially at straights, while the average accident location is on urban roads in 59.9% and on rural roads in 40.1% of cases. Participant A consists mostly of M1/N1 vehicles (passenger cars / light commercial vehicles) (84.2%) and for Participant B this is mostly motorcycles (88.7%).

Participant A and/or Participant B may overlook each other and make errors while turning or overtaking. In some cases, Participant B may not be at adequate speed or distance.

2.2 Background

According to the German In-Depth Accident Study (GIDAS) database, the accident type 202 is the most common accident type within the lane change scenario shown in Figure 2.

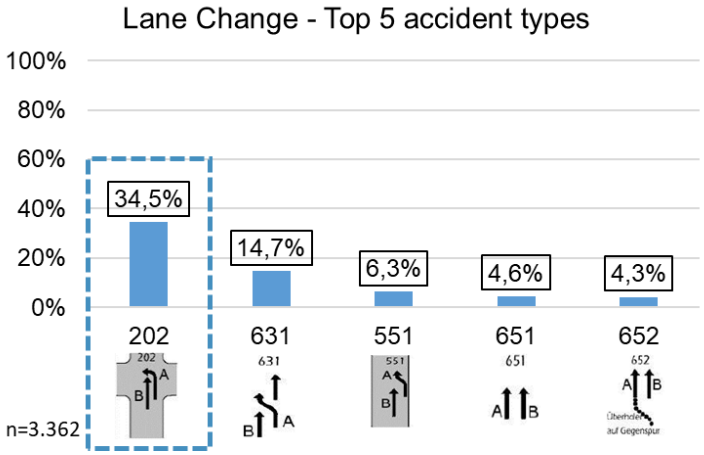

Figure 2: Selection of lane change accident type[3]

Moreover, the accident types 631 and 551 do have a significant share in lane change accident scenarios.

2.3 Objective/ Desired Behaviour

Ideally, Participant B should receive an advisory notification that Participant A is about to turn left (i.e., Do Not Pass Warning) or to pull out from the parking space. If the overtaking process by Participant B has already been initiated, Participant A should receive a notification about the overtaking Participant B (i.e., blind spot detection). In this case, the intention would be to stop the left turning, the overtaking or the pull-out process in order to avoid the crash. If Participant A would start to turn left anyway, an active intervention combined with an earliest possible warning would mitigate the situation.

[3] Gesamtverband der Deutschen Versicherungswirtschaft e.V. (GDV), Unfallforschung der Versicherer; Unfalltypenkatalog, Leitfaden zur Bestimmung des Unfalltyps

2.4 Expected Benefits

According to the GIDAS data base, lane change is the third frequent accident scenario as shown in Figure 3.

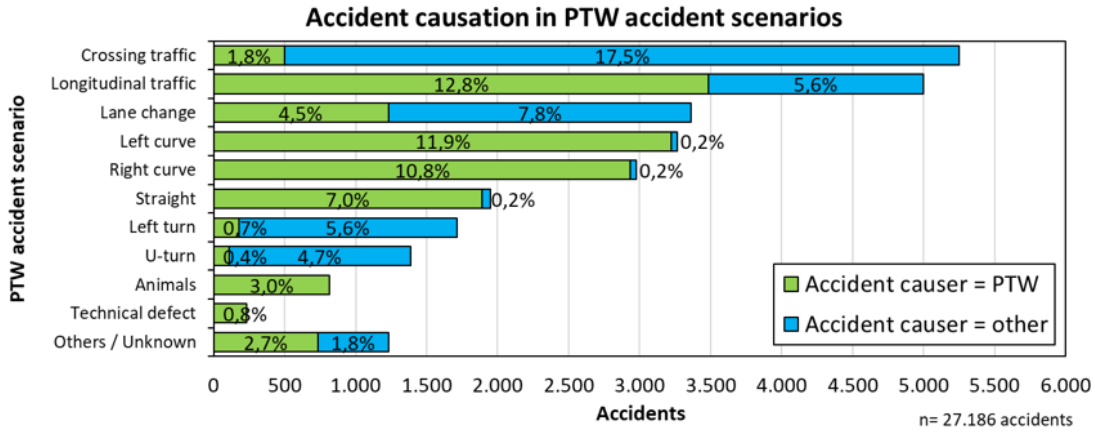

Figure 3: Accident causation in the PTW scenarios based on the GIDAS database [4]

Technologies which prevent or mitigate lane change accident scenarios have high potential to save lives and reduce injuries.

