Connected Motorcycle Consortium

CMC Basic Specification

Overview

CMC has developed a Basic Specification related to the incorporation of powered two-wheelers in Cooperative Intelligent Transport Systems, with the ultimate goal of enhancing rider safety. The CMC Basic Specification consists of multiple documents, and this document represents the summary.

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1 Safety for Powered Two Wheelers

1.1 Powered Two Wheelers

The term Powered Two Wheeler (PTW[1]) is used to refer generically to motorised two-wheeled road-going vehicles, commonly called motorcycles or scooters. PTWs are used for a variety of purposes. According to a survey[2] conducted in Europe, the primary use of PTWs is leisure riding, accounting for 49% of total usage. The second most significant important use is commuting, which accounts for 30% of total usage.
PTWs have great potential in the future of mobility. Not only will the current importance of PTWs for leisure continues, but also they will also have a growing role in commuting due to their greater efficiency in urban traffic as a result of their small size and environmental footprint.

Figure 1: A variety of Powered Two Wheelers

1.2 PTW accidents

Unfortunately, when looking at fatality rate (Figure 2), the PTW rider is more likely to be killed or seriously injured in an accident than other types of road users. The reported number for PTW riders is high and they are therefore typically included in the Vulnerable Road Users (VRU) group along with pedestrians and pedal cyclists. PTW riders are considered to be a special case of VRU because they share the same roads with cars and travel at similar speeds.

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

[2] Delhaye, A., Marot, L. (2015), The Motorcycling Community in Europe, Deliverable 9 of the EC/MOVE/C4 project RIDERSCAN. (https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/projects_sources/riderscan_d9.pdf, accessed on 22.10.2020)

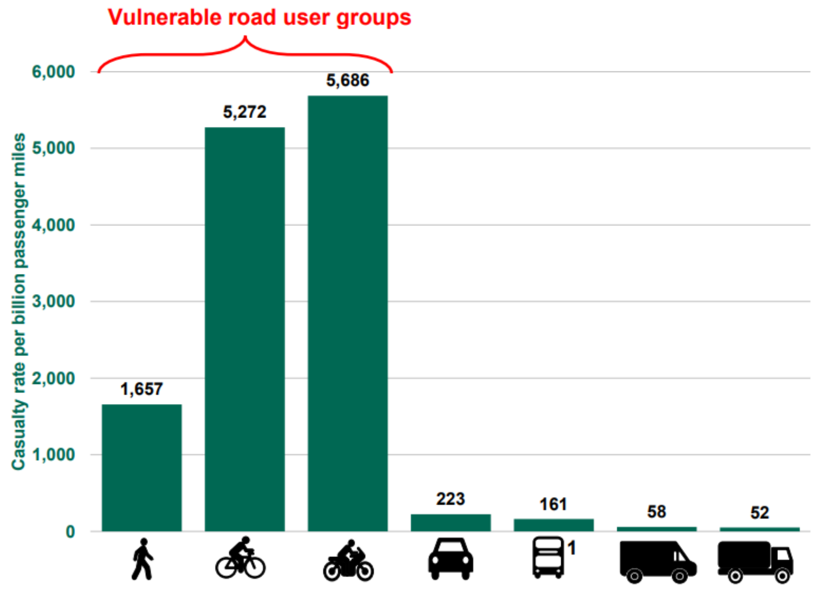

Figure 2: Casualty rate per billion passenger miles by road user type, Great Britain [3]

The main cause of PTW accidents is that PTWs are overlooked by other vehicles. As shown in Table 1, other vehicles are the primary accident cause of PTW accidents in more than 50% of total accidents according to the study[4] conducted by ACEM. Because of this, drivers of other vehicle drivers need to pay particular attention to PTWs.

Table 1: Primary accident contributing factor [4]

Factor	Percentage
Human – Other Vehicle driver	50.5
Human – PTW rider	37.4
Environmental	7.7
Vehicle	0.3
Other failure	4.1
Total	100

Even though the safety features of the vehicle have been enhanced in recent years, PTW rider fatalities still accounted for 28% of the 1.35 million[5] fatalities worldwide in 2016.

[3] Department of Transport, Reported road casualties in Great Britain: 2018 annual report. (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/834585/reported-road-casualties-annual-report-2018.pdf, accessed on 22.10.2020)

[4] ACEM, In-Depth Investigation of Motorcycle Accidents, Version 2.0 of the MAIDS report (http://www.maids-study.eu/pdf/MAIDS2.pdf, accessed on 22.10.2020)

[5] World Health Organization, Global status report on road safety 2018 (https://www.who.int/publications/i/item/global-status-report-on-road-safety-2018, accessed on 22.10.2020)

