SAFERIDER

ADVANCED TELEMATICS FOR ENHANCING THE **SAFE**TY AND COMFORT OF MOTORCYCLE **RIDER**S

FP7-ICT1-216355

HMI CONCEPTS & STRATEGIES

Deliverable No.		5.1	
Workpackage No.	5	Workpackage Title	Human-Machine Interface Design & Development
Activity No	A5.1	Activity Title	Warning concepts and strategies
Authors		Frederik Diederichs, Benjamin Fischle (FHG-IAO)	
Dissemination Level[1]		PU	
Status[2]		F	
File Name		SAFERIDER_FHG-IAO_WP5_V2_D5.1_HMI Concepts & Strategies	
Project start and duration		1st January 2008, 36 Months	

Project Coordinator:
Evangelos Bekiaris
Centre for Research & Technology Hellas (CERTH)
Hellenic Institute of Transport (HIT)
6th km Charilaou-Thermi Rd
57001, Thermi, Thessaloniki, Greece
Tel: +30-2310-498453, Email: abek@certh.gr

[1] PU: Public; RE: Restricted; CO: Confidential
[2] F: Final; D: Draft; RD: Revised Draft

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Description
A	Acoustic/Auditory
AA	Acoustic Output
ADAS	Advanced Driver Assistance System
ARAS	Advanced Rider Assistance System
AS	Speech Output
BSW	Black Spot Warning
CW	Curve Warning
DI	Directional Information
FCW	Frontal Collision Warning
H	Haptic/Tactile
HMI	Human-Machine Interaction/Interface
HUD	Head-Up Display
ISS	Intersection Support
IW	Imminent Warning
NRG	Navigation & Route Guidance
PTW	Powered Two-Wheeler
RG	Route Guidance
SA	Speed Alert
SW	Safety Warning
TB	Vibrating Braclet
TDS	Telediagnostic Service
THA	Haptic Handle
THL	Haptic Helmet
TS	Tactle Seat
TT	Force Feedback Throttle
TTC	Time-To-Collision
TTR	Time-To-Response
V	Visual
VA	Visual Attractor
VD	Dash Board Display
WTB	Weather, Traffic and Black Spot Warning

1 Executive Summary

This report treats the conceptualization of the SAFERIDER human-machine-interaction elements for Advanced Rider Assistance Systems and In-Vehicle Information Systems for powered two-wheelers. It is based on results of work package WP1. With respect to riders' needs and wants the task is to find an efficient warning strategy combined with a minimum of distraction from the road ahead. These goals often lead to a trade-off. The concept includes two levels of warning urgency:

1. Cautionary warnings (safety warnings)
2. Imminent warnings (critical warnings)

To meet the requirements of the target group, expert interviews were conducted. The results have an influence on the HMI proposal as well as research-based knowledge has. Taking into account the use cases, specific HMI elements are selected in order to provide effective warning combined with minimum disturbance. The elements are selected from a pool of possible HMI elements including tactile/haptic, acoustic and visual information transmission elements.

The conceptualization process is affected by a methodology similar to the one of a morphological box in accordance to VDI guideline 2221. Three individual, independent and consistent HMI concepts are proposed and evaluated by relevant criteria. The main target is to develop on the one hand an unobtrusive HMI system, on the other hand, to provide the rider with intuitive signals, causing quick and correct reaction.

2 Guidelines

For the design project of the SAFERIDER human machine interface (HMI) it seems to be convenient to follow the systematic design methodology approach according to VDI 2221 to some extent:

According to Beier (unknown year), the VDI design methodology is often used in projects. It consists of a consecutive algorithm, in which every main phase is to be conducted after the completion of the previous one. Upon completion of one phase, the results of this phase are to be checked for consistence with the task and compatibility with given requirements. If necessary, single parts of a phase can be repeated, resulting in an iterative engineering process (Beier, unknown year).

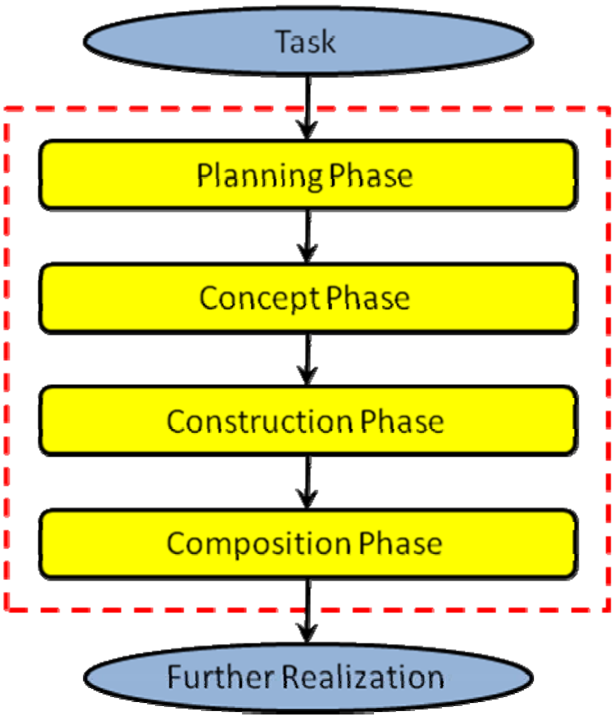


Figure 2.1: Design methodology according to VDI 2221.

For this work the concept phase is essential. The result of this phase is a principal solution based on the fundamentals resulting from the planning phase and ideas generated during the concept phase. The VDI guideline provides a toolbox for solving design problems and to support creativity. Some elements of this methods toolbox where used to develop the initial HMI concept for SAFERIDER project, such as morphological box, literature research and analysis of existing products.

2.1 General Design Principles

An extensive review of guidelines for HMI design was performed, in order to collect indications for starting the design process. As no document specifically addresses the case of PTWs, it was decided to adopt guidelines developed in the Automotive domain, aiming to select recommendations and requirements that may be applied to the PTW domain. Where possible, the vocabulary was adapted to the specific case; particularly, Assistance Systems will be indicated as ADAS (Advanced Driver Assistance Systems) when referred to the Automotive domain, and as ARAS (Advanced Rider Assistance Systems) when referred to the PTW domain.

The following references were taken into account for creating a sample of general design principles:

- EU Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems.
- Guidelines for the Design and Installation of Information and Communication Systems in Motor Vehicles – United Nations Report.
- DIN EN ISO 15005 Road vehicles – Ergonomic aspects of transport information and control systems – Dialogue management principles and compliance procedure .
- DIN EN ISO 15006 Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and compliance procedures for in-vehicle auditory presentation.
- DIN EN ISO 15007 Road Vehicles -- Measurement of driver visual behaviour with respect to transport information and control systems -- Definitions and parameters.
- DIN EN ISO 15008 Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and compliance procedures for in-vehicle visual presentation.

Since many guidelines are contained in more than one reference, only the most comprehensive one is chosen to be listed here. Only in a few cases further references are taken into account, providing additional information. The selected guidelines for road vehicles have been checked for relevance for PTW issues. Thus, the sample presented does not claim to be complete. For further information about specific topics, please refer to the relevant references. The general design principles presented in this the following Table 2.1 are numbered with preceding “A”.

Table 2.1: Relevance of design principles for PTW.

No.	Citation	Interpretation for PTW
	Overall design principles:	
A1	*“The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users.”* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A2	*“The allocation of driver attention while interacting with system displays and controls remains compatible with the attentional demand of the driving situation.”* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A3	*“The system does not distract or visually entertain the driver.”* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A4	*“The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users. “* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A5	*“Interfaces and interface with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible. “* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
	Installation principles:	
A6	*“The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturers’ instructions for installing the system in vehicles.“* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A6/1	Displays and interaction elements should be mounted in a manner that allows unobstructed performance of the driving task and system functions (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
A6/2	Interaction elements should be designed and positioned such that unintended operation is avoided (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
A7	*“No part of the system should obstruct the driver's view of the road scene.“* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A8	*“The system should not obstruct vehicle controls*	This guideline is quite general and is

	and displays required for the primary driving task." (European Commission, 2006).	therefore also valid for PTW.
A9	*"Visual displays should be positioned as close as practicable to the driver's normal line of sight."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A10	*"Visual displays should be designed and installed to avoid glare and reflections."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
	Information presentation principles:	
A11	*"Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A11/ 1	Individual dialogues with the system must be created such that the driver identifies the priority of presented information. (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
A11/ 2	The system should present visual information as long as necessary. (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
A11/ 3	The driver should be informed of necessary inputs for reaching a desired objective. (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
A12	*"Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms and/or abbreviations should be used. "* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A13	*"Information relevant to the driving task should be accurate and provided in a timely manner."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A14	*"Information with higher safety relevance should be given higher priority."* (United Nations Economic Commission for Europe, 1998).	This guideline is quite general and is therefore also valid for PTW.
A15	*"System generated sounds, with sound levels that cannot be controlled by the driver, should not mask audible warnings from within the vehicle or the outside."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.