2.5 Actors and Relations

2.5.1 ADAS only

In the majority of analysed cases from the GIDAS data base Participant A is a car which is about to turn left or would like to change to the left lane or park out. The car is equipped with on-board ADAS, such as camera and radar. Typically, Participant B is a PTW which is initiating an overtaking manoeuvre. The car is providing a blind spot warning triggered by the recognition of the oncoming PTW. If no action occurs an Autonomous Emergency Braking (AEB) will be initiated. For Participant B a warning could be triggered if Participant A enters the projected trajectory of Participant B that is about to overtake (I.e., Forward Collison Warning).

2.5.2 ADAS + C-ITS

In the majority of analysed cases from the GIDAS data base Participant A is a car which is about to turn left or would like to change to the left lane or park out. The car is equipped with on-board ADAS and C-ITS Technology, that enables direct communication between the participants (V2X – Communication). Therefore, the car is receiving and processing the V2X messages sent by the participants. The car is providing an active intervention such as Autonomous Emergency Braking (AEB) based on on-board sensors, which will be accompanied by a warning. The PTW is equipped with a V2X communication unit and the PTW is sending a Cooperative Awareness Message (CAM) regularly. The PTW issues a Do Not Pass Warning (DNPW) to the rider if Participant A's intention to turn left becomes clear (e.g., turns on the indicator) while the overtaking is initiated or already in progress.

[4] GIDAS dataset from 30.06.20 weighted to Germany 2019, https://www.gidas.org/start.html

2.6 Traffic Situations

The DNPW can occur on rural road, in urban areas and on the motorway. As already briefly mentioned in the summary the Lane Change scenario covers several situations such as accident types 202, 631 and 551. Basically, however, the scenario remains the same. Participant B wants to overtake or pass but is not seen by Participant A, who wants to turn, overtake, or join the queue.
In this chapter some possible situations are explained more in detail.

2.6.1 Road Types

Situation 1-1: Lane Change at T-junction: Participant A (red car) wants to turn left at a T-junction while Participant B (PTW) is trying to overtake.
Situation 1-2: Lane Change at Straight: Participant A (red car) is driving in the right lane of a two-lane road and is approaching a vehicle ahead. Participant B (PTW) is driving in the same direction as Participant A in the left lane. Participant A wants to change to the left lane in which participant B is riding.
Situation 1-3: Lane Change at Straight (parking space): Participant A (red car) is in a parking space and wants to move into the driving lane. Participant B (PTW) is in the driving lane which Participant A would like to enter.

Situation 1-1 **Situation 1-2** **Situation 1-3**

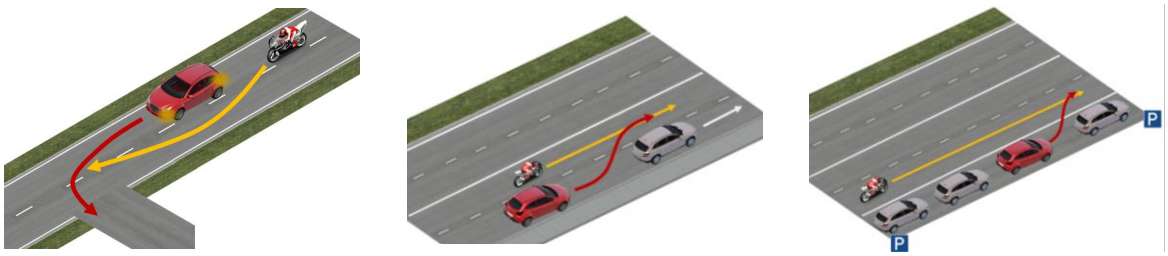

Figure 4: Road type situations for Lane Change scenarios

2.6.2 Line-of-Sight Visibility

According to the GIDAS database, approx. in 5% of the cases Participant A had a view obstruction within Accident Type 202. Possible view obstructions include waiting, starting, or moving vehicles. Therefore, two different situations will be addressed.