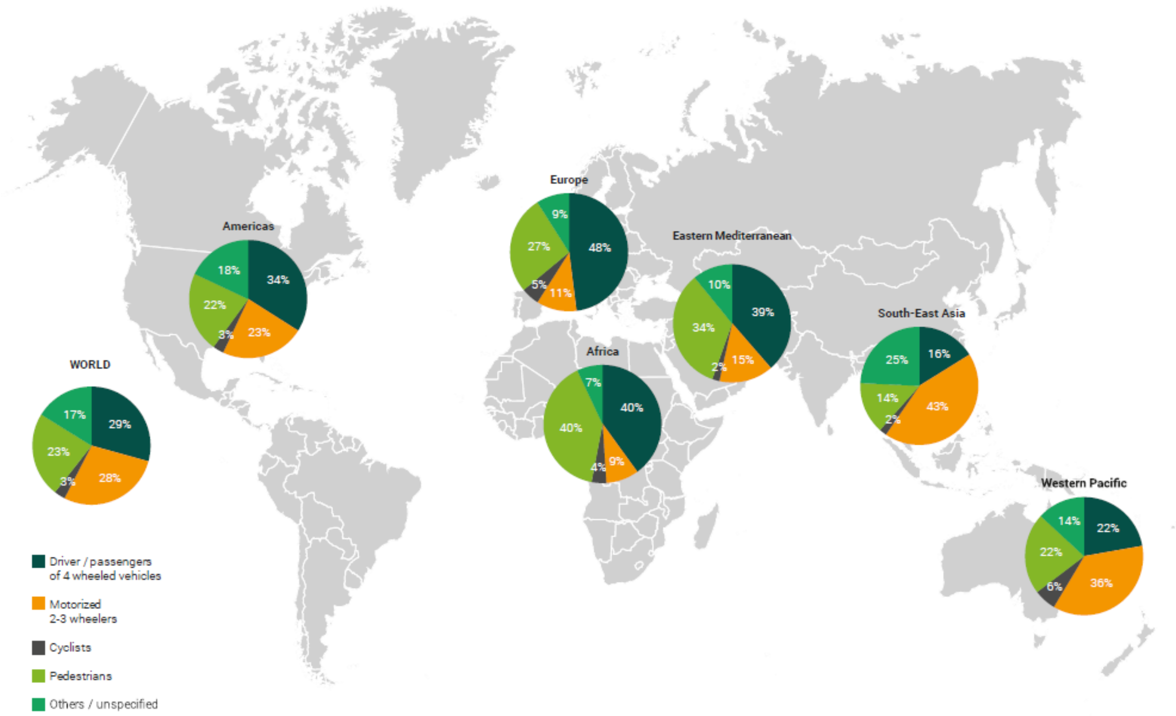

Figure 3: Distribution of deaths by road user type [5]

In the European Union in 2016, the total number of fatalities was 25,651, of which 3,657 were PTW riders. PTW rider fatalities accounted for more than 14% of the total road fatalities. As shown in Figure 4, the rate of PTW rider fatalities had been declining year by year, however in recent years the rate of decline has slowed down.

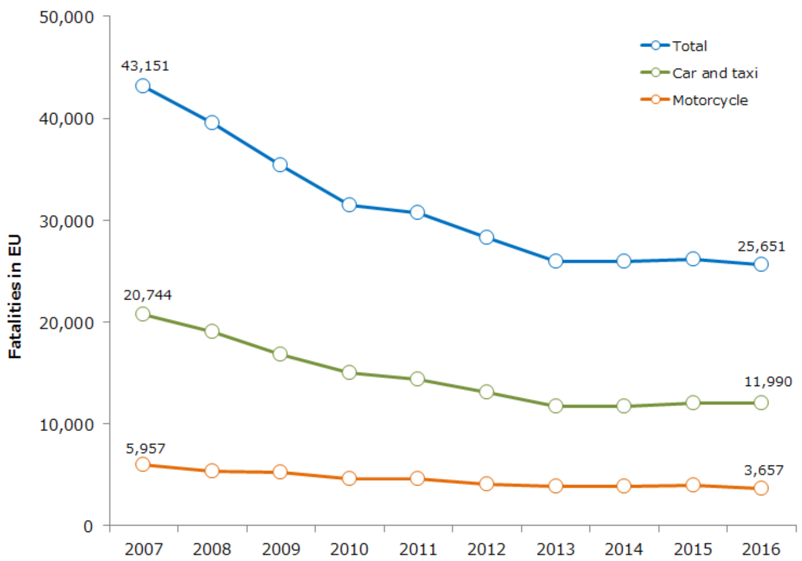

Figure 4: Annual number of fatalities in EU [6]

[6] European Commission, Annual Accident Report 2018 (https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2018.pdf, accessed on 22.10.2020)

1.3 Safety Technology: C-ITS

Automotive industry is continuously working on active safety features that aim to prevent accidents. Especially, Cooperative Intelligent Transport Systems (C-ITS) are an example of a safety technology for cars that is also applicable to PTWs.
C-ITS is a communication technology that allows road vehicles to communicate with each other, with roadside infrastructure and with other road users. These systems are often referred to as Vehicle-to-Vehicle (V2V) or Vehicle-to-Infrastructure (V2I) communication. Assuming the interoperability with other vehicles is ensured, C-ITS has a high potential to prevent accidents before they occur. PTWs are often overlooked in traffic and the riders are much more vulnerable than car occupants. Nevertheless, the role of C-ITS for PTWs has not been well considered in the past.

