Connected
Motorcycle
Consortium

CMC Basic Specification

HMI Guideline

This document aims to create a safe Human-Machine Interface design guideline, according to state-of-the-art research and technologies. Even the best C-ITS application can only produce a safety benefit when potential warnings are recognised by the rider.

Document Information

Document Title:	HMI Guideline
Version:	1.0
Release Date:	11/12/2020

Disclaimer

Index

1 Preamble

Any rider assistance system that informs or warns the rider about a potential hazardous situation, needs to focus on a proper human-machine interface (HMI) to deliver this warning in a non-distractive and salient way. Consequently, the HMI is a highly relevant component of any C-ITS application when it comes to the improvement of safety for Powered Two-Wheeler[1] (PTW) riders. Therefore, the main aim of this document is to provide design guidance for HMIs on PTWs for Cooperative Intelligent Transport Systems (C-ITS).

This document refers to the National Highway Traffic Safety Administration (NHTSA) guideline "Human Factors Design Guidance For Driver-Vehicle Interfaces" [2] and has been commented on by the Connected Motorcycle Consortium (CMC) to be applicable to PTWs. As the PTW sector does not have sufficient research experience regarding this topic yet, a first step towards a PTW specific HMI guideline is the assessment of an established HMI guideline from the car sector as to the applicability to PTWs. The assessment has been done by HMI experts from different PTW Original Equipment Manufacturers (OEMs) together with the Wuerzburg Institute for Traffic Sciences (WIVW GmbH) as independent human factors research institute. The PTW specific comments and recommendations are based on prior experience, OEM internal tests and available literature or even studies conducted within the CMC.

The NHTSA guideline contains empirically proven HMI design recommendations that have been gathered over decades. This sophisticated document was therefore chosen as the baseline to start from. Modifications for the application of car guidelines to PTW are clearly necessary, because there are major differences between the two vehicle concepts (Figure 1). These differences concern ergonomics, available space for HMI applications, driver positioning or influence of environmental conditions to name just a few of them.

This HMI guideline is only applicable to human-machine interfaces directly installed on the PTW. It does not cover other fields of application such as devices installed in a PTW helmet. Even if this might be a useful HMI design possibility one day, it is out of scope for this guideline.

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

The target vehicles in this document are Powered Two-Wheelers (PTWs). PTW is used to refer generically to motorised two-wheeled road-going vehicles, commonly called motorcycles or scooters. As defined by the European Commission, PTW includes all two-wheel vehicles regardless of their engine capacity. However, this document can be extended to other vehicle types such as three wheeled vehicles if the vehicle dynamics are similar to those of a PTW.

[2] Campbell, J. L., Brown. J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., … & Morgan, J. L.. (2016). Human factors design guidance for driver-vehicle interfaces (Report No. DOT HS 812 360). Washington, DC: National Highway Traffic Safety Administration.

		AUTOMOTIVE	PTW
VIDEO	Position	The display are positioned 10-12 degrees under the line of sight	The display are positioned 30-50 degrees under the line of sight (depends by type of PTW)
	Distance	at 400 mm to driver's eyes	at 500 mm to driver's eyes
	Illuminance	The cockpit is close, except windows and windscreen	Solar reflection is the most problem
	Variables	Text, colour, icons, position, pictograms	Text, colour, icons, position, pictograms
	Action to receive	Move eyes in display direction	Move eyes in display direction
	Obstacle to receive	Display partially obstructed by wheel	Field of Vision limited by helmet
	Size	Usually more than 200mm	Usually less than 150mm
AUDIO	Position	depends on vehicle, not near to ear	2 speakers, very near to ear
	Variables	Speech, Tones, Volume, Frequency	Speech, Tones, Volume, Frequency
	Action to receive	No action	No action
	Obstacle to receive	less than 70 dB (depends on vehicle)	At 100 km/h, about 80 dB
HAPTIC	Position	Wheel, pedal, saddle	Handle, helmet, saddle
	Variables	Frequency/ Amplitude	Frequency/ Amplitude
	Action to receive	No action	No action
	Obstacle to receive	Only vibrations which are reduced by chassis	Vibration are more high than automotive

Figure 1: Comparison of automotive and PTW rider feedback method and characteristics (Pieve et al., 2009[3], p. 2).