	Interface with displays and controls:	
A16	*"The driver should always be able to keep at least one hand on the steering wheel while interacting with the system."* (European Commission, 2006).	The guideline must be adopted to meet rider's requirements: The driver should always be able to keep both hands on the handlebar while driving. Interaction with the system requires vehicle stopping.
A17	*"The system should not require long and uninterruptible sequences of manual-visual interfaces. If the sequence is short, it may be uninterruptible."* (European Commission, 2006).	Considering guideline A16 interpretation makes this particular guideline useless for PTW. However, merely visual interfaces should be avoided as well.
A18	*"The driver should be able to resume an interrupted sequence of interfaces with the system at the point of interruption or at another logical point. "* (European Commission, 2006).	Considering guideline A16 interpretation makes this particular guideline useless for PTW.
A19	*"The driver should be able to control the pace of interface with the system. In particular the system should not require the driver to make time-critical responses when providing inputs to the system."* (European Commission, 2006).	Considering guideline A16 interpretation makes this particular guideline useless for PTW.
A20	*"System controls should be designed such that they can be operated without adverse impact on the primary driving controls."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A21	*"The driver should have control of the loudness of auditory information where there is likelihood of distraction."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A22	*"The system's response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A23	*"Systems providing non-safety related dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.

	System behaviour principles:	
A24	*"While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A25	*"The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A26	*"System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or, as a less preferred option, clear warnings should be provided against the unintended use."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A27	*"Information should be presented to the driver about current status, and any malfunction within the system that is likely to have an impact on safety."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
	Information about the system:	
A28	*"The system should have adequate instructions for the driver covering use and relevant aspects of installation and maintenance."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A29	*"System instructions should be correct and simple."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A30	*"System instructions should be in languages or forms designed to be understood by the intended group of drivers."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A31	*"The instructions should clearly state which functions of the system are intended to be used by the driver while driving and those which are not."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A32	*"Product information should be designed to accurately convey the system functionality."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.

A33	*"Product information should make it clear if special skills are required to use the system as intended by the manufacturer or if the product is unsuitable for particular users."* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.
A34	*"Representations of system use (e.g. descriptions, photographs and sketches) should neither create unrealistic expectations on the part of potential users nor encourage unsafe use"* (European Commission, 2006).	This guideline is quite general and is therefore also valid for PTW.

2.2 Warning Design Guidelines

The following references (listed in the Table 2.2) were taken into account for creating a sample of general design principles:

- Lerner, N. D. [et al.] *Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices*. NHTSA, 1996.
- Campbell, J. L. [et al.] *Crash Warning System Interfaces: Human Factors Insights and Lessons Learned*. NHTSA, 2007.

Remark: The guidelines of this section are numbered with preceding “B”.

Table 2.2: Relevance of warning design guidelines for PTW.

No.	Citation	Interpretation for PTW
B1	**Multiple Levels of warning** “All warning devices should be capable of generating at least two levels of warning – imminent […] warnings and cautionary […] warnings. Devices which provide continuous analog-type warnings (e.g., graded warnings) should provide an obvious change in the warning display when the level of warning changes from a cautionary to an imminent […] warning.” (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B1/1	**How to Select the Number of Warning Stages (see also** Table 2.3**)** *“The data on this topic are mixed, but suggest the following heuristics for selecting one-stage warnings versus two-stage warnings:* • *Use a one-stage warning:* ➢ *When the primary goal of a […] warning […] system is to warn a distracted driver.* ➢ *If the rate of false alarms associated with a two-stage system significantly reduces driver trust in the system or increases driver frustration with the system.* • *Use a two-stage warning:* ➢ *When the primary goal of the […] system is to promote safer headway distances.* ➢ *In situations where the hard braking that may be associated with one-stage systems could produce an undesirable response (i.e., buses and heavy vehicles).* ➢ *For a Lane Change Warning (LCW) system.* • *Use a multi-stage (or continuous) warning system:* ➢ *When the primary goal of an [warning] system is to provide continuous headway information.”* (Campbell, et al., 2007).	This guideline is also valid for the HMI of ARAS/IVIS on PTW. The terms “warning stages” and “warning levels” are used synonymously.

Table 2.3: Comparison of warning stages strategy (Campbell, et al., 2007).

	One-stage	*Two-stage*
Advantages	*-May best address distracted-driving situations.* *-May be simpler for drivers to comprehend.*	*-May minimize requirements for hard braking (has value for buses and heavy vehicles).* *-May assist drivers in developing a coherent mental model and better awareness of the CWS device.* *-May reduce startle effects from ICWs alone.* *-May aid drivers in maintaining safe headway and in anticipating potential crashes.*
Disadvantages	*-May provide less time for the driver to recognize and respond to an emerging crash situation.*	*-May increase likelihood of real or perceived false alarms.* *-May reduce driver trust and use of the system due to false alarms.*

Table 2.2: Relevance of warning design guidelines for PTW.(continuation)

No.	Citation	Interpretation for PTW
B2	**Unique warning signals for short-term Warnings** “For each potential signal modality (e.g., visual, acoustic, voice, tactile), there are features that are uniquely reserved for [short-term] warnings. These features are selected to insure a conspicuous and urgent warning message, and to guarantee that such warnings are immediately distinguishable from any other sort of message that may be presented in the vehicle.” (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW. The expression “short-term warning” refers to guideline C9 and is a synonym for “imminent warning”. For the SAFERIDER project two warning stages are proposed: Imminent warning and safety warning.

No.	Citation	Interpretation for PTW
B3	**Dual modality for short-term warnings** "No warning modality will be uniformly effective across the broad range of vehicle users and internal and external driving environments. Therefore, [short-term] warnings are normally presented in two modes (e.g., visual and acoustic). A visual display is used as the redundant mode because it has advantages for dealing with simultaneous hazards" (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B4	**Warning Prioritization** "Multiple imminent […] warnings occurring simultaneously should be automatically prioritized in terms of their severity and urgency. Only the highest priority […] warning should be presented in the auditory or tactile modality. All […] warnings should be presented simultaneously in the visual modality. Crash avoidance warnings should take precedence over all other in-vehicle warnings." (Lerner, et al., 1996). "When auditory or tactile displays are used, a clearly distinguishable cue should be provided to the driver between the termination of the highest priority imminent warning and initiation of the next highest priority warning. In case of directional warnings the directional nature of the warning indication is sufficient to provide this cue." (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW. For determining the priority of warning messages it is recommended to use the ISO 16951:2004 approach.
B4/1	If several systems are installed, the integrated application should consider the relative priority of its functions (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
B5	**Compatibility with Driver Behaviors** "Characteristics of the warnings must be compatible with driver behavior. This includes both normal driver actions that are related to the maneuvers being monitored (e.g., changing lanes, backing up), and also to the emergency vehicle control responses that are desired in reaction to the warning. "(Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B5/1	Information presentation and dialogues must be consistent in terms of modality, display location, adjustment and dialogue management (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
B6	**Minimization of Nuisance Warnings** "The criteria for triggering a warning will always represent some trade-off between broader protection and the frequency of undesired warnings. To whatever extent data permit, these criteria need to be based on available information about crash scenarios and driver capabilities." (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
B7	**Application of Power** "Power should be applied to the warning device when the vehicle ignition switch is turned on even if the device is capable of being turned off manually during vehicle operation. This application of power should place the device into the standby mode of operation (e.g., device is receiving power, but sensors and warning interface are not activated). Any device which must be physically attached to or worn by the driver (e.g., driver alertness monitoring devices) is excepted. Such devices should be manually turned on by the driver, and should not be automatically turned on with the vehicle ignition switch." (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B8	**Failure of Multi-Sensor Devices** "For warning device displays that are capable of being activated by more than one sensor, the failure of any one of the sensors should be treated as a failure of the full device, and so indicated by the device's status indicator(s)." (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B9	**Warning Display Testing** "The driver should be provided with the capability to test each warning display manually at any time during vehicle operation. The display should be activated for a sufficient time period (approximately 5 seconds) to permit manual adjustment of display intensity (e.g., volume, brightness)." (Lerner, et al., 1996).	For PTW use this guideline is adapted in a way, that recommends warning display testing only when the vehicle is standing still and ignition is turned on. While driving, the rider's hands should stay at the handle bar.