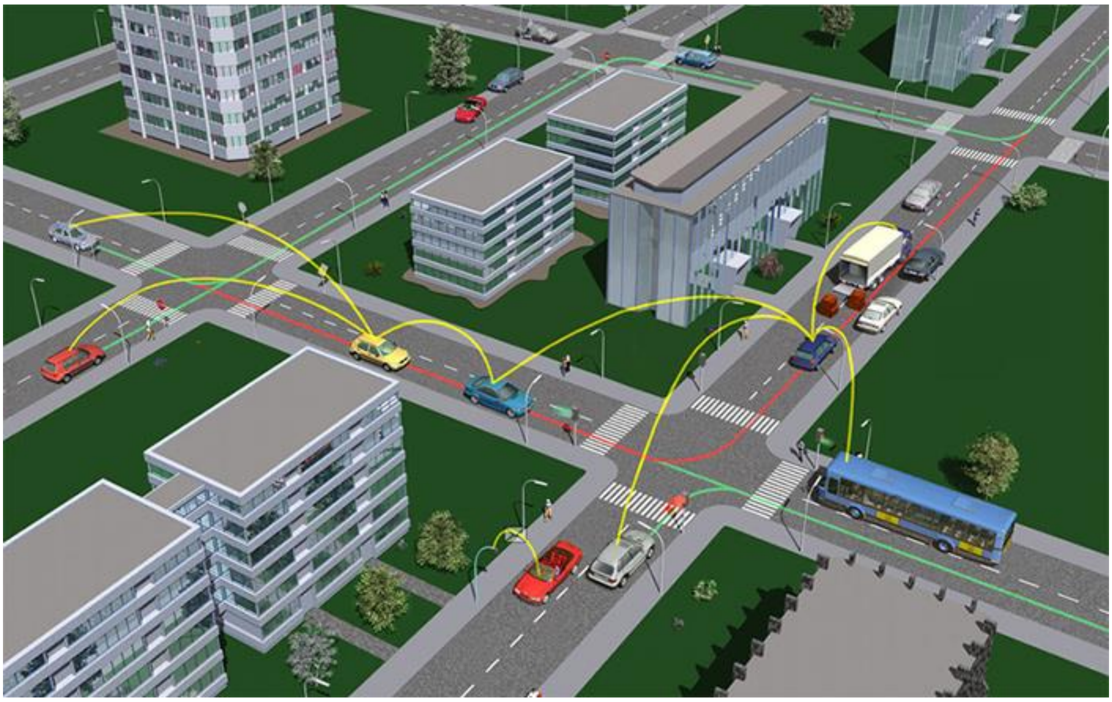

Figure 5: Cooperative Intelligent Transport System without PTW [7]

The potential for enhanced safety of C-ITS applications improves as the number of active users and devices increases. Therefore, the penetration of C-ITS technology is a critical factor for road safety. According to the impact assessment[8] of C-ITS deployment conducted by the European Commission, annual deployment is predicted to increase rapidly for new vehicles, aftermarket and infrastructure as shown in Figure 6. An increase of C-ITS systems in the market should enhance overall road safety.

[7] CAR 2 CAR Communication Consortium (https://www.car-2-car.org, accessed on 22.10.2020)

[8] European Commission, Study on the Deployment of C-ITS in Europe: Final Report (http://ec.europa.eu/transport/sites/transport/files/2016-c-its-deployment-study-final-report.pdf, accessed on 22.10.2020)

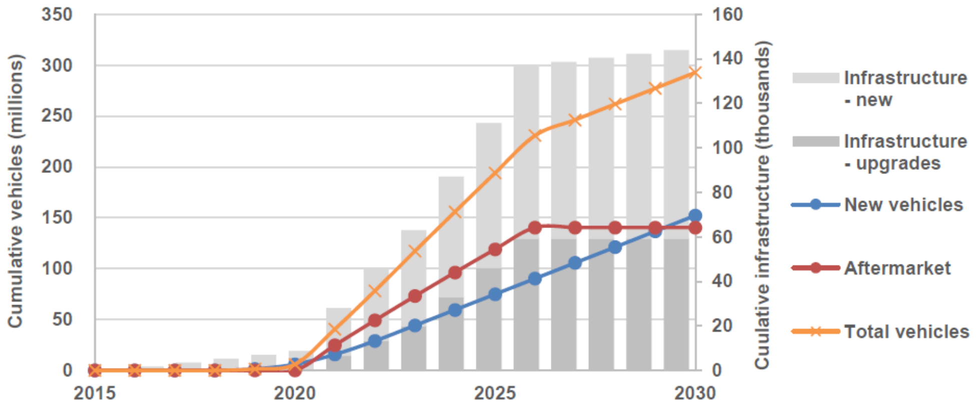

Figure 6: Deployment of C-ITS systems to both vehicles and infrastructure [8]

Whilst C-ITS technology has great potential to improve safety for both cars and PTWs, specifications for cars cannot simply be transferred to PTWs because of the different characteristics, such as vehicle size and dynamics. This means that C-ITS systems and the applications for cars need to be specially tailored to PTWs.

1.4 CMC – Connected Motorcycle Consortium

So far, C-ITS specifications for cars have not sufficiently taken PTW specific safety factors into consideration, and as a result PTW rider safety will not fully benefit from C-ITS systems. There are also challenges for the adaptation of these specifications to PTWs. The Connected Motorcycle Consortium (CMC) was established to tackle both issues. By collaborating between PTW manufacturers, suppliers, researchers and associations CMC aims to make PTWs part of the future connected mobility.

CMC is an R&D platform to foster co-operation in research and development in the field of C-ITS. It is open to a wide range of organisations including motorcycle OEMs, automotive parts suppliers and research institutions. The key objective of CMC is to enhance safety for PTW riders by making PTWs part of C-ITS systems.

1.5 Target vehicle of CMC

The target vehicles of CMC Basic Specification in general follow the definition of PTWs in the European Union[9], excluding powered cycle with pedals. This means L1e (excl. L1e-A) and L3e are the focus. However, other vehicle types such as three-wheeled vehicles (i.e. L2e, L5e) are also included if the vehicle dynamics are similar to PTWs.

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[9] REGULATION (EU) No 168/2013

2 Structure of the CMC Basic Specification

The C-ITS specification for PTWs developed by CMC is called the "CMC Basic Specification". CMC Basic Specification is composed of 7 documents as explained in Table 2.

Table 2: CMC Basic Specification

Document Name	Explanation	Section
Assessment of C-ITS application potential	A review of the potential contribution of C-ITS applications toward rider safety by accident analysis.	3.1
Application Specification	Use cases and technical description of C-ITS applications for PTWs.	3.2
System Specification	System architecture and challenges for PTW C-ITS with its solutions.	3.3
Evaluation Report	Evaluation test result and analysis conducted to verify applications and system.	3.4
CMC Position towards other standards	Position of CMC towards other specifications i.e. C2C-CC, 5GAA, ETSI.	3.5
Application Roadmap	Roadmap of C-ITS applications for PTWs based on safety benefit and technical evolution.	3.6
HMI Guideline	Guideline for HMI on C-ITS for PTWs.	3.7

Figure 7 illustrates the structure of each Chapter within CMC Basic Specification. "Assessment of C-ITS application potential" was prepared to identify the important accidents types for PTW and C-ITS application potential. Based on this, high priority applications are defined in "Application Specification" with important use cases. Then, "System Specification" describes system challenges for PTWs and potential solutions to implement C-ITS applications. These applications and system have been verified and the results are described in "Evaluation Report".