Furthermore, the design recommendations regarding interaction with the HMI refer to the vehicle being in motion (riding) as opposed to standstill. The definition of riding, following the Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices (National Highway Traffic Safety Administration, 2012), is:
Riding means whenever the vehicle's means of propulsion (engine and/or motor) is activated unless one of the following conditions is met:

- For a vehicle equipped with a transmission with a “Park” position:
    - The vehicle's transmission is in the “Park” position.
- For a vehicle equipped with a transmission without a “Park” position:
    - All two of the following conditions are met:
        - The vehicle's transmission is known (via direct measurement with a sensor) or inferred (by calculating that the rotational speed of the engine divided by the rotational speed of the driven wheels does not equal,

3 Pieve, M., Tesauri, F., & Spadoni, A. (2009). *Mitigation accident risk in powered two wheelers domain: improving effectiveness of human machine interface collision avoidance system in two wheelers.* Paper presented at the Human System Interactions (HSI), 2009. Catania, IT.

allowing for production and measurement tolerances, one of the overall gear ratios of the transmission/vehicle) to be in the neutral position,

- and the vehicle's speed is less than 5 mph.

Some general comments regarding deviations between NHTSA's publications and this CMC document shall be made:

- It must be stated that the original NHTSA document typically refers to English/ alphanumeric characters, but other languages / characters should be individually considered in lingual condition/ criteria.
- Moreover, we refer to the term rider whenever the original document refers to driver.
- In general, the implementation of auditory warnings on a PTW is way more challenging than in a car. As long as these technical challenges are not reliably solved, auditory warnings cannot be recommended unrestrictedly for the variety of PTW types.

This HMI guideline contains design recommendations and examples to support PTW HMI designers. The recommendations given are not mandatory but shall serve as support for the design of PTW HMI concepts that offer ideal guidance to the rider while minimizing negative aspects such as distraction.

2 Introduction

The following chapter contains a brief introduction of the CMC as well as the Task Group HMI for C-ITS on PTW.

2.1 CMC - Connected Motorcycle Consortium

The CMC is a collaboration between manufacturers, suppliers, researchers and associations to make PTW part of the future connected mobility. CMC is a non-profit organization established by key motorcycle makers with the unilateral goal to promote and develop C-ITS on a global scale.

CMC targets to improve PTW rider safety and comfort. Connected mobility / Vehicle-to-Vehicle Communications / Cooperative Integrated Transportation Systems are being developed, but PTW-specific safety aspects have not been taken into consideration sufficiently so far. CMC is paving the way for PTW connectivity by making PTWs part of C-ITS and connected mobility. CMC aims to create a common basic specification for PTW ITS, with as many cross-manufacturer standards as possible.

The basis of CMC was laid in the year 2015 when the founding members BMW Motorrad, Honda and Yamaha agreed upon the need to further enhance motorcycle/ scooter safety by the means of C-ITS. This initial partnership has led to the establishment of CMC in 2016. Since then, manufacturers, suppliers and research institutes joined forces to collaborate. [4]

2.2 HMI approach of CMC

CMC investigates general features of PTW HMIs for C-ITS applications that all OEMs can rely on. Topics to be addressed are, for instance, specific properties of visual warnings (e.g., flash rate of warnings to maximize recognizability), or design recommendations regarding information timing etc. The focus lies on the information flow between PTW and rider. Therefore, results from psychological and cognitive ergonomic research are mainly considered. The overall aim of CMC is to provide general recommendations on how to design PTW HMI solutions for C-ITS applications.

[4] **Connected Motorcycle Consortium** (https://www.cmc-info.net/ accessed on 02.11.2020)

2.3 Scope of the Guideline

This HMI guideline mainly applies to HMI design for C-ITS applications. Depending on the specific topic, the scope might even go beyond pure C-ITS applications. For example, the definition of a minimum character height limited by aspects of human eyesight, may also be applied to other HMI design issues.
All topics are retrieved from the NHTSA Guideline "Human Factors Design Guidance For Driver-Vehicle Interfaces"[5] and have been analysed by a group of PTW HMI experts. The necessary PTW-specific modifications were commonly developed in a series of workshops.

2.4 Chapter relations

Figure 2 shows the relationship between different chapters in this document. This shall help the reader to identify relevant chapters for a specific topic. For instance, if someone is interested in Chapter 3.4 Warning Stages, the illustration shows that Chapters 3.14 and 3.15 dealing with prioritizing messages and using master warnings might also be relevant.

[5] Campbell, J. L., Brown. J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., … & Morgan, J. L.. (2016). Human factors design guidance for driver-vehicle interfaces (Report No. DOT HS 812 360). Washington, DC: National Highway Traffic Safety Administration.