Situation 2-1: No obstruction: Participant B (PTW) can see Participant A (red car) and react immediately to any changes in behaviour of Participant A.

Situation 2-2: With obstruction: Participant B (PTW) is driving behind Participant C (red car) and both are behind Participant A (agriculture vehicle). Participant A is indicating to turn left but Participant C does not immediately initiate braking, therefore Participant B does not know about Participant A's intention to turn left and starts to overtake both vehicles. Condition that there is no oncoming traffic. This type is shown in

Situation 2-1 **Situation 2-2**

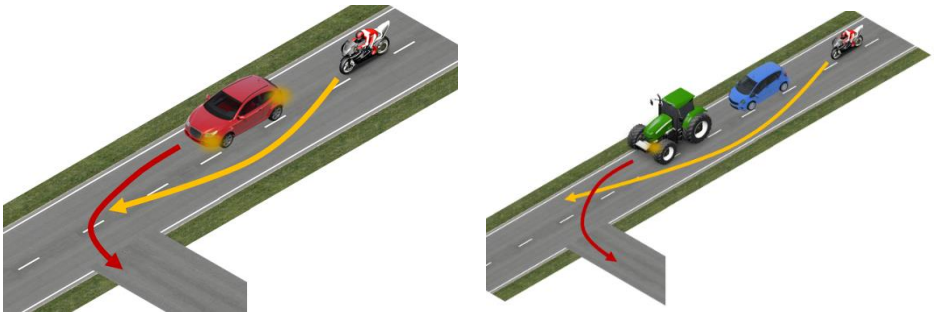

Figure 5.

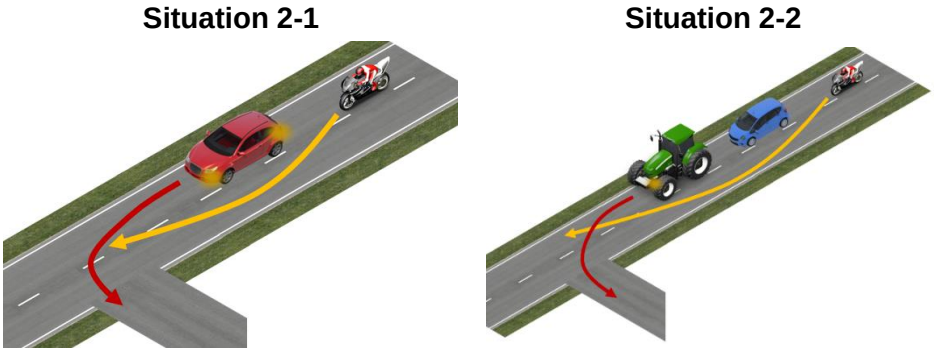

Figure 5: Road type situations for lane change without (left) and with view obstruction (right)

2.7 Use Case Scenarios

Scenario 1 (based on accident type 202):