No.	Citation	Interpretation for PTW
B10	**Fail Safe Design** "[…] warning devices should be designed to fail in a safe manner. Failure should not cause critical functions (e.g., automatic prioritization of detected hazards) to produce false warnings. Malfunctioning systems should be automatically placed in a failure mode. The failed condition should be displayed to the driver by means of a status indicator." (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B10/1	Missing input data must not result in undefined system behavior or failure (DIN EN ISO 15005:2002).	This guideline is quite general and is therefore also valid for PTW.
B11	**Automatic Termination of Warnings** "In a hazardous driving situation, the driver has only a few seconds, at most, to react to the warning to avoid [a crash]. By requiring the driver to manually silence the warning, an additional unnecessary task is placed on the driver during a high workload situation. Therefore, the device should provide an automatic termination of the warning when the hazard no longer exists." (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B12	**Compatibility of Warning to Driver Response** "[Any warning] should be presented in a manner that is compatible with the rider's desired [reaction]. The warning should induce an orienting response where appropriate, causing the rider to look in the direction of the hazard. The warning should adequately capture the driver's attention without startling the driver." (Lerner, et al., 1996). "The warning should not induce the driver to look in a direction other than that to which attention should be directed in order to avoid a crash." (Lerner, et al., 1996).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.

No.	Citation	Interpretation for PTW
B12/1	**How to Make Warnings Compatible with Driver Responses** *"Warnings should: 1) be presented in a manner that is compatible with the driver's desired vehicle control response, 2) induce an orienting response, where appropriate, causing the driver to look in the direction of the hazard, and 3) adequately capture the driver's attention without startling the driver.* *Before attempting to link warnings with a specific driver response, designers should be:* • *Confident that the [warning] device (i.e., sensors, processors, DVI) is capable of determining the desired driver response with very high levels of accuracy and reliability.* • *Clear as to what kind of response (i.e., a perceptual response—looking in the direction of the hazard, or a motor response—braking or turning away from a hazard) the warning is intended to elicit.* • *Confident that the warning will indeed elicit the desired driver response under most driving situations and conditions."* (Campbell, et al., 2007).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
B13	**Prevention of False/Nuisance Warnings** "False warnings (i.e., those triggered by an inappropriate stimulus event) and nuisance warnings (i.e., those triggered by an appropriate stimulus event under conditions that are not useful to the driver) should be minimized without seriously degrading the hazard detection	In Lerner et al. methods to reduce the number of false/nuisance warnings are suggested and should be complied with.

	performance of […] warning devices." (Lerner, et al., 1996). "[…] warnings may be inappropriate because assumptions about driver, vehicle or environmental characteristics (e.g., reaction time, braking distance) make the timing of the warning inappropriate." (Lerner, et al., 1996).	

2.2.1 Imminent Warnings

Imminent warnings are to be used only where criteria for imminent hazardous situations are met. The alerting features reserved for this category of warning should not be used for other situations. An imminent hazardous situation is one in which the potential for a collision or for losing control over the PTW is such that it requires immediate corrective action by the rider.
Imminent warnings must be presented in at least **two modes**. One mode must be **visual**, and one must be **auditory or tactile** (Lerner, et al., 1996). For each mode, the warning should incorporate those features uniquely reserved for imminent warnings situations.
According to Lerner et al. (1996) there are several reasons for the requirement for multiple modes of warning:

1. No single mode will be effective for all potential riders under all anticipated operational conditions.
2. Warnings that do not require any specific physical orientation of the sensory receptors are essential to ensure immediate perception. Vision does not meet this criterion (i.e. the rider might not be looking in the direction of the display). Acoustic signals or speech messages, however, do not require any particular orientation of the body for recognition (Lerner, et al., 1996). These signals are generally more intrusive than visual displays and are generally recommended (Van Cott et al., 1972 in Lerner et al., 1996).

Even though an acoustic or speech (or perhaps tactile) cue is required by the urgency of the imminent warning situation, there is also a necessity for a visual display. It is required to handle situations in which more than one warning should be presented to the rider. The additional display will provide distinct cues for each hazard without obscuring one another. According to general human factors guidelines' opinion a maximum of four different distinct auditory signals must not be exceeded to be able to distinguish among different events. Therefore it is necessary to reserve the most intrusive cues to the imminent warning situations. Voice messages may be more capable of distinguishing among different alerts, but there is a certain time required for speaking the full message. It is recommended by Lerner et al. (1996) that for every warning modality used, there are unique signal aspects that reliably indicate that this is a high-priority warning that requires immediate action. The message of an imminent warning should be quickly understandable even for untrained, unfamiliar, and inattentive riders.

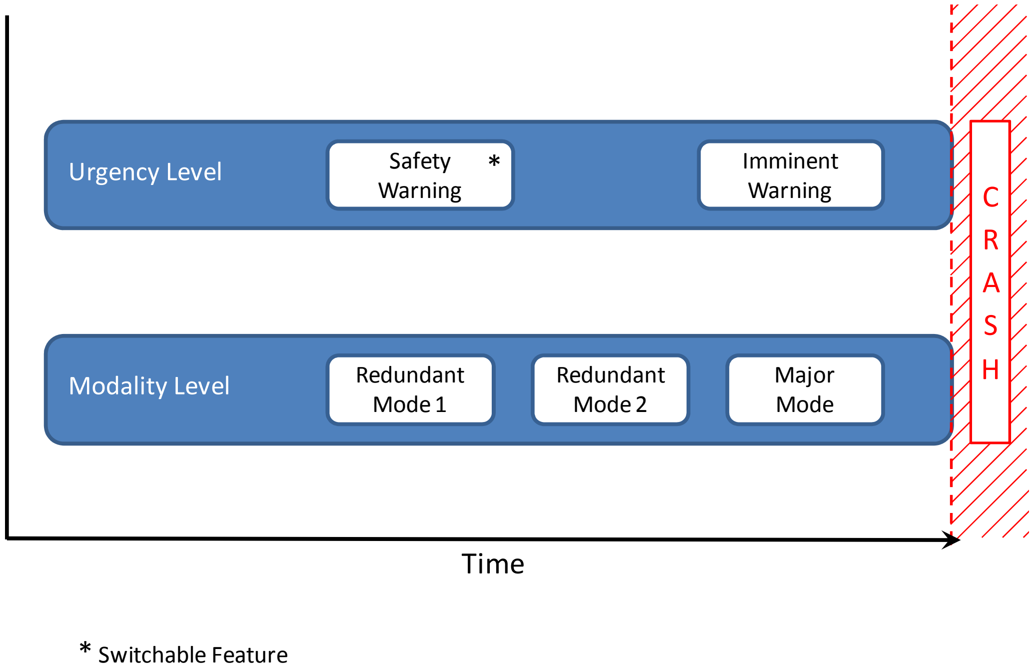


Figure 2.2: Diagram of basic features as visualization of recommendations given by Lerner et al. (1996).

2.2.2 Safety Warnings

Cautionary warnings are lower in urgency than imminent warnings are, but still deal with a potential hazardous situation that requires the rider's attention. Cautionary warnings are proposed to be distinct from, and more urgent than those that are not time critical, e.g. black spot or weather warning. They should be presented visually or by means of auditory or tactile signals that are less intrusive and annoying than imminent warnings. Cautionary warnings normally provide an earlier warning than imminent warnings do. But this results in more false or nuisance alarms. In order to provide a high user acceptance and to protect the higher urgency status of imminent warnings, cautionary warnings must be less intrusive and annoying. Accordingly, visual displays are generally less annoying than acoustic or voice messages. However, the PTW environment might make visual warnings ineffective, unless a head-up display is used, and additional acoustic cautionary signals might be required. In these cases, intrusiveness should be limited.