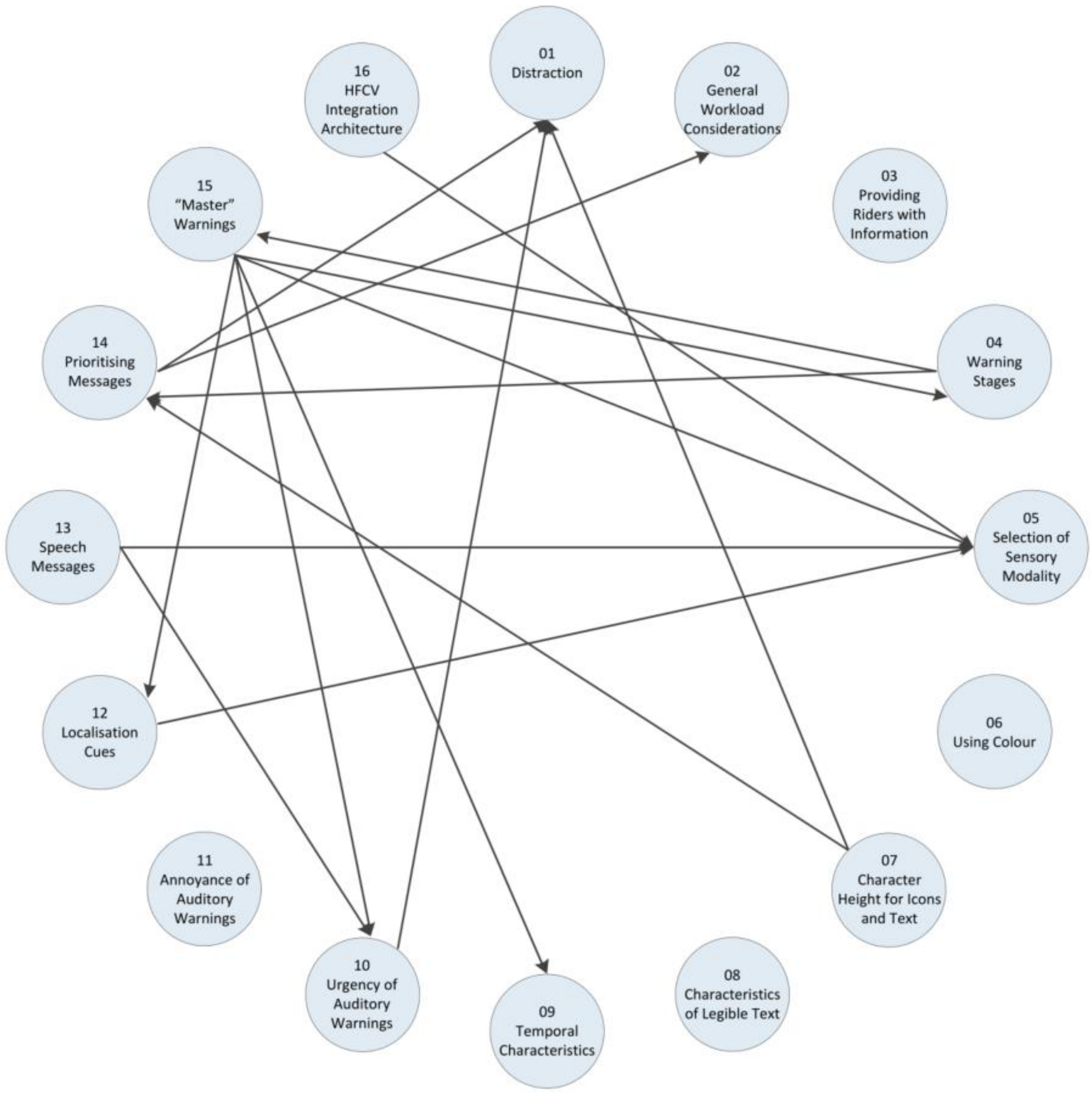

Figure 2: Illustration of chapters with related content.

2.5 Procedure

As stated previously, the aim of this guideline is to comment on a sophisticated HMI guideline from the automotive sector in order to make it applicable to PTWs. Figure 3 shows the procedure for the assessment of the NHTSA document.

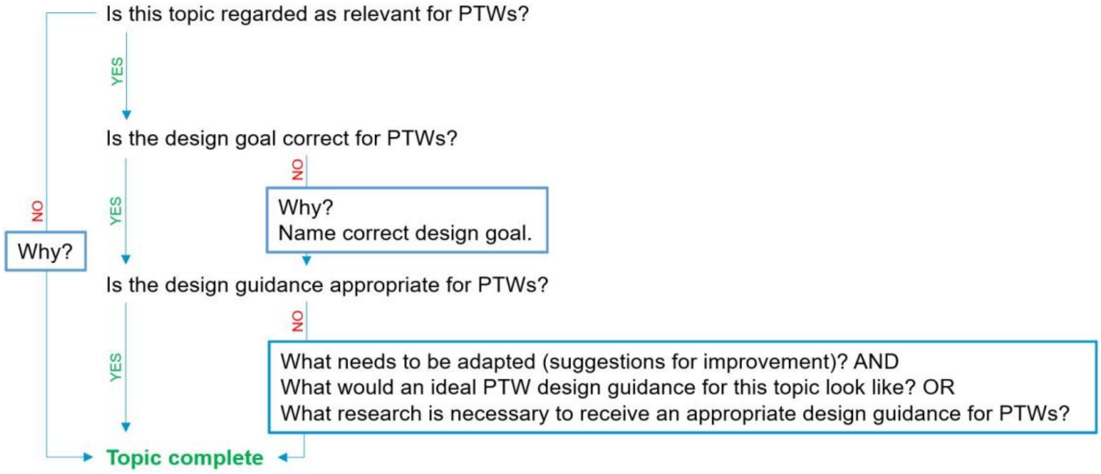

Figure 3: Procedure for the assessment of each chapter in the NHTSA guideline.