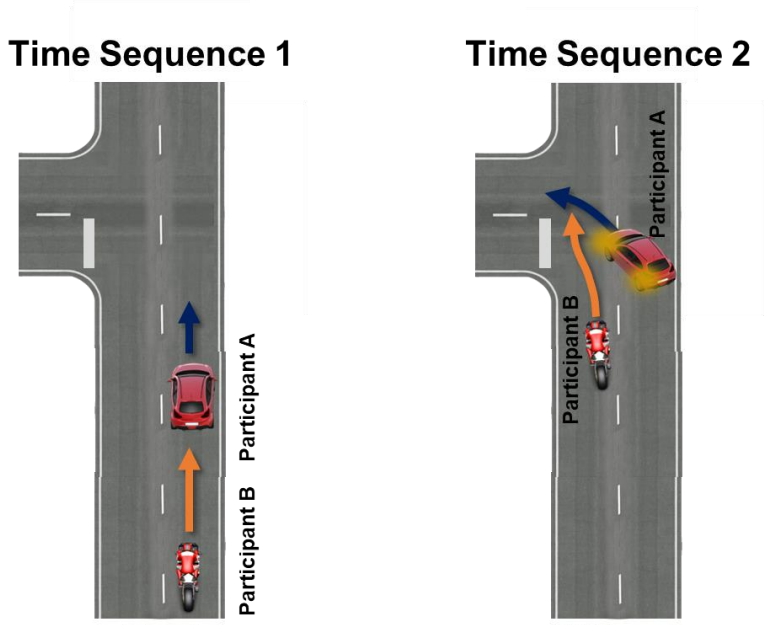

Figure 6: Scenario 1 – Participant B is following Participant A, Participant A wants to overtake and recognizes too late that Participant A wants to turn left

Standard situation:

As shown in *Figure 6* Participant B (PTW) is following Participant A (red passenger car). Participant B wants to overtake and recognizes too late that Participant A wants to turn left. Challenges in this case may be that participant A does not set the turn signal or sets it too late or that Participant B does not recognize the signal or recognizes it too late. Participant A is most often a passenger car, while Participant B typically is a PTW.

Special characteristics of Scenario 1:

Participant B (PTW) is following Participant C (grey passenger car). Participant A (red passenger car) is running in front of Participant C. The PTW rider cannot see Participant A, because it is hidden in front of Participant C. The main challenge of this scenario is a view obstruction due to a non-permanent obstacle, such as a passenger car in this example. This scenario is illustrated in *Figure 7*.

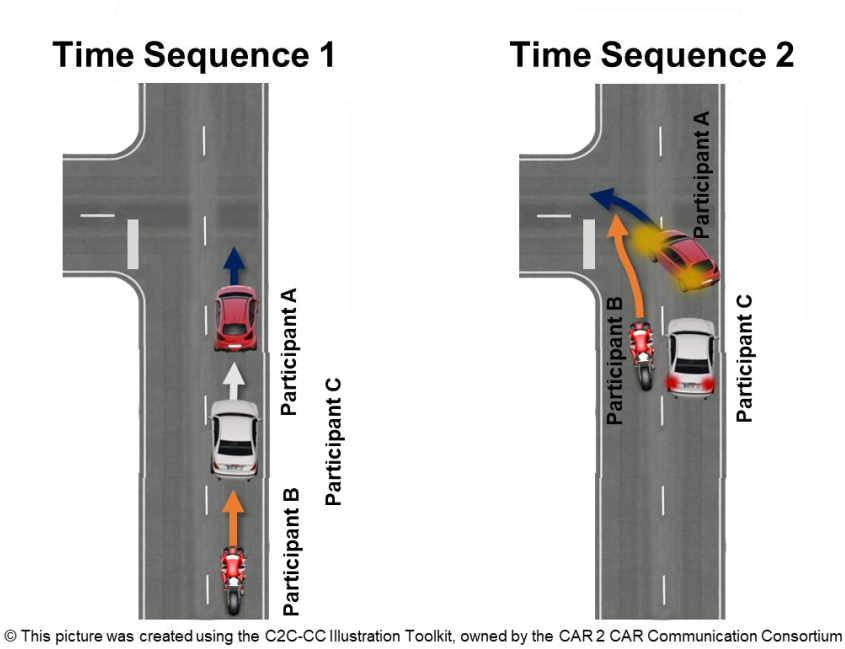

Figure 7: Special characteristics of Scenario 1 - Participant A and Participant B cannot see each other due to view obstruction caused by Participant C

Participant A indicates its intention to turn left at the junction (turn signal on). Participant B cannot see Participant A. In this scenario, Participant A can also be a slow-moving vehicle, like an agricultural machine.