Through these documents, CMC has compiled the necessary changes to other C-ITS standards (i.e. C2C-CC, 5GAA, ETSI) into "CMC Position towards other standards". Furthermore, "Application Roadmap" was created from the point of view safety benefits and technical evolution.

HMI specification is out of scope of CMC. However, CMC is compiled "HMI Guideline" to provide recommendations to HMI design specifically for C-ITS applications of PTW.

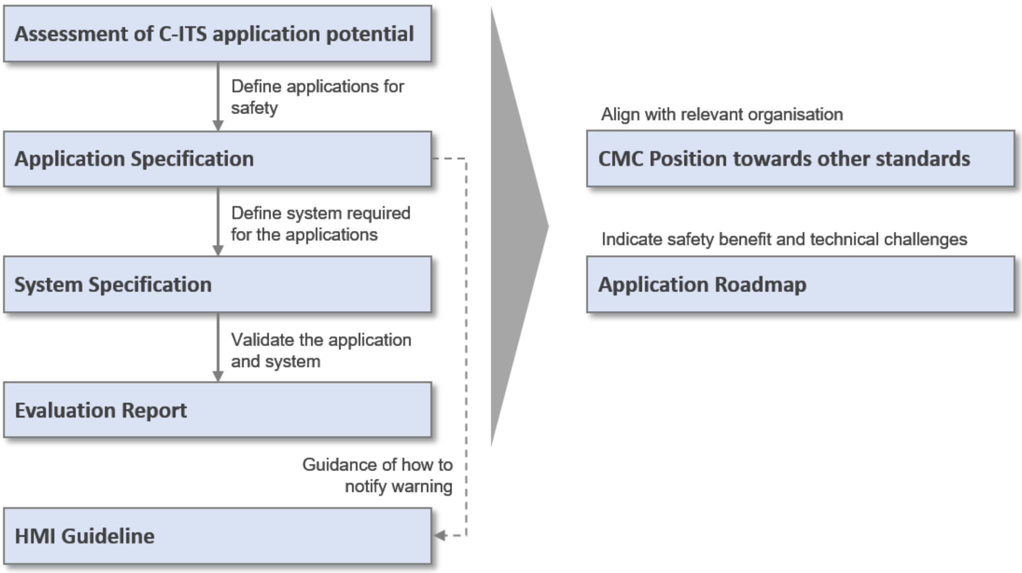

Figure 7: Structure of CMC Basic Specification

Chapter 3 contains a short summary of each document that constitutes CMC Basic Specification.

3 Summary of the CMC Basic Specification

As explained in Chapter 2, CMC has developed a collection of specifications for C-ITS enabled PTWs called CMC Basic Specification. In this chapter, a short introduction of each document introduced in Table 2 is provided with its interrelationship.

3.1 Assessment of C-ITS application potential

3.1.1 Typical PTW accident scenario

The primary cause of accidents involving PTWs is other road users overlooking them in traffic.

One example of a typical accident scenario is shown in Figure 8. This photograph is taken from the viewpoint of a car. The car is turning left while a PTW is approaching from the front, but the car driver is not aware of the presence of the PTW. This situation results in a crash. Since PTWs do not offer the same level of protection to their riders as cars to their occupants, there is a higher risk of serious injury for PTW riders than for car drivers.

In this situation, the most important role of C-ITS technology is to notify other vehicles of the presence of the PTW, so that drivers can take action to avoid potential crashes.

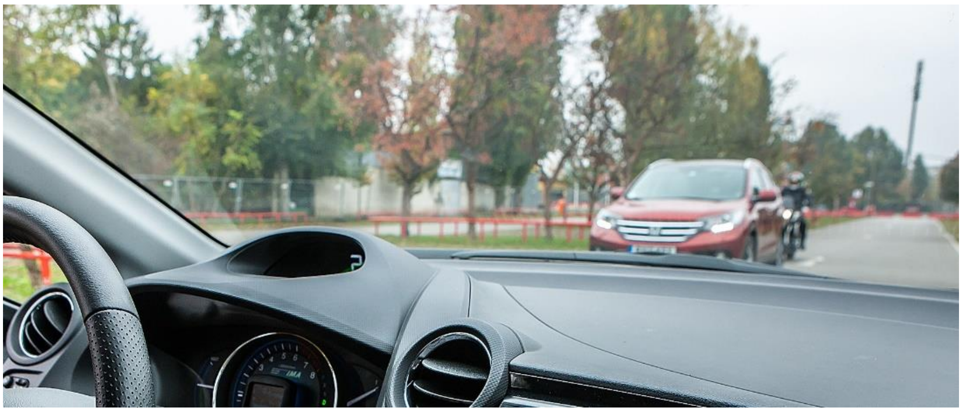

Figure 8: Difficulty of noticing the PTW from Car perspective

3.1.2 Accident analysis

An in-depth accident analysis has been conducted by CMC based on the GIDAS database and German national accident statistics. The example of Figure 9 shows an analysis of the frequency of each type of accident scenario, separated by accident causer (i.e. either the PTW or the other road user).

The outcomes show that in the Crossing traffic scenario, the other road user is most frequently the accident causer. Often, the other vehicle driver overlooks the PTW rider or misinterprets the speed or distance of the PTW. In that respect, this situation is similar to the Lane change, Left turn and U-turn scenarios.