As a first step, chapters have been excluded from this guideline if the content was perceived as competitive instead of cooperative / safety relevant. Then a rating on the relevance of each chapter in the NHTSA guideline with respect to its applicability and usefulness for a PTW HMI guideline was done. This document only refers to chapters of the NHTSA guideline that were perceived as important to all OEMs involved. This rating resulted in the assessment of 16 chapters from the original NHTSA document.

If the chapter and its topic were perceived as relevant for PTWs, the design goal was assessed. If it was perceived as not applicable without changes, comments and reasons were collected. The final step was the assessment of the design guidance. Once again, comments have been made, if the design guidance had to be modified in order to be applicable to PTW HMIs.

3 HMI Guideline: CMC statements on NHTSA HMI guideline

The following chapters contain general statements regarding the topic discussed together with specific remarks on the original NHTSA guideline chapter. The title of each paragraph delivers the reference between the NHTSA document and the CMC document.

3.1 Distraction

CMC suggests that, for safe riding, design consideration is required to consider that tasks and messages do not divert attention from riding itself. As an example, a C-ITS visual feedback device downward viewing angle influences the overall distraction, when the rider needs to look far down from the forward line of sight. Nevertheless, it must be stated that a visual warning in a non-ideal position is assumed to be better than no warning at all.

Table 1 shows recommendations on different HMI topics related to driver distraction. While columns one, two and three are quoted from the NHTSA guideline, columns four and five contain CMC assessment on relevance of the specific topic to PTWs and an explanation what makes the major difference to cars[6].

Table 1: References to and comments on the NHTSA Visual-Manual Guidelines[7].

Recommendation/Guideline Topic from AutoAlliance Statement of Principles [8]	Topic Covered	Section in Visual-Manual Guidelines [9]	Relevant for PTW-C-ITS	CMC Comments
No Obstruction of View	Device location in relation to driver.	V. A	Yes	C-ITS visual feedback devices must be visible to the rider.
Easy to See and Reach	Driver access to a device.	V. B	Yes	C-ITS visual feedback devices must be easy to see, input devices must be easy to reach (while in motion)
Maximum Display Downward Angle	Device location in relation to driver.	V. C	Yes	These recommendations refer to any C-ITS visual feedback device. CMC has established that different values should be applied to PTW (see section below).

[6] Campbell, J. L., Brown. J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., … & Morgan, J. L.. (2016). Human factors design guidance for driver-vehicle interfaces (Report No. DOT HS 812 360). Washington, DC: National Highway Traffic Safety Administration, p. 3-2.

[7] National Highway Traffic Safety Administration. (2012). *Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices*. Washington, DC: National Highway Traffic Safety Administration (NHTSA).

[8] Alliance of Automobile Manufacturers. (2006). Statement of principles, criteria and verification procedures on driver interactions with advanced in-vehicle information and communication systems, including 2006 updated sections (Report of the Driver Focus-Telematics Working Group). Available at www.autoalliance.org/index.cfm?objectid=D6819130-B985-11E1-9E4C000C296BA163.

[9] National Highway Traffic Safety Administration (2013). Visual-manual NHTSA driver distraction guidelines for in-vehicle electro nic devices (Report No. DOT 37-13; Docket No. NHTSA-2010-0053). Available at http://www.distraction.gov/downloads/pdfs/113 02a-Distraction_Guidelines_Final_Notice_010815_v1_tag.pdf, accessed on 02.11.2020.