Participant A turning left can also cause the distance between Participants A and B and C to be reduced due to the speed reduction associated with the turning manoeuvre, thus creating an even more unfavourable angle of view.

From the Participant B's point of view: In this situation, it is possible that Participant B will enter the opposite lane in order to overtake Participant C that slows down behind Participant A. Meanwhile, it is also possible that Participant B has not yet noticed Participant A that already starts turning left. Often a lack of perception and misinterpretation cause these situations.

Scenario 2 (based on accident type 631):

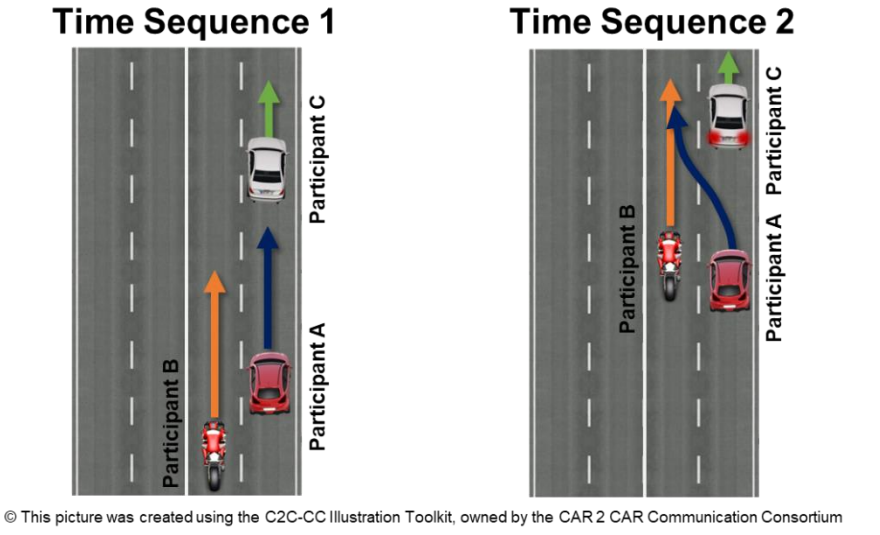

Figure 8: Scenario 2 - Participant A wants to change to the left lane and disregards Participant B, who is already in the left lane and overtakes Participant A.

The starting situation contains Participant A (red passenger car) slowly driving on the right side of a straight lane behind participant C (grey passenger car). Participant B (PTW) is approaching from behind and positioned in a lane left to Participant A. The main challenge characterising this scenario is human error. View obstruction is not an important contributing factor. Challenges can occur when Participant B is riding with excessive speed. If Participant C is driving very slowly or even braking, he can cause a spontaneous overtaking attempt of Participant A who fails to check if the lane is free. This scenario is shown in *Figure 8*.

Generally speaking, Participant A attempts an overtake and changes one lane to the left, crossing Participant B's trajectory. Meanwhile, Participant B does not recognize Participant A, who is about to change to the same lane, or recognizes it too late. It is possible that Participant B does not see the indicator set by Participant A or sees it too late. Participant A is most often a passenger car, while Participant B typically is a PTW.

Scenario 3 (based on accident type 551):