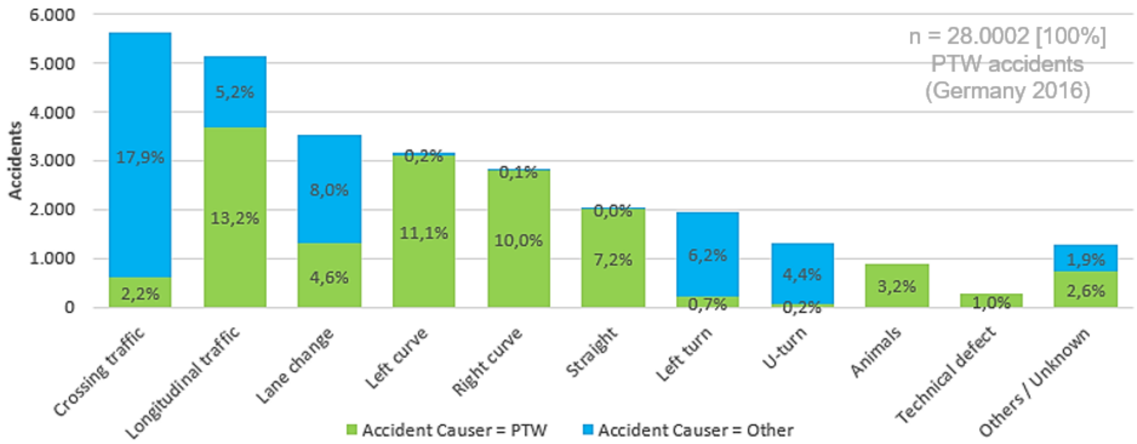

Figure 9: Accident Scenario Analysis, Germany 2016

3.1.3 Assessment of C-ITS application potential for PTWs

Based on the accident analysis result, the potential of C-ITS technologies for safety was analysed. The precondition of the analysis is that the penetration of C-ITS system in the market is 100%, so the figures shown in this section is the maximum potential.

The contribution of C-ITS applications to PTW rider safety is shown in Figure 10. Each application was split by accident causer. Note that an explanation of each application is described in "Application Specification" of which a summary is written in 3.2.

MAI/MAW defined in 3.2.3 are able to address 23% of all PTW accidents. This is the figure when other vehicles use these applications, therefore it is important for other vehicles to implement these applications to achieve a high potential impact on rider safety.

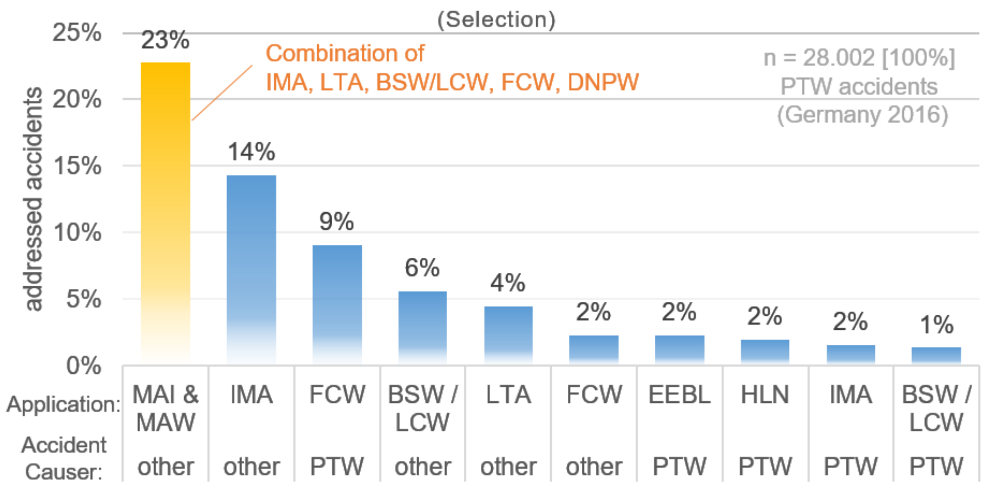

Figure 10: Potential of C-ITS applications for PTW

Further analysis of the results can be found in CMC Basic Specification "[Assessment of C-ITS application potential]".

3.2 Application Specification

3.2.1 Grouping of applications

The analysis from section 1 indicated that rider safety could be enhanced through the following three categories.

A) <u>See and Be Seen by others</u>
It is important for drivers of other vehicles, especially cars, to detect PTWs in order to avoid accidents. Around half of all accidents are caused by a car and can be potentially avoided by detecting PTWs beforehand.

B) <u>Be Aware of the unexpected</u>
It is also important for PTWs to notice potential hazards that are unexpected or 'out of the ordinary', so that the rider can take action to prevent them developing into critical situations.

C) <u>Ride with Less Stress</u>
Reducing rider stress levels also has an influence on safety, although its contribution cannot be extracted from accident data.

CMC has developed specifications for C-ITS applications for deployment in both PTWs and other vehicles based on these three categories.

3.2.2 List of C-ITS applications for PTW

CMC has developed specifications of 19 applications, as listed in Table 3. In this table, each application is classified using the categories defined in 3.2 .
A detailed description of each application can be found in the CMC Basic Specification "Application Specification".

Table 3: List of C-ITS applications for PTW

Abbreviation	Application	Category
IMA	Intersection Movement Assist	See and Be Seen by others Note: These applications are explained as MAI/MAW (See 3.2.3)
LTA	Left Turn Assist	
LCW/BSW	Lane Change Warning / Blind Spot Warning	
FCW	Forward Collision Warning	
DNPW	Do Not Pass Warning	
EEBL	Electronic Emergency Brake Light	Be Aware of the unexpected
HLN	Hazardous Location Notification	
AEVW	Approaching Emergency Vehicle Warning	
AWW	Adverse Weather Warning	
RWW	Road Works Warning	
SVW	Stationary Vehicle Warning	
TJW	Traffic Jam Warning	

DCW/CSW	Dangerous Curve Warning / Curve Speed Warning	
WWD	Wrong Way Driving	
SSVW	(Stop) Sign Violation Warning	
TLVW	Traffic Light Violation Warning	
GLOSA	Green Light Optimal Speed Advisory	Ride with Less Stress
IVS	In-Vehicle Signage	
LMA	Lane Merge Assist	

Category "See and Be Seen by others" are applications that inform the driver of the presence of PTW by using Cooperative Awareness Message (CAM) transmitted by PTW. Therefore, it is important for automobile OEMs to support these applications. CMC has named a combination of these applications MAI/MAW to differentiate them from other applications (See 3.2.3).