Lateral Position of Visual Displays	Device location in relation to driver.	V. D	Yes	Positioning the C-ITS visual feedback device in the forward line of sight. In terms of lateral position this is easier to be achieved for PTW than for cars.
Minimum Size of Displayed Textual Information	Size of visually presented text.	V. E	Yes	Displayed textual information must be readable.
Per Se Lock Outs	Device usage while driving.	V. F	Yes	Lock Outs are only relevant for adjustments of settings of C-ITS-functions (e.g. adjusting which types of warnings are active).
Acceptable Test-Based Lock Out of Tasks	Tasks performed while driving.	V. G	No	This topic is out of scope for PTW-C-ITS.
Sound Level	Sound level of a device.	V. H	Yes	Should be considered at a later stage. Acceptable level for PTW shall be addressed. For challenges see comments on chapter 3.10.
Single-Handed Operation	Driver control of the vehicle.	V. I	Yes	C-ITS related input devices should ideally be operated with the left hand OR should at least not require both hands at a time (while in motion).
Interruptibility	Driver interaction with the device.	V. J	Yes	It shall be possible to interrupt visual-manual interaction with the C-ITS device and continue later.
Device Response Time	Feedback provided to the driver by the device.	V. K	Yes	Feedback must be clear and timely.
Disablement	Presentation of non-safety-related information to the driver.	V. L	Yes	Both, safety and non-safety related C-ITS applications can be disabled.
Distinguish Tasks or Functions Not Intended for Use While Driving	Driver access to devices while driving.	V. M	Yes	A separation between assessment of C-ITS warning delivery while riding and tasks not intended for use while riding (e.g., change settings) can be made.---
Device Status	Presentation of system status information.	V. N	Yes	The rider needs to recognize whether the C-ITS application is running.
Visual Task Completion	Driver interaction with the device.	-	No	This topic is out of scope for PTW-C-ITS
Driving Relevant Information	Information presented to the driver.	-	No	This topic is out of scope for PTW-C-ITS
Speech-Based Communication Systems	Driver interaction with the device.	-	No	This topic is out of scope for PTW-C-ITS
Pace of Interaction with Device	Driver interaction with the device.	-	No	This topic is out of scope for PTW-C-ITS

The recommendations cited above mainly deal with visual information. Due to the fundamentally different vehicle concept in terms of vehicle geometry or ergonomics, it must be assumed that no simple generalisation from car thresholds to PTW thresholds is possible[10].

[10] Pieve, M., Tesauri, F., & Spadoni, A. (2009). *Mitigation accident risk in powered two wheelers domain: improving effectiveness of human machine interface collision avoidance system in two wheelers.* Paper presented at the Human System Interactions Conference, 2009. HSI 09. Catania, IT.

3.2 General Workload Considerations

The NHTSA chapter focuses on information displays for secondary tasks. The adapted design goal for CMC is the design of C-ITS feedback devices instead of information displays for secondary tasks.

On top of that, CMC considers that the workload caused by the primary task (riding the PTW) seems to be higher than the workload for driving a car[11]. For example, keeping stability of the PTW is an additional part of the primary task which increases the default workload (compared to a car, as considered by NHTSA guidelines).

Additionally, the option of reducing workload by sharing tasks with a co-driver (like in a 4-wheel vehicle) is not possible in the PTW context. The rider must deal with all types of tasks (primary, secondary), which increases the importance of thinking about workload when designing C-ITS feedback devices.

11 Buld, S., Will, S., Kaussner, A., & Krüger, H.-P. (2014*). Entwicklung eines Verfahrens zu Erfassung der Fahrerbeanspruchung beim Motorradfahren* (FE 82.0368/2009/). Bremen: Bundesanstalt für Straßenwesen.

3.3 Providing Riders With Information on System Function and System Messages

CMC generally agrees with the introduction given by the NHTSA guideline having ABS as an example. To establish applicability to PTWs in the C-ITS context, the example of EEBL (Electronic Emergency Brake Light) can be used.

The EEBL application enables a vehicle to broadcast its own emergency braking situation to the surrounding vehicles, including those that have their line of sight obstructed by other vehicles or bad weather like fog or rain (© This picture was created using the C2C-CC Illustration Toolkit, owned by the CAR 2 CAR Communication Consortium

Figure 4).

In case there are multiple vehicles driving behind each other, and the first vehicle has to perform an emergency braking, this application drastically reduces the delay in reaction time by subsequent vehicles: each driver / rider is informed immediately of the emergency braking performed ahead, and the risk of collision could be avoided.

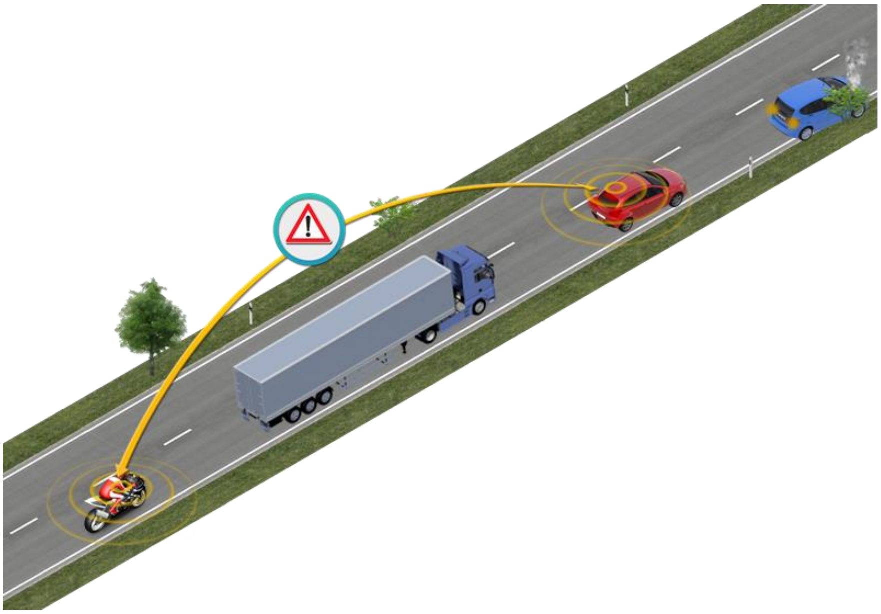

Figure 4: Illustration of an EEBL scenario.