2.3 Guidelines for Auditory Displays

The following references (listed in the Table 2.4) were taken into account for creating a list of guidelines for auditory displays. They are listed in Table 2.3.

- Campbell, J. L. [et al.] *Crash Warning System Interfaces: Human Factors Insights and Lessons Learned*. NHTSA, 2007.
- DIN EN ISO 15006:2006 Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and compliance procedures for in-vehicle auditory presentation.
- Stevens, A. [et al.] *Design Guidelines for Safety of In-Vehicle Information System.* TRL & DTLR, 2002.
- Lerner, N. D. [et al.] *Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices*. NHTSA, 1996.

Remark: Guidelines in this section are numbered with preceding "C".

Table 2.4: Relevance of auditory displays for PTW.

No.	Citation	Interpretation for PTW
C1	**When to use Auditory Warnings** *"Appropriate situations for using auditory warnings include the following:* • *To present high priority alerts and warnings.* • *To provide a warning to drivers in situations in which they may be distracted or looking away from a visual display.* • *To draw attention directly to the location of a potential crash threat.* • *As the primary modality in an [imminent warning], where it can be used in conjunction with visual (or haptic) displays that provide redundant cues to the driver* (see also figure 2.2, remark of the author). • *To indicate the onset of a system malfunction or limitation. Use a brief auditory tone followed by a continuous visual message.* • *To augment a visual warning display in a non-time-critical situation.*	This guideline provides a practical approach for designing auditory displays and is applicable for PTW use.

No.	Citation	Interpretation for PTW
	Auditory warnings are good for: • *Getting the attention of a driver who is distracted or looking away from a visual warning.* • *Time-critical information.* • *Low-complexity, high-priority messages.* • *Few and short messages.* • *Discrete, sequential, or spatially-localized information.* *Auditory warnings are not good for:* • *Frequent warning messages because they are obtrusive and can be annoying.* • *Continuous information.* • *High complexity / informational messages.* • *High-noise environments that can mask auditory warning signals […].”* (Campbell, et al., 2007).	

Table 2.5: Auditory signals available (Campbell, et al., 2007).

Warning Type	Explanation	Example
Simple Tone	*Single or grouped frequencies presented simultaneously.*	*Square wave*
Earcon	*Abstract musical tones that can be used in structured combinations to create auditory messages. Sometimes referred to as complex tones.*	*“Ding” or two-tone chimes*
Auditory Icon	*Familiar environmental sounds that intuitively convey information about the object or action they represent.*	*Car horn or skidding tire sounds*
Speech Message	*Voice messages that add information beyond pure sound.*	*“Danger”*

C2.	Determining the Appropriate Auditory Signal	Interpretation for PTW
	Design Guidelines: • *“Use simple tones and auditory icons when an immediate response is required.* • *Auditory icons are recommended for collision warning applications where short reaction times are required.* • *Speech-based warnings should be used sparingly, especially if false or nuisance rates are expected to be high.* *Speech messages may be used for simple informational or status messages that are not time critical.”* (Campbell, et al., 2007).	This guideline is also valid for the HMI of ARAS/IVIS on PTW.
C3	**Perceived Urgency and Annoyance of Auditory Warnings** Auditory alerts should communicate a level of urgency that is consistent with the urgency of the hazard. Signal attributes that convey differing levels of urgency are provided below:	This guideline is also valid for the HMI of ARAS/IVIS on PTW.

Table 2.6: Urgency characteristics of auditory signals (Campbell, et al., 2007).

To increase the perceived urgency:	*To decrease the perceived urgency:*
• *Use faster auditory signals.*	• *Use slower auditory signals.*
• *Use regular rhythms.*	• *Use irregular rhythms.*
• *Use a greater number of pulse burst units (4).*	• *Use a fewer number of pulse burst units (1).*
• *Use auditory signals that speed up.*	• *Use auditory signals that slow down.*
• *Use high fundamental frequencies.*	• *Use low fundamental frequencies.*
• *Use a large pitch range.*	• *Use a small pitch range.*
• *Use a random pitch contour.*	• *Use a down or up pitch contour.*
• *Use an atonal musical structure.*	• *Use a resolved musical structure.*

Table 2.7: Specifications of urgency characteristics of auditory signals (Campbell, et al., 2007).

<table>
<tr><td></td><td>Temporal Parameters:

Speed (slow = 1.5 pulse/sec; fast = 6 pulse/sec)

Rhythm (regular = all pulses equally spaced; irregular = pulses not equally spaced)

Number of units (1 = 1-4 pulse burst; 4 = 4-4 pulse bursts)

Speed change (slowing down; speeding up)</td><td>Melodic Parameters:

Fundamental frequency (low = 200 Hz; high = 800 Hz)

Pitch range (small = 3 semitones; large = 9 semitones)

Pitch contour (down/up; random)

Musical structure (resolved = from natural scales; atonal = random sequence of pulses)</td></tr>
<tr><td></td><td colspan="2">“To minimize annoyance:
• Sound characteristics of pulse duration, burst density, sound type, and speed all increase perceived urgency more than perceived annoyance.
• Minimize the rate of false or nuisance alarms to reduce the potential for annoyance.
• Avoid continually repeating a warning. An auditory warning should not be repeated more than three times per crash avoidance situation, and these repetitions should occur in immediate succession.” (Campbell, et al., 2007).</td></tr>
</table>

No.	Citation	Interpretation for PTW
C3/1	In addition to guideline C3, Table2.3 (Lerner, et al., 1996) recommends: *“Intensity of warnings increases as time-to-[hazard] decreases; intensity of warnings decreases as time-to-[hazard] increases.”* (Lerner, et al., 1996).	
C4	Frequencies between 200 Hz and 8000 Hz are recommended for audible speech displays in vehicles. For sound signals the spectrum between 400 Hz and 4000 Hz is recommended. Sine tones should be avoided as standing waves cause resonance and antiresonance and audibility of the signal in the area of the driver’s head cannot be guaranteed. Broad band signals or mixed narrow-band signals with clearly distinguishable center frequencies have to be used (DIN EN ISO 15006:2006).	It is unclear, whether this guideline is applicable to PTW without being modified. Tests have to be conducted to ensure audibility.
C5	Signal audibility in vehicles should be as high as possible (in general 95%). To meet this criterion, the amplitude should be between 50 dB(A) and 90 dB(A). Levels above 90 dB(A) should be avoided. Normally a Signal-to-Noise Ratio (SNR) of 5 dB(A) is considered adequate to assure audibility. A SNR of 15 dB(A) or higher should be avoided (DIN EN ISO 15006:2006).	It is unclear, whether this guideline is applicable to PTW without being modified. Tests have to be conducted to ensure audibility and amplitude limits.
C6	Too high amplitudes and unexpected or unfamiliar signals could cause defensive reaction or startle response, compromising safe driving. A loudness slope that doesn’t exceed 1 dB/ms is recommended (DIN EN ISO 15006:2006).	This guideline is quite general and is therefore also valid for PTW.
C7	The signal level should be adaptable in a range of ±10 dB(A) around a nominally audible rate (DIN EN ISO 15006:2006).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
C8	Except security relevant messages, the audible information presentation should be switchable (DIN EN ISO 15006:2006).	This guideline is quite general and is therefore also valid for PTW.
C9	The level should be automatically adaptable to the frequency spectrum of background noise (DIN EN ISO 15006:2006).	This guideline is quite general and is therefore also valid for PTW.
C10	Especially for speech displays, a frequency-specific amplification should be foreseen, allowing drivers to adapt the signals to their hearing (DIN EN ISO 15006:2006).	This guideline is quite general and is therefore also valid for PTW.
C11	Acoustic signals should be separated into classes according to the urgency of the intended driver reaction. To be able to differentiate between these classes, different combinations of acoustic parameters can be chosen. A classification in three time categories seems to be appropriate (DIN EN ISO 15006:2006).	Assumed that the rider of a PTW has less time to glance at additional information that is visually displayed, it seems to be convenient to classify to signals into only two categories, in order to provide easy understanding.