For certain applications which trigger Decentralized Environmental Notification Message (DENM), in the category of "Be Aware of the unexpected", the triggering conditions are similar to car, however some modifications are required for PTWs due to specific PTW characteristics, for example the presence of a vehicle stand.

3.2.3 MAI/MAW

In CMC, applications categorised as "See and Be Seen by others" are defined as MAI (Motorcycle Approach Indication) / MAW (Motorcycle Approach Warning).

MAI provides information to the car driver to indicate the presence of an approaching PTW, even if the risk of a collision is not high, while MAW provides a warning to the car driver, so that the driver can take action to avoid an imminent collision with an approaching PTW.

MAI/MAW consist of Vehicle-to-Vehicle (V2V) applications that support PTW use cases. CMC provides the important use cases and technical specifications which effectively contribute to the safety of PTWs.

One of the use cases of MAI/MAW is shown in Figure 11. In this scenario with crossing traffic, the car driver is informed of an approaching PTW, even when the driver is unable to see the PTW due to an obstruction or poor weather conditions.

Based on the CAM transmitted by the PTW, if the other vehicle detects a possible crossing with the PTW, or if the relative distance between the two vehicles decreases below a certain threshold, a notification or warning is shown to the car driver.

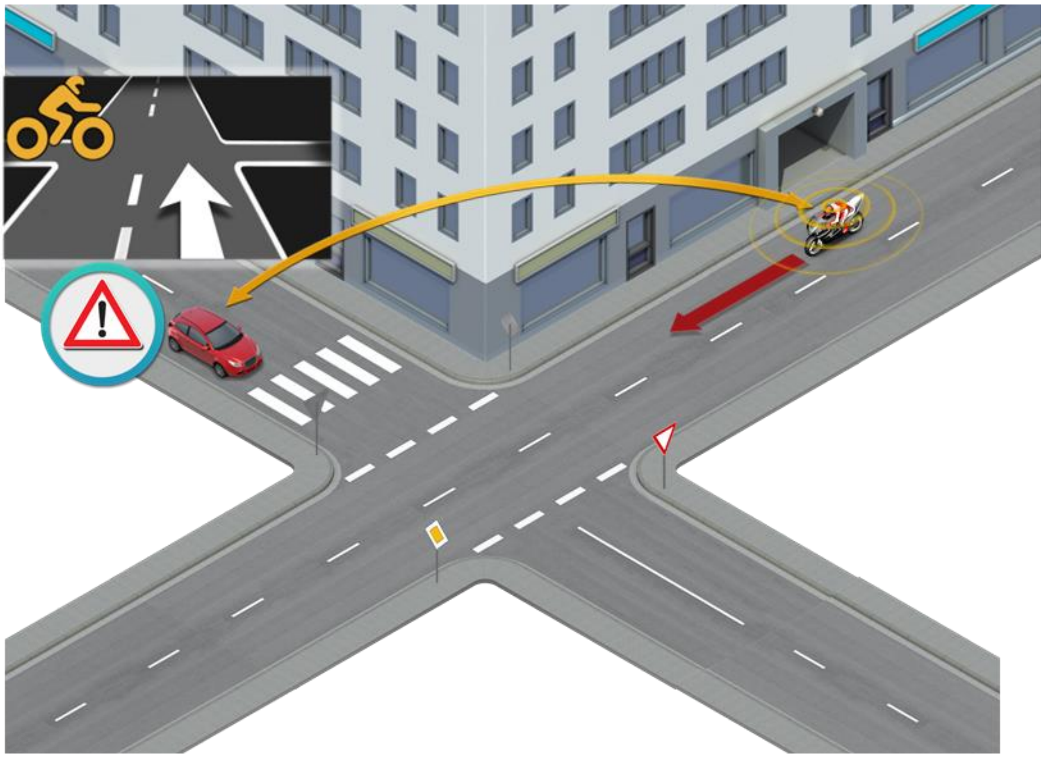

Figure 11: Example use case of MAI/MAW

3.3 System Specification

In order to implement C-ITS applications, hardware and system specifications for cars cannot simply be transferred to PTWs. Further consideration is required to meet PTW-specific characteristics. CMC Basic Specification "System Specification" describes system architecture and PTW specific components and systems.

3.3.1 Hardware diagram

Figure 12 shows a high-level hardware diagram of a PTW with C-ITS functionality. Each component is similar to those used in cars, but there are some specific challenges for PTWs, i.e. C-ITS antenna, localisation system and security.

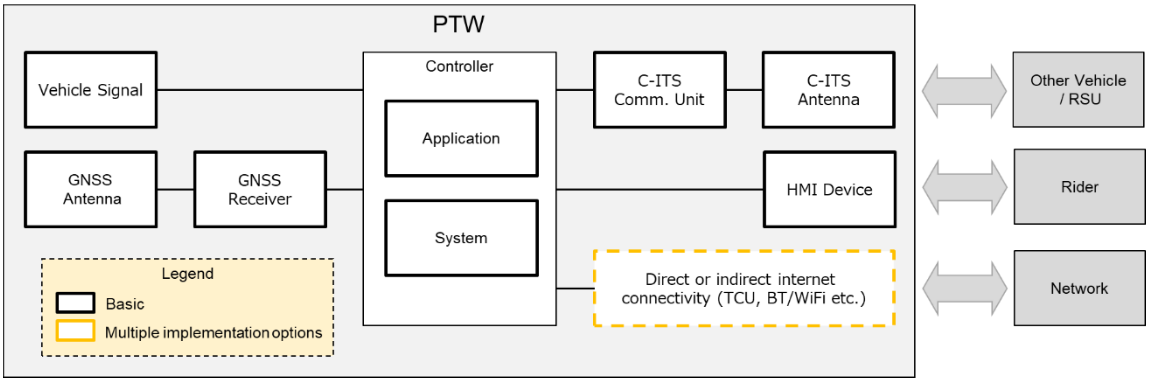

Figure 12: Hardware Diagram

3.3.2 C-ITS Antenna

The standard mounting position on a car – the roof top – is not available on a PTW. Therefore, a suitable solution (dimension, position, integration) must be defined for PTWs.
The usage of two antennas in diversity mode is one potential solution. Those antennas need to be mounted in an appropriate position, for example front and rear.