If provided with adequate information before riding (for example, via user manual or information pamphlet), riders will know that they may need to take preventive actions (such as braking or performing an evasive manoeuvre) when receiving an EEBL warning.

To provide riders with clear and concise information on system function, states, and how to respond when the system activates, the method of the ABS example applies to C-ITS applications for PTWs as well.

3.4 Warning Stages

CMC agrees to the chapter about warning stages. Nevertheless, it is important to point out that warnings to prevent a collision are of more importance for PTW riders than for car drivers as the risk of physical harm is higher.

CMC suggests considering the following examples for better understanding of two-stage warnings and multi-stage warnings in the PTW context:

- Consider using a two-stage warning:
  - In situations where hard braking could have undesirable effects, (e.g. while riding on low friction roads, which might induce slip and fall). Hard-braking may be more likely with one-stage systems that only activate for imminent situations.
- Consider using a multi-stage graded warning system:
  - When the situation evolves gradually (e.g., for stationary vehicle warning, if a vehicle crashed or has broken down, it may be possible for the following vehicles to implement an early warning that allows the riders to adjust their behaviour to prevent hard braking or risky manoeuvres).

3.5 Selection of Sensory Modality

Currently, visual feedback devices are commonly available across PTW concepts (e.g., from sports bike to tourer) and cost range (from low priced entry level PTW to costly high-end products). Therefore, visual feedback devices will mark the starting point for PTW C-ITS HMI solutions. Nevertheless, auditory cues, haptic cues or any other means of delivering information might be used as soon as sophisticated technical solutions are available.

CMC notes that any visual feedback device - not just Head-Up Displays (HUD) or High Head-Down Displays (HHDD) - may provide spatial information (e.g., a warning indication in the side mirrors to indicate a hazard at the left or right side of the PTW). CMC notes that visual messages can be used to provide more detailed information, such as proximity or direction of hazard, which may be difficult to discern from other modalities.

CMC clarifies that, once a solution is available to convey auditory messages, the recommendations for auditory messages hold true for PTW applications as well. More evidence is available (Pieve et al., 2009[12]) to support the assertion that auditory warnings can draw attention directly to the location of a potential crash threat in PTW applications. Furthermore, there is empirical evidence that shows high levels of acceptance towards auditory cues for non-critical information (Touliou et al., 2012[13]).

While auditory messages may not be feasible or universal on PTWs, haptic messages might be possible instead. Even if unintentionally available, a promising example of haptic messages which may be used in PTWs is a brake lever vibration while decelerating with ABS (haptic feedback requires the rider to be in contact with the feedback source). Literature suggests that even other haptic devices such as a force feedback throttle may be used (Huth, Biral & Lot, 2012[14]).

CMC clarifies that the selection of message type should be based on which type of message is most effective and practicable.

[12] Pieve, M., Tesauri, F., & Spadoni, A. (2009). *Mitigation accident risk in powered two wheelers domain: improving effectiveness of human machine interface collision avoidance system in two wheelers.* Paper presented at the Human System Interactions Conference, 2009. HSI 09, Catania, IT.

[13] Touliou, K., Margaritis, D., Spanidis, P., Nikolaou, S., & Bekiaris, E. (2012). Evaluation of Rider's Support Systems in Power Two Wheelers (PTWs). *Procedia-Social and Behavioral Sciences, 48*, 632-641.

[14] Huth, V., Biral, F., Martín, Ó., & Lot, R. (2012). Comparison of two warning concepts of an intelligent Curve Warning system for motorcyclists in a simulator study. *Accident Analysis and Prevention, 44*, 118-125.

3.6 Using Color

CMC suggests using colour displays instead of monochrome displays for optimisation of C-ITS information. Monochrome displays remain state of the art in some segments and are not excluded by this recommendation and this recommendation does not preclude the inclusion of C-ITS information in monochrome displays.

CMC clarifies that the quantity of colours used to code information is in addition to monochromatic background information. This is to ensure that there is no misinterpretation (and subsequent limitation) of using only two colours in addition to the monochrome configuration.