<table>
<tr><th>No.</th><th colspan="5">Citation</th><th>Interpretation for PTW</th></tr>
<tr><td rowspan="5">C12</td><td></td><td>Category</td><td>Signal</td><td>Speech</td><td></td><td rowspan="5">This guideline is quite general and is therefore also valid for PTW.</td></tr>
<tr><td></td><td>Short-term Info</td><td>applicable</td><td>Not recom-mended</td><td></td></tr>
<tr><td></td><td>Medium-term Info</td><td>applicable</td><td>applicable</td><td></td></tr>
<tr><td></td><td>Long-term Info</td><td>Applicable as announce-ment of a visual or speech display</td><td>Recom-mended (speech display)</td><td></td></tr>
<tr><td></td><td colspan="3">from (DIN EN ISO 15006:2006)</td><td></td></tr>
<tr><td>C13</td><td colspan="5">Some signal tones providing an understandable sound to every driver, have not to be trained before use, and are therefore recommended (DIN EN ISO 15006:2006).</td><td>This guideline is quite general and is therefore also valid for PTW.</td></tr>
<tr><td>C14</td><td colspan="5">Conspicuity must be measured to grant the activation of the right behavior and to prevent false reactions (in accordance to ISO 15006 – section 5.3.2.2 and appendix A) (DIN EN ISO</td><td>This guideline is quite general and is therefore also valid for PTW.</td></tr>
</table>

	15006:2006).	
C15	*"When multiple sounds are used within complex systems, the sounds should be designed as an integrated set. By doing so, the audibility of the signals with one another and background noise can be optimized."* (Stevens, et al., 2002).	The audibility of sounds provided to motorcyclists has to be proved by extensive testing. It is necessary to find the optimal sound parameters for each environment and each type of speaker.
C16	*"The onset rate for sounds or tones used in […] warnings should be rapid enough to alert the driver, but not so rapid as to induce severe startle effects. Onset rates of greater than 1 dB/ms but less than 10 dB/ms are recommended. The offset rate should be equal to the onset rate."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
C17	*"A single sound or tone used as a […] warning signal should be between 200 and 500 ms in duration. If complex tones as opposed to pure tones are used, durations near the bottom of this range are recommended."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
C18	*"Speech displays are not recommended for providing time- or distance-to-[hazard] information."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
C19	*"Speech warning displays should be highly intelligible, but readily distinguishable from the normal human voice. "* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
C20	*"Speech displays may be used to present imminent and cautionary […] warnings. […] Generally, more time is required to deliver a speech message than to alert the driver through other modes. For this reason, speech displays are not recommended for presenting specific information of dynamic structure. Acoustic displays, which can cycle quickly, are capable of providing such information more succinctly than speech displays."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW. Yet, it has to be added that Lerner et al. (1996) primarily refers to crash avoidance warning systems, i.e. this guideline is only applicable to warning messages, not to IVIS messages (e.g., navigation and route guidance).
C21	*"Speech warnings should be as brief and concise as possible (e.g., one to three words)."* (Lerner, et al., 1996).	This guideline is quite general and is therefore

		also valid for PTW.
C22	*"The vocabulary used in speech messages should be limited in size, and should consist of words which can be easily discriminated from one another. If sufficient time is available, polysyllabic words are recommended over monosyllabic words."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
C23	*"The content of speech messages should be limited to that which alerts the driver to the [hazardous] situation and directs the drivers' attention to its location."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
C24	*"Voice messages should not be repeated numerous times [i.e., in general not more than three times] because of their tendency to irritate the driver and upset passengers."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
C25	*"[…] warning vocabularies and messages should be developed and tested separately for each language to be represented within the system or device."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.

No.	**Citation**	**Interpretation for PTW**
C26	*"An alerting tone should not be used preceding voice messages unless its benefits in the crash avoidance context can be demonstrated."* (Lerner, et al., 1996).	As already mentioned in guideline C20 interpretation, Lerner et al. (1996) predominantly provides guidelines for crash avoidance warning systems. Thus, guideline C26 is only valid for the design of speech messages for crash avoidance warnings. Lerner et al. (1996) continues, that "a number of studies [...] and standards [...] recommend the use of an alerting tone preceding speech warning messages, because the tone can speed response to the speech message to some extent."

Since a complete exposure of the relevant guidelines' text segments and a complete sampling of all guidelines are not possible within the scope of this document, it is recommended to have a closer look at the original references, in order to get more detailed information about particular topics.

2.4 Guidelines for Visual Displays

The following references (listed in the Table 2.8) were taken into account for creating a sample of guidelines for visual displays. They are listed in Table 2.4.

- Campbell, J. L. [et al.] *Crash Warning System Interfaces: Human Factors Insights and Lessons Learned*. NHTSA, 2007.
- DIN EN ISO 15008:2003 Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and compliance procedures for in-vehicle visual presentation.
- Stevens, A. [et al.] *Design Guidelines for Safety of In-Vehicle Information System.* TRL & DTLR, 2002.
- Lerner, N. D. [et al.] *Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices*. NHTSA, 1996.
- Wogalter, M. S.[et al.] *Research-based guidelines for warning design and evaluation.* Elsevier Science Ltd., 2002.

Remark: Guidelines in this section are numbered with preceding “D”.

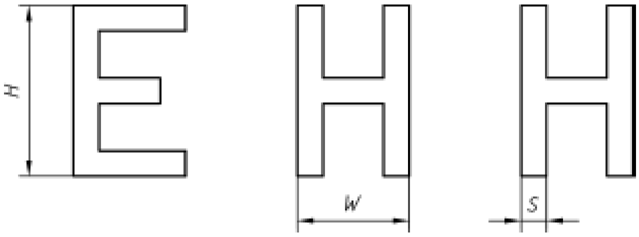
Table 2.8: Relevance of visual displays for PTW.

No.	Citation	Interpretation for PTW
D1	*“Primary visual displays could serve as the main visual display of the warning device. Secondary visual displays are optional [and can be used] to provide additional information […].”* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
D2	*“Primary displays should immediately and reliably capture the driver’s attention and direct the driver to the direction or nature of the hazard. These displays should be simple and should be more conspicuous than secondary displays.”* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
D3	Because complex displays require excessive eye-off-the-road time and cause a slow decision-making process, simple indicators should be used as primary visual displays, providing only information necessary for the driver to resolve the hazardous situation. (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
D3/1	*“A driver should not be required to transpose, compute, interpolate, or translate displayed […] warning information.”* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
D4	*„Applicable situations include:* • *Providing redundant or supplemental information that accompanies a primary auditory or haptic ICW.* • *Providing primary warning information in a situation in which drivers can reasonably be expected to see the visual warning as part of the regular information-acquisition process (e.g., a visual [warning] for a [Lane Change Warning] system that is presented on the rear-view and side-view mirror, or on an A-pillar).* • *Providing continuous lower-priority information such as a [cautionary warnings]."* (Campbell, et al., 2007).	It is unclear whether this guideline is valid for powered two-wheelers. PTW feature limit possibilities for auditory warnings, therefore importance and use of visual displays might be increased compared to cars.
D5	**Location:**	
	"Primary display visual warnings should be located within 15 degrees of the driver's expected line of sight in a given […] situation." They *"should be entirely visible at all times. Primary visual displays should not be obscured by other visual displays or structures […]."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
D5/1	*"Visual displays showing high priority information during driving should be located within 15° of the driver's vertical viewing position and ideally 15° horizontally with a maximum separation of 30°."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D5/2	"Visual displays positioned close to the driver's normal line of sight reduce the total eyes-off-the-road time relative to those that are positioned further away." (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
D6	**Legibility:**	
	"[…] warning displays should be legible at a glance. Display characters (e.g., alphanumerics, geometric shapes) should subtend a minimum visual angle of at least 12 minutes of arc." (Lerner, et al., 1996). *"Testing should be conducted for specific displays to ensure that the display is legible for 95% of the expected driving population."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
D6/1	*"To ensure legibility of information the designer needs to consider not only the position of the visual display, but properties such as **brightness, contrast, size and resolution**. These should be such that the displayed information is clearly legible during daylight and darkness and does not cause visual discomfort or distract the driver when not being directly viewed."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D7	**Brightness (luminance, intensity)**	
	"*The brightness (luminance) of the overall display should appear uniform to drivers. […] The brightness of the display should be adaptable to changes in ambient light (e.g., day or night) to ensure that the display is legible in all ambient light conditions."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D8	**Contrast**	
	The contrast ratio […] describes the relation between the luminance of the foreground and background. This should be at a minimum of 5:1 in night conditions, a minimum of 3:1 at daylight conditions and a minimum of 2:1 at sunlight conditions (DIN EN ISO 15008:2003). Stevens et al. (2002) recommends a contrast of 5:1 and mentions that too high contrast could cause problems of glare, while too low contrast slows down the reading process.	Motorcycles have an environment different from which a car has. The light conditions are often changing and generally more difficult. It is uncertain, whether this guideline is applicable to PTW without adaption. Therefore it is proposed to test each visual display device to ensure legibility.