Figure 13: Mounting positions of the antennas

3.3.3 Localisation

The PTW position on the road in C-ITS systems is usually determined by the Global Navigation Satellite System (GNSS). However, any estimation necessary when the system has poor satellite signals, needs special consideration for example when the PTW is surrounded by high buildings or is ridden in a tunnel.
In this case, the position is usually calculated based on the last know position by GNSS and a course is estimated using the vehicle sensors. This process is called “Dead Reckoning”.
This process is more of a challenge for PTWs than it is for other vehicles, because a PTW leans when it turns or navigates a curve, making a difference compared to cars.
In CMC, a special Dead Reckoning algorithm for PTWs was developed to solve this problem. The software was developed and installed to prototype PTWs and evaluated.

3.4 Evaluation Report

3.4.1 Prototype PTW

CMC has built several prototype PTWs to test C-ITS systems and applications. Figure 14 shows the PTW prototypes developed by CMC.
The C-ITS system described in this chapter and some important applications for PTWs have been developed and installed on these prototypes.

Figure 14: Prototype PTWs

3.4.2 System test

With the prototype PTWs, CMC has conducted tests to confirm the feasibility of using a PTW specific C-ITS system, especially the antenna and the localisation algorithm. Figure 15 illustrates one of the test scenarios to evaluate antenna performance in a near real world situation. In this example, two cars are parked between transmitter and receiver, but with the two-antenna solution, still over 500m communication range was still achieved. Note that the performance of both front and rear antennas was tested by riding in both directions as shown by the red arrow in Figure 15.

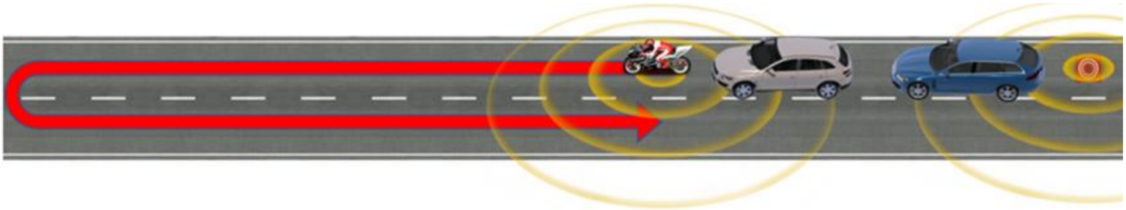

Figure 15: Antenna Dynamic test

3.4.3 Application test

CMC has developed software for some applications and conducted an evaluation test with prototype PTWs and cars in order to:

1. Verify if C-ITS applications can be implemented on PTWs.
2. Verify if parameters defined in "Application specification" are acceptable.

Figure 16 shows the MAI evaluation test. A PTW equipped with a C-ITS system is transmitting CAMs, while a car with the MAI application successfully detects and processes these messages in order to notify the information of PTW to the driver.

CMC has conducted a variety of such real-world tests using prototype vehicles to verify the parameters that were defined in the theoretical study.

Figure 16: MAI evaluation test

A detailed description of the application test is included in CMC Basic Specification "Evaluation Report".

3.5 CMC position towards other standards

Other relevant C-ITS standards such as C2C-CC, 5GAA and ETSI have been reviewed from the PTW point of view. Based on these standards, CMC has developed PTW application and system specifications and summarised a common position towards these standards. Relevant requirements are cited and directly commented as a proposal.

One example is the comment towards C2C-CC Basic System Profile [10] "Triggering Conditions and Data Quality Stationary Vehicle Warning" which describes the triggering conditions for stationary vehicle warning for the following three C-ITS services:

- 'stationary vehicle warning — stopped vehicle'
- 'stationary vehicle warning — broken-down vehicle'
- 'stationary vehicle warning — post-crash'

[10] Car 2 Car Communication Consortium Basic System Profile V1.5.1 (https://www.car-2-car.org/documents/basic-system-profile/ accessed on 22.10.2020)

The precondition of the stopped vehicle and the broken-down vehicle includes the following description (RS_tcStVe_118, RS_tcStVe_140).

> *"If the preconditions in RS_tcStVe_117/ RS_tcStVe_139 and all of the following conditions are satisfied, the triggering conditions for this C-ITS service are fulfilled and the generation of a DENM shall be triggered:*
>
> - *the ego vehicle has enabled hazard lights;*
> - *the vehicle is stationary;*
> - *the Triggering Timer has expired.*
>
> *Note: PTWs may not be equipped with hazard lights. PTWs without hazard lights will not trigger this use case."*

For PTWs it is not mandatory to be equipped with hazard lights, so the first condition may not be applicable. CMC suggested adding a note to make aware that PTWs which are not equipped with hazard light cannot trigger this use case. As a result, C2C-CC has decided to reflect the suggestion in the latest version of the specification.

All such comments are described in CMC Basic Specification "CMC Position towards other standards".

3.6 Application Roadmap

To further enhance rider safety and to make sure that PTWs can communicate with other vehicles in the future, C-ITS applications for PTWs need to be continuously developed and improved.
CMC has created the "Application Roadmap", shown in Figure 17, which indicates C-ITS applications for PTWs in the future. The most important applications in terms of safety benefit are so-called "See and Be Seen by others" applications. However, these applications still pose several technical challenges and also require collaboration with other vehicle manufacturers. The applications in the other two categories "Ride with Less Stress" and "Be Aware of the unexpected" are more similar to the equivalent applications in cars.