- Correct example interpretation of the NHTSA chapter from CMC point of view: Four colours (e.g., Red, Amber/Yellow, Green and Blue) may be used in addition to black and white background information.
- Incorrect example interpretation of the NHTSA chapter from CMC point of view – Two additional colours (e.g., Red and Amber/Yellow,) may be used in addition to black and white background information

Figure 5 shall further clarify this. The warning icon on the left side uses only one colour (yellow) in addition to monochromatic background information (shades of black and white). The warning icon on the right side makes use of two colours (amber and red).

Figure 5: Exemplary warning icons using one colour (yellow; left) and two colours (amber and red; right).

CMC recommends referring to ISO15008 (Road vehicles - Ergonomic aspects of transport information and control systems - Specifications and test procedures for in-vehicle visual presentation) for applicable information on colour combinations to be used and avoided.

CMC recommends referring to ISO2575 (Road vehicles — Symbols for controls, indicators and tell-tales) and ISO6727 (Road vehicles — Motorcycles — Symbols for controls, indicators and tell-tales) for details of meanings for colours (e.g. red, amber/yellow, green, blue).

3.7 Selecting Character Height for Icons and Text

CMC generally agrees with the introduction given by the NHTSA guideline. However, the C-ITS visual feedback device used on PTWs is different from a car such as the effect by environmental condition being more significant, e.g. direct sunlight, rain, etc. For the usage of C-ITS visual feedback devices, a visual icon should be designed in a way that the icon itself can be processed and the correct reactions are triggered without the necessity of reading a text within the icon. Therefore, text within the icon is not considered for PTW C-ITS HMI recommendations in this chapter.

Further, the more time critical the information, the closer it should be positioned to the optimum field of view. This CMC recommendation provides a suggestion on where within a display information or warnings shall be positioned. The location of the display itself is not a pure HMI decision (e.g., aerodynamics, design etc.) and therefore out of scope for this document.

In addition, minimum visual angle of primary graphical elements mentioned in NHSTA guideline has 34 arcminutes for non-time-critical applications, but it should be considered that some C-ITS applications are time critical, which may result in different recommendations. Further PTW-specific research is necessary to propose empirically based PTW thresholds.

3.8 Characteristics of Legible Text

CMC generally agrees to the chapter about “Characteristics of Legible Text” for Latin/ Roman characters. For other languages/ characters different rules might apply.

ISO15008 contains details and recommendations on reproducibility of Latin and Non-Latin characters which are applicable to consideration in this context.

3.9 Temporal Characteristics of Visual Displays

CMC conducted a motorcycle simulator study with N = 16 participants to investigate the relationship between flash rate of visual warning icons and recognizability. With the given setup, it showed that static warnings as well as warning icons with a flash rate of 1.5 Hz can be used for advisory warnings as recognizability in the instrument cluster was on a comparable level. From a subjective point of view, the riders preferred flashing icons for advisory warnings.

CMC would recommend that all motion cues that induce too much attraction (in addition to the examples of “bouncing” and “zooming” as mentioned in the NHTSA guidelines) should not be used.

3.10 Perceived Urgency of Auditory Warnings

CMC notes that, currently, visual interfaces are available across PTW concepts while technical solutions to deliver auditory warnings at a required sound level and/or direction are not.

Depending on background noise, availability of a wind shield, type of helmet etc. the obstacle to receive auditory warnings e.g., at 100 km/h is approx. 80 dB (Pieve et al., 2009[15]; Schueler, F., 2007[16]). Even though there are technical constraints to overcome, the starting point for auditory warnings on PTW applications should be the recommendations made within the NHTSA guidelines until further research can be conducted.

A specific consideration for PTW implementation of auditory warnings is whether any market-specific regulations exist, which prevent the use of audio devices integrated within rider helmets (e.g., reliability of audio connection, battery level of exterior device). These devices are not PTW-fixed and therefore out of scope for this document.

If no technical solution exists to deal with these challenges, CMC recommends to not use auditory warnings. Generally, this holds true for all chapters dealing with auditory warning design.

[15] Pieve, M., Tesauri, F., & Spadoni, A. (2009). *Mitigation accident risk in powered two wheelers domain: improving effectiveness of human machine interface collision avoidance system in two wheelers.* Paper presented at the Human System Interactions Conference, 2009. HSI 09, Catania, IT.

[16] Schueler, F. (2007*). Anforderungen an Helme für Motorradfahrer zur Motorradsicherheit. Demands on helmets for active safety of motorcycles*. Berichte der Bundesanstalt für Straßenwesen, Reihe F: Fahrzeugtechnik (64).

3.11 Perceived Annoyance of Auditory Warnings

CMC agrees to the chapter content with the limitations already mentioned in chapter 3.10 Perceived Urgency of Auditory Warnings.

3.12 Using Localization Cues to Indicate Direction

The content of this chapter requires limitations discussed in chapter 3.10 (method of generating sound which can be perceived by a PTW rider) to be overcome first.