No.	Citation	Interpretation for PTW
D8/1	The ratio of average luminance of the display and of the surrounding (luminance balance) should not exceed 10:1 (Stevens, et al., 2002). Yet, higher values are often acceptable; at a ratio of 100:1, reading performance decreases slightly but yet significantly (DIN EN ISO 15008:2003).	This guideline is quite general and is therefore also valid for PTW.
D8/2	$Contrast = \frac{L_f - L_b}{\text{[illegible]}}$ L_f= Luminance of the foreground L_b= Luminance of the background (DIN EN ISO 15008:2003)	This guideline is quite general and is therefore also valid for PTW. Additional information about measuring methods and requirements is provided in DIN EN ISO 15008:2003.
D8/3	*"Reflections and glare visible to the driver […] reduce legibility and should be avoided for example through:* • *Provision of a display brightness control* • *Appropriate display surface texture and finish* • *Appropriate colour choice* • *Appropriate image polarity* • *Use of recess or cowl* *Designer should ensure that any reflections and glare reduction, or contrast enhancement techniques of this type, do not cause the display to contravene other relevant standards."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW, but displays have to be tested to ensure legibility.
D9	**Resolution, Size and Spacing**	
	"The resolution of the display should be high enough to show the driver solid images of information via symbol or text. The number of pixels measures a display's resolution. The single pixels of a display tie together to form a contour of a picture (text or symbol). With an increasing number of pixels, the contour of the picture will appear clearer." (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
D9/1		
	Figure 2.3: Character height, width and stroke (DIN EN ISO 15008:2003).	
	The minimum required character height should be a visual angle of 15'. This angle describes the relationship between the viewing distance and character height. For colour displays a character height of 20 arc minutes is recommended, and a value of 24' being optimal (DIN EN ISO 15008:2003). The visual angle can be calculated by using the following equation:	This guideline is quite general and is therefore also valid for PTW.
	$\alpha = 60 \times \tan^{-1}\left\lvert\frac{H}{d}\right\rvert$, where d is the distance from the viewer's eye to display surface and α is the visual angle in arc minutes.	
	The ratio of character width to height for alphanumeric displays should be between 0.6 and 0.8. The ratio of stroke to character height must be between 0.08 and 0.16 (DIN EN ISO 15008:2003).	

No.	Citation	Interpretation for PTW
D9/2	*"Character spacing refers to the horizontal space between adjacent characters. This is usually expressed in terms of the stroke width of the characters. The space between the characters should be a minimum of one stroke width. Wider spacing should be used for more prominent, dynamic and safety critical information. The more critical the information, the wider the spacing should be; although legibility will be reduced if it becomes excessively large."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D9/3	The space between two text lines must be at least one stroke width. No character parts or diacritical marks must be placed in this area (DIN EN ISO 15008:2003).	This guideline is quite general and is therefore also valid for PTW.
D9/4	The distance between two words must be at least one character width (DIN EN ISO 15008:2003).	This guideline is quite general and is therefore also valid for PTW.
D10	**Colour**	
	"Colours should be: • *Coded such that their meaning is clear and should conform to stereotypical norms […].* • *Used to make it easier to find the required information under both day and night-time viewing conditions.* • *Chosen so that red/green and blue/yellow combinations are avoided."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW. For further information about stereotypical norms, please refer to DIN EN 60073:2003

Table 2.9: Character/background colour combinations (DIN EN ISO 15008:2003).

Background Colour	Character Colour						
	white	**yellow**	**amber, orange**	**red, purple**	**green, cyan**	**blue, violet**	**black**
White		-	o	+	+	++	++
Yellow	-		-	o	o	+	++
amber, orange	o	-		-	-	o	+
red, purple	+	o	-		-	-	+
green, cyan	+	o	-	-		-	+
blue, violet	++	+	o	-	-		-
Black	++	++	+	+	+	-	

++	very good
+	good
o	acceptable
-	not recommended

No.	Citation	Interpretation for PTW
D11	**Screen Image Stability** *"The screen display should not vibrate or flicker to an extend where information becomes blurred […]. Vibration and flicker are likely to increase reading time and consequently the time required to complete the task and thus will increase visual distraction from the driving task."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D12	**Image Blinking** Blinking (or flashing) of any visual image should only be used to attract attention and inform about critical conditions. For attracting attention, a single blink frequency of 2 to 4 Hz with a duty cycle of 50% is recommended. If legibility of the displayed information is required, a single blink rate of 1/3 Hz to 1 Hz with a duty cycle of 70% is recommended (DIN EN ISO 15008:2003).	This guideline is quite general and is therefore also valid for PTW.

No.	**Citation**	**Interpretation for PTW**
D12/1	"If two or more imminent […] warnings occur simultaneously, the flashes should be synchronous." (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
D13	**Head-Up Displays**	
	"Head-up displays (HUD) consist of a virtual image that is optically superimposed on the driver's forward field of view, using either the windshield or a separate optical element. • *[…] Do not present the HUD image in the driver's central field of view as it will mask external objects.* • *Drivers should be able to turn the HUD off.* • *Important HUD information should be coupled with an auditory alert.* • *While the HUD image must be visible in all potential viewing conditions, luminance contrast requirements for HUDs are a concern because of the dynamic interference with the background road traffic environment.* • *Virtual image distances should be between 2.5 to 4 meters from driver's eyes.* • *Information should only be displayed temporarily in the HUD. The HUD should not be used to display information continuously.* • *HUD displays should not be used to display complex information, for example detailed navigation information that cannot be processed quickly, rather, a simple display with very few elements should be used.* • *Use images that conform the road environment (e.g., virtual road signs projected by the road side)."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D14	**Message**	
	"Messages presented while driving should not consist of more than four units of information. Concrete words which have clear meanings should be used whenever possible." (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.

No.	Citation	Interpretation for PTW
D14/1	*"Numerical data should use accepted and understood units; and provide an appropriate level of precision."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D14/2	*"Abbreviations should only be used when it is necessary; and should not be used for safety-critical information. […] internationally and nationally agreed standards related to abbreviations should be [taken into account]."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D14/3	*"Safety-critical information should be given a command style. However, the command style should be used infrequently."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D14/4	*"High priority messages, such as immediate hazards or vehicle status warnings, should be preceded by an auditory alerting tone."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D14/5	*"Messages that convey non-critical information should be given in an informative style."* (Stevens, et al., 2002).	This guideline is quite general and is therefore also valid for PTW.
D14/6	*"An effective warning consists of four message components […], each of which serves a different purpose: 1. signal word to attract attention, 2. identification of the hazard, 3. explanation of consequences if exposed to hazard, 4.directives for avoiding the hazard."* (Wogalter, et al., 2002). The four most common signal words according to Wogalter et al. (2002) are DANGER, WARNING, CAUTION, and NOTICE. With DANGER connoting the greatest degree of hazard, and NOTICE the least.	This guideline is quite general and is therefore also valid for PTW. For more detailed information about the other message components please refer to Wogalter et al. (2002).