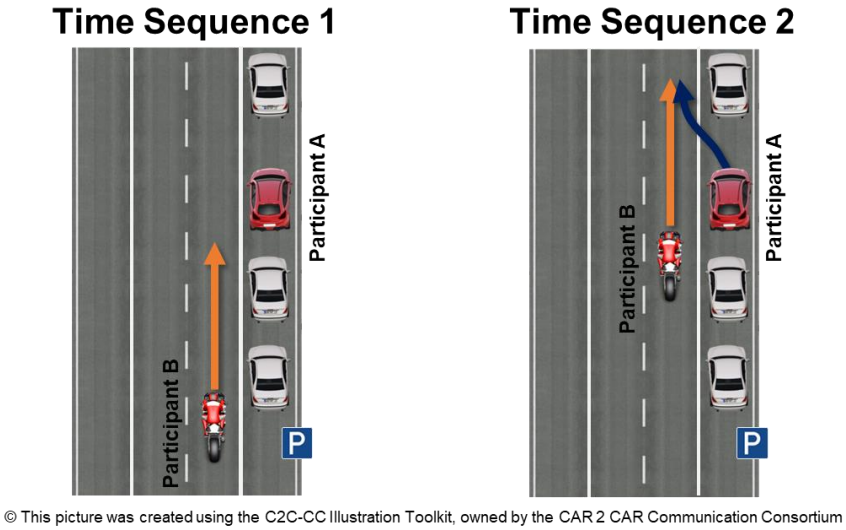

Figure 9: Scenario 3 - Participant A wants to drive out of the parking space and overlooks Participant B, who is already in the main lane and is passing Participant A.

The starting situation, shown in *Figure 9*, contains Participant A (red passenger car) that is parking on the right side of a straight lane. Participant B (PTW) is approaching from behind and is positioned in a main lane left to Participant A. Participant A wants to leave the parking space. The main challenge characterising this scenario is human error. View obstruction is not an important contributing factor. Challenges could occur when Participant B is riding above the legal speed limit. This might increase the chance of Participant A overlooking Participant B. In addition, it is possible that Participant A has focused on other road users or has forgotten to check if the lane is free.

2.8 Display / Alert Principle

2.8.1 ADAS only

Participant A would most probably receive a warning comparable to a blind spot detection system as the conflict partner is approaching from behind and typically left to Participant A. The notification itself should contain the direction of the threat and might therefore also be implemented in a side mirror, for instance. An additionally auditory notification seems appropriate as a fast response is required. The intention is to stop the vehicle from turning. If Participant A fails to react towards the warning the vehicle might also be stopped autonomously (at least for passenger car vehicles etc.). Participant B would receive a warning comparable to a Forward Collision Warning when Participant A crosses Participant B's trajectory.

2.8.2 ADAS + C-ITS

In addition to the above-mentioned advantages of ADAS, the C-ITS application could trigger earlier notifications. Participant A could receive a notification about the oncoming Participant B if the latter has started the overtaking manoeuvre already and Participant A is about to start the left-turn (e.g., recognized by the indicator). Participant B could receive a notification about Participant A's intention to turn, when the overtaking manoeuvre is initiated. The main aim in both cases would be to direct the attention towards the other conflict partner that is either not yet visible or whose intention did not become clear. It must be assumed that visual information is necessary to explain which other vehicle is the conflict partner as different vehicles might be moving in the near surrounding. In order to quickly guide the driver/ rider's attention towards that information an auditory or haptic notification would probably be necessary.

3. Supplemental Information

Neukum, A. (2011). Wenn das Fahrzeug mehr sieht als der Fahrer – Konsequenzen für die Gestaltung der Fahrer-Fahrzeug Schnittstelle. Paper presented at the Ko-FAS Zwischenpräsentation, Aschaffenburg, Germany

Winner, H., Hakuli, S., Lotz., L. & Singer, C. (Hrsg.). (2015). Handbuch Fahrerassistenzsysteme: Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort. Springer Vieweg: Wiesbaden. S. 906.

4. Abbreviations

ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
C2C-CC	CAR 2 CAR Communication Consortium
CAM	Cooperative Awareness Message
CMC	Connected Motorcycle Consortium
C-ITS	Cooperative Intelligent Transport Systems
DNPW	Do Not Pass Warning
FCS	Forward Collision Warning
GIDAS	German In-Depth Accident Study
MAEB	Motorcycle Autonomous Emergency Braking
PTW	Powered Two-Wheeler
TTC	Time-To-Collision
V2X	Vehicle-to-everything