Application specific limitations of generating sound which can be perceived to be from different locations (in front or behind) could be problematic with current solutions available (i.e. helmet mounted headset and speakers). Furthermore, one must also consider that, if information comes from speakers within a helmet, the position/ orientation of the head may then differ to the location of the object/ event the rider shall be made aware of.

Additionally, this chapter relates to chapter 3.5 Selection of Sensory Modality. As the connection/ availability of headsets (if selected as the method of providing auditory warnings) cannot be guaranteed, a warning strategy may require mitigation strategies to use other redundant warning types.

3.13 Presenting Warnings Using Speech Messages

The method of implementing auditory messages is a significant primary subject to be resolved in order to allow speech messages to be implemented.

Furthermore, CMC notes that the presented research focuses on English speech messages and that there might be differences when other languages are used.

The guidance in this chapter is heavily affected by the comments on chapters 3.5 (Selection of Sensory Modality) and 3.10 (Urgency of Auditory Warnings).

3.14 Prioritizing Messages Presented to Riders

Since the workload on PTWs seems to be higher than cars[17], the message prioritization is even more important on PTWs.

The original design guidance chapter referred to a dedicated visual screen for continuous visual information, which might be a legacy from the 2002 standard of the NHTSA guideline, where static (e.g., speedometer) and dynamic content was separated. Since displays can be used to show static and/ or dynamic content, it is possible for continuous visual information and other dynamic visual information (requested by the rider or regarding external environment or hazard) to be shown on the same display.

The following examples might clarify different priority order indices (POI) criteria from PTW point of view (Table 2).

Table 2: C-ITS application examples for message prioritization criteria. Criteria are cited from Campbell et al. (2016), p. 10-2[18].

Criteria	**C-ITS Examples**
1) "Safety Relevance: The degree to which the information affects the safe operation of the vehicle."	
Directly Relevant	• Intersection Movement Assist
Indirect/Somewhat Relevant	• Stationary Vehicle Warning
Not Relevant	• Green Light Optimal Speed Advisory
2) "Operational Relevance: The degree to which the information increases the ease and convenience of the driving task, for example, by decreasing travel time and the stress associated with driving."	
Highly Relevant	• Adverse Weather Warning • Road Works Warning
Moderately Relevant	• In-Vehicle Signage
Little or No Relevance/ Significance	• Does not apply to C-ITS

[17] Buld, S., Will, S., Kaussner, A., & Krüger, H.-P. (2014*). Entwicklung eines Verfahrens zu Erfassung der Fahrerbeanspruchung beim Motorradfahren* (FE 82.0368/2009/). Bremen: Bundesanstalt für Straßenwesen.

[18] Campbell, J. L., Brown. J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., … & Morgan, J. L.. (2016). Human factors design guidance for driver-vehicle interfaces (Report No. DOT HS 812 360). Washington, DC: National Highway Traffic Safety Administration.

3.15 Using "Master" Warnings in Integrated Warning Systems

Generally, specific warnings as well as generic warnings for C-ITS applications may be used. If generic warnings are used, information about direction of the hazard is assumed to be beneficial and should be provided. As noted by the NHTSA guidelines, the selection between generic or specific warnings can vary depending upon the scenario encountered. An effective system would use a combination of generic and specific warnings as appropriate.

A generic warning, which requires to divert attention to the source/ location of the warning (e.g., visual display interface) in order to interpret the warning for meaning/ location before then addressing the subject of the warning may increase the overall reaction time. If such a condition could occur, a generic warning for that scenario would not be appropriate. Instead an appropriate alternative method of warning or a specific (or less generic) warning should be implemented.

PTW specific research is necessary to provide empirical evidence for the benefits of different warnings.

This chapter correlates with chapter 3.5 (Selection of Sensory Modality), chapter 3.9 (Temporal Characteristics), chapter 3.10 (Urgency of Auditory Warnings) and chapter 3.12 (Localization Cues). This chapter should also be considered when determining whether multi-stage warnings (chapter 3.4) are appropriate. Once again, the challenges for the implementation of auditory warnings as described in chapter 3.10 Perceived Urgency of Auditory Warnings need to be kept in mind.

3.16 Overview of the Human Factors for Connected Vehicles (HFCV) Integration Architecture

CMC agrees to the general design goal of the topic.

Nevertheless, the presented integration architecture is just one possiblity among others. An alternative solution might be taken.

Abbreviations

C-ITS	Cooperative Intelligent Transport Systems
EEBL	Electronic Emergency Brake Light
HFCV	Human Factors for Connected Vehicles
HHDD	High Head-Down Displays
HMI	Human Machine Interface
HUD	Head-Up Display
NHTSA	National Highway Traffic Safety Association
OEM	Original Equipment Manufacturer
POI	Priority Order Index
PTW	Powered Two Wheeler