2.5 Guidelines for Tactile Displays

Tactile displays can be separated into two types:

1. Vibrotactile displays
2. Counterforce displays (e.g., upward force on accelerator pedal in cars)

The following references (listed in the Table 2.10) were taken into account for the research of guidelines:

- Lerner, N. D. [et al.] *Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices*. NHTSA, 1996.
- Jones Lynette A. and Sarter Nadine B. *Tactile Displays: Guidance for their Design and Application* [Article] // Human Factors: The Journal of the Human Factors and Ergonomics Society. - Cambirdge, MA : Human Factors and Ergonomics Society, February 2008.

Remark: Guidelines in this section are numbered with preceding "E".

Table 2.10: Relevance of tactile displays for PTW.

No.	Citation	Interpretation for PTW
E1	*"The type of tactile display chosen and the location of the display with reference to the driver's body, should be such that the driver can easily associate the display with a particular […] situation and determine an appropriate response."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.
E2	*"Vibrotactile displays, once activated, should cycle continuously until the [hazardous] situation no longer exists, the driver has taken appropriate corrective action, or the display has been manually terminated."* (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW. However, it should be part of further research to answer the question, how long a vibrotactile display should be presented without annoying the rider of a PTW.
E3	Frequencies of 3Hz should be avoided, because it matches the resonating frequency of the internal organs of the human body and may cause nausea and discomfort (Lerner, et al., 1996).	This guideline is quite general and is therefore also valid for PTW.

More guidelines and principles on the design of tactile displays and their characteristics are provided in section 3.3.

2.6 Relevant Literature

In order to give an overview over the relevant literature that was part of the development process of this concept, the following table shows important references and provides a short description of each of them. It contains books, reviews, articles, standards and principles dealing with human factors, human-machine interaction or warning design but is not exhaustive (cf. Section "Literature"). Some relevant standards are listed in addition to those referred to in the previous section.

Table 2.11: List of relevant literature.

"Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices", Lerner et al., COMSIS Corporation. (NHTSA Project No. DTNH22-91-C-07004). Silver Spring: NHTSA, 1996	This book contains all basic information about human factors for warning devices. The guidelines are applicable for systems that go beyond crash avoidance systems as well. It is a broadly known and highly accepted source of knowledge, for designing HMI-components and concepts.
"Update of the European Statement of Principles on Human Machine Interface for in-vehicle information and communication systems", European Commission, 2006	Essential aspects for the HMI of in-vehicle information and communication systems are summarized in this statement. It provides recommendations on safe and efficient communication. The principles are rather unspecific and do not promote any technical realization.
"Guidelines for the Design and Installation of Information and Communication Systems in Motor Vehicles", United Nations Economic Commission for Europe, Inland Transport Committee, 1998	Very similar to the "European Statement of Principles", these guidelines give quite general advice on designing information and communication systems in vehicles.
"Crash warning system interfaces: Human factors insights and lessons learned." Campbell et al., National Highway Traffic Safety Administration, 2007	A very convenient approach of providing design guidelines. Advantages and disadvantages of several topics are presented in tabular form, what makes it very efficient. In its guidelines' recommendations it thus goes slightly beyond Lerner et al. (1996) and gives more advice on technical details.
"Tactile Displays: Guidance for their Design and Application" Jones, Lynette A. and Sarter, Nadine B. [Article] in: Human Factors - The Journal of the Human Factors and Ergonomics Society. - Cambirdge, MA : Human Factors and Ergonomics Society, February 2008	This article is one of very few scripts that provide elaborate information about the specifications of tactile output devices. It serves concrete recommendations about the design of specific display characteristics, such as frequency, amplitude and so on.

“Research-based guidelines for warning design and evaluation” Wogalter [et al.], [s.l]: Elsevier Science Ldt, 2002	This review is a short sample of guidelines for warning design. Yet simple, it particularly contains broad information about wording in warning design and some other relevant topics.
ISO Standards (for this work only the corresponding german versions were available): DIN EN ISO 15005 DIN EN ISO 15006 DIN EN ISO 15007 DIN EN ISO 15008 ISO 2575 and ISO 6727 EN ISO 60073 EN ISO 9241	For descriptions of the standards please visit the homepages of the International Organization for Standardization (http://www.iso.org) and the European Committee for Standardization (http://www.cen.eu) respectively.
“Design Guidelines for Safety of In-Vehicle Information Systems” Stevens, A. [et al.], [s.l.]: TRL and DTLR, 2002	The book provides broad information about the design of in-vehicle information systems. It refers to other standard works and the relevant ISO standards and is a well structured pooling of information.

3 HMI Elements

At the beginning of this work an expert interview with 5 PTW driving instructors and PTW experts was conducted. One focus of the interview laid on possible HMI elements preferred by the target group. A second focus lay on expectations within the target group concerning new ARAS and IVIS for the PTW market and the concrete information they assume to be necessary and at which time.
HMI guidelines were used to define the basic requirements. Most of common literature refers to the automotive sector. It was therefore necessary to interpret the available guidelines with respect to PTW conditions (see also section 2). The results of the interpretation of guidelines are the content of the following sections.

3.1 Visual Output

The most versatile kind of output is the visual display. Great amounts of information can be transferred at a certain time, yet understandable, distinguishable and clear. But visual displays have some disadvantages concerning distraction and the time, required to notice visual output.

3.1.1 Design of the dashboard display

Figure 3.1: Possible Cockpit layout.

The screen of the dashboard display is primarily used to display the actual environment of the PTW for navigation and route guidance matters. It is supposed that the PTW uses this screen in addition to the conventionally used analogue displays for necessary vehicle data, such as speed, fuel level, beam light, etc. In case of an additionally occurring warning, different strategies are available to handle these two concurrent outputs of interest.

Constant navigation in display

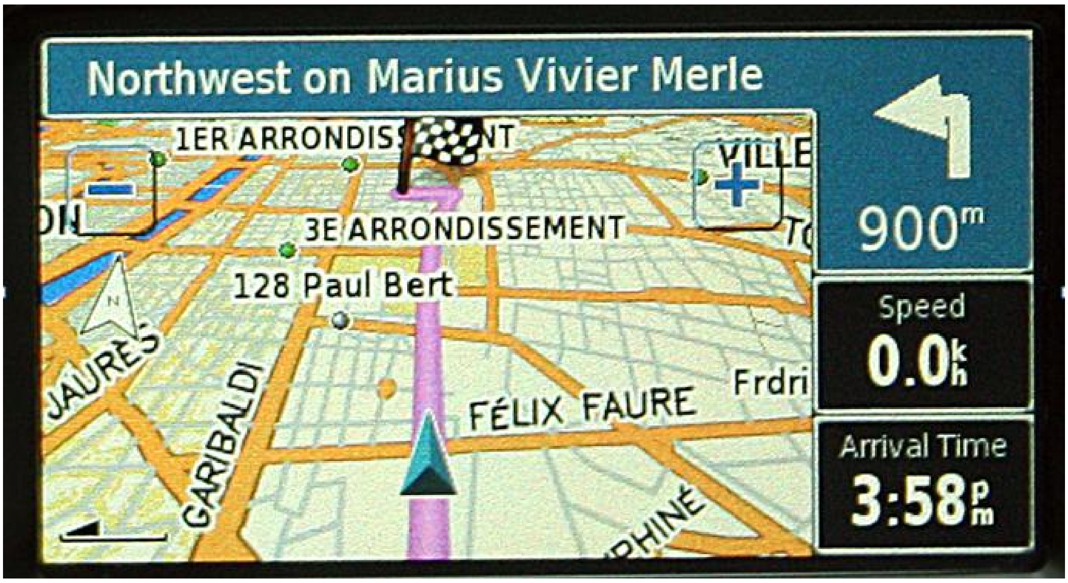


Figure 3.2: Constant navigation.

The first possibility to handle this task is to keep the navigation layout on the screen of the dashboard display and use other warning modalities different from visual mode for displaying the warning message. This could be either auditory or tactile displays. Further it is possible to use a second visual display to transfer the warning message content to the rider. Due to limited space in the dashboard of a PTW, this would probably be a head-up display. It has to be taken into account that for imminent warnings at least one modality must be visual (Lerner, et al., 1996).

Which way ever the additional warning message might be displayed, the screen of the dashboard display will remains the same.