Details of the roadmap can be found in CMC Basic Specification "Application Roadmap".

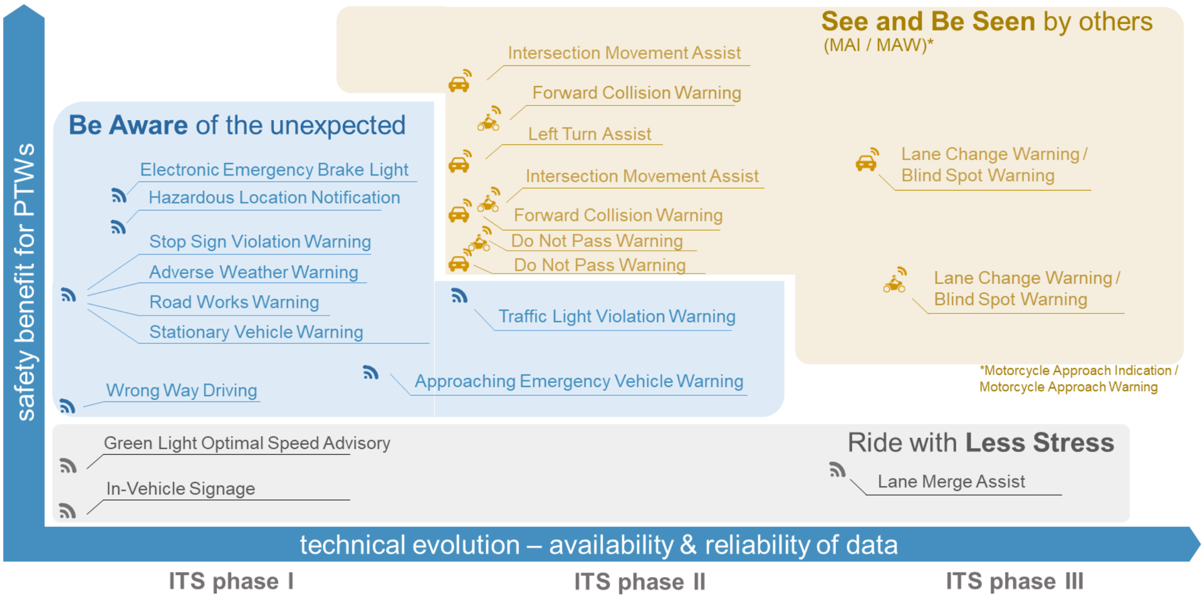

Figure 17: Application Roadmap

3.7 HMI Guideline

HMI requirements for C-ITS systems are not defined in CMC, because HMI policies differ amongst OEMs, and are considered as a competitive area. Despite this, an inconsistency between HMIs provided by different OEMs can cause confusion to the riders, therefore resulting in decreased rider safety.

For this reason, CMC has created an HMI guideline which contains design recommendations and provides examples to support PTW HMI design. Following these recommendations is not mandatory but aims to ensure consistent design of PTW HMIs that offer ideal support to the rider whilst minimizing negative aspects such as distraction.

One example is to use similar colours to communicate similar meanings. By using consistent colour-coding for similar messages, rider confusion will be minimised when riding PTWs from different OEMs. CMC recommends to refer to ISO15008[11] for applicable information on colour combinations to be used or to be avoided.

All guidelines and details can be found in CMC Basic Specification "HMI Guideline".

[11] ISO 15008:2017, Road vehicles - Ergonomic aspects of transport information and control systems - Specifications and test procedures for in-vehicle visual presentation

4 Conclusions

For the purpose of rider safety, CMC has developed CMC Basic Specification of C-ITS technology for PTWs.

Study of PTW accidents and the potential safety benefit of C-ITS has been conducted and described in “Assessment of C-ITS application potential for PTWs”. C-ITS Applications and systems for PTWs have been defined in “Application Specification” and “System Specification”.

CMC has also prepared prototype C-ITS vehicles and conducted evaluation tests to verify the system, applications and their parameters. The test results were summarised in the “Evaluation Report”.

CMC Basic Specification is strongly related to other C-ITS standards, such as the Basic Specification Profile defined by the C2C-CC. Therefore, the “CMC position towards other standards” has been created to describe the points that need to be adapted from the original standards in order to accommodate PTWs.

To indicate the correlation between the safety benefits of C-ITS applications and their technical challenges for PTWs, the “Application Roadmap” has been defined. CMC revealed that an alignment in HMI design is important for rider’s safety as described in the “HMI guideline”.

CMC will continue to develop and enhance CMC Basic Specification and to communicate with C-ITS stakeholders so that C-ITS technology for PTWs can be widely accepted by the C-ITS community.

Abbreviations

5GAA	5G Automotive Association
ACEM	European Association of Motorcycle Manufacturers
C2C-CC	CAR 2 CAR Communication Consortium
CAM	Cooperative Awareness Message
CMC	Connected Motorcycle Consortium
C-ITS	Cooperative Intelligent Transport Systems
DENM	Decentralized Environmental Notification Message
ETSI	European Telecommunications Standards Institute
EU	European Union
GIDAS	German In-Depth Accident Study
GNSS	Global Navigation Satellite System
HMI	Human-Machine Interface
ITS	Intelligent Transport Systems
MAI	Motorcycle Approach Indication
MAW	Motorcycle Approach Warning
OEM	Original Equipment Manufacturer
PTW	Powered Two Wheeler
RSU	Road Side Unit
R&D	Research and Development
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
VRU	Vulnerable Road Users

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YAMAHA MOTOR CO., LTD	Taro Onoue
YAMAHA MOTOR CO., LTD	Yoshiaki Uchida
YAMAHA MOTOR CO., LTD	Yasushi Hashimoto
YAMAHA MOTOR CO., LTD	Mariko Nohara
YAMAHA MOTOR CO., LTD	Hayato Nishioka
YAMAHA MOTOR EUROPE N.V.	Hennes Fischer