Warning as overlay or shared screen

The second possibility is to find a compromise between the navigation screen on the one hand and the warning message output on the other. Two different types of compromises are conceivable:

- The warning message covers the navigation display. The advantage of this is that the warning message can be clearly perceived and navigation advice is still available (in figure 3.2 on the right side of the display screen). However, some route information gets lost behind the warning message sign/icon. Rider disturbance cannot be excluded.
- The navigation display shrinks and fills just a part of the screen, thus preparing free space on the screen for additional warnings. The warning signs are scaled smaller and are therefore harder to be recognized by the rider. The same applies to the navigation display in a shared screen.

Figure 3.3: Warning as Overlay.

Figure 3.4: Shared Screen.

Warning removes Navigation and takes full display

The third possible design of the dashboard display takes up the principle of the most imminent warning to be displayed exclusively, i.e. the navigation display is removed from the screen and instead the warning message appears. This alternative would provide the best conspicuity and understandability and has probably the shortest time to response. Depending on the urgency of the warning, several interstates are imaginable. Thus, a safety warning could be displayed in addition to the navigation advices, whereas an imminent warning would be displayed exclusively.

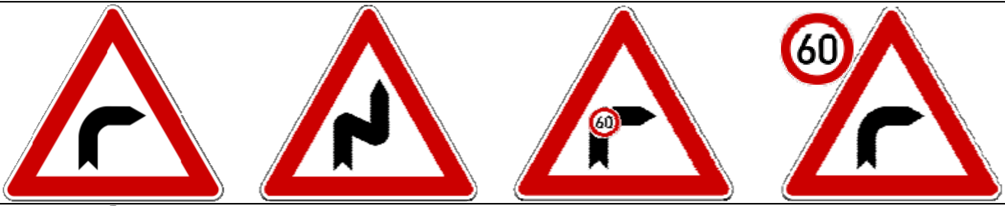
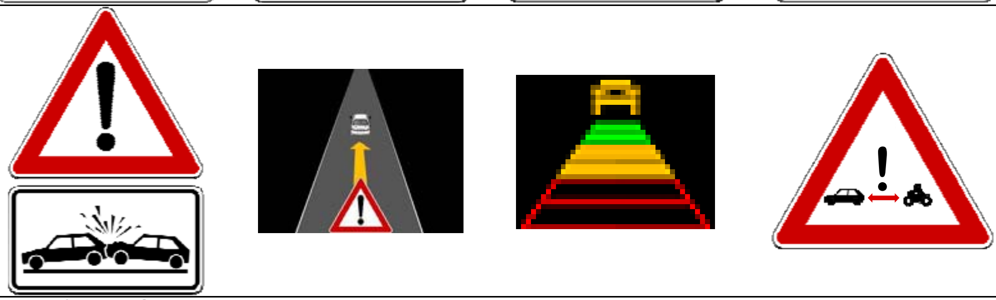
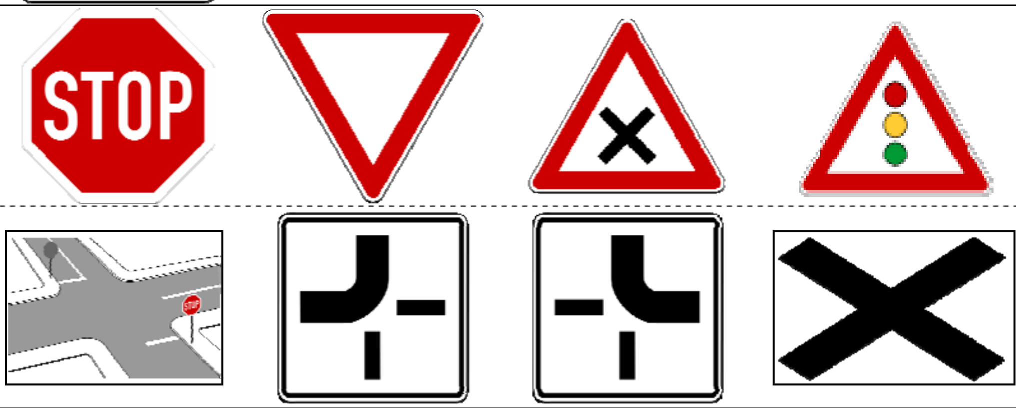
Figure 3.5: Warning as small overlay.

Figure 3.6: Exclusive warning icon.

3.1.2 Familiar road signs

According to Wogalter, et al. (2002) pictorial symbols are noted earlier, thus making warnings more salient. Visually displayed information should be such that the driver can assimilate it with a few glances which are brief enough not to adversely affect driving. Where available internationally and/or nationally agreed standards related to icons and symbols should be used (European Commission, 2006). To keep symbolism as simple as possible it is proposed to use familiar road signs and commonly used pictorial symbols. Some general examples for each application are shown in Table 3.1.

Table 3.1: Proposed traffic signs and symbols for ARAS.

ARAS/IVIS System	Proposed Signs
Speed Alert	For the application Speed Alert it is proposed to use speed limit sign with numbers indicating the maximum speed allowed. Numbers at least in steps of 10 km/h. 
Curve Warning	
Frontal Collision Warning	
Intersection Support	

.

Table 3.2: Proposed traffic signs and symbols for IVIS.

Navigation & RG	Because of the great variety of navigation devices available on the market and the great experience with route guidance symbolism the manufacturers have, it is abdicated to propose exactly the signs that are already used or any additional ones.
Weather, Traffic & BSW	

3.1.3 Urgency of Visual Warnings

Visual warnings should provide information about the nature of the hazard and be visually conspicuous with good attention-getting properties.
To be able distinguish between the urgencies of the different warnings it is advisable to vary the sign and symbols used in three characteristics:

- Size
- Flashing rate
- Colour

Bigger size grants faster recognition and is therefore used for more urgent warnings than symbols of smaller size are. Yet, it is also a matter of unobtrusiveness. So, at least for safety warnings there might be a trade off between salience and unobtrusiveness. For imminent warnings it is clear that design of visual warning messages must take into account these characteristics. Thus, imminent warning icons must be greater, flashing quicker (and probably brighter) and must be red. For safety warnings yellow or amber should be used as primary colour.

Flashing could be used to support noticeability of more urgent warnings. An abrupt onset (rapid luminance change) is optimal for capturing attention, and this effect can be enhanced by flashing the visual warning at a frequency of 3 to 10 Hz, with 4 Hz being optimal for imminent warnings. Visual displays for safety warnings, however, should be presented as a steady indicator (not flashing) (Campbell, et al., 2007).

Drivers typically have inherent colour stereotypes for different levels of warning urgency. The colour red is usually associated with critical, high-priority information (e.g., danger), and is hence appropriate for use as part of a visual imminent warning (Campbell, et al., 2007).

According to Green (Green, et al., 1993) the guideline principle for designing visual displays' background is to minimize glare. Since there are more pixels for the background than for the text (foreground), using a dark background will minimize glare from the display, especially at night. This is called a negative contrast. The most difficult display conditions occur during the daytime, though, when the sun is low in the sky. Luminance and contrast must be fitted such that visual warnings can be perceived at any time (Green, et al., 1993).

3.1.4 Realistic Schematic Display of Intersection

For the ARAS system Intersection Support it makes sense to provide additional information to the rider in form of a schematic presentation of the current intersection. This information is most useful, when it is displayed early before reaching the intersection. Because of the complex configuration of the crossing roads, it might take some time to get completely noticed and understood. Therefore, when reaching the intersection, the presentation of the intersection should no longer be displayed to avoid rider's distraction. Many navigation devices already feature this functionality which is proposed to be adopted.

Figure 3.7: Schematic display of intersection.

3.1.5 Visual Attractor

In addition to the dashboard display a visual attractor might be installed in the rider's field of vision. It consists of an array of several bright LEDs, emitting (possibly flashing) red light. The attractor is used draw the rider's attention to the road ahead. The attractor is probably most effective when installed on the upper end of the PTW's windshield directing to the rider or when emitting the light to the shield and illuminating by this a larger area.

Figure 3.8: Visual Attractors in the Driver's Field of Vision.

Recently, Honda presented a visual attractor within the scope of the Car-To-Car Communication Consortium (http://www.car-to-car.org), when introducing car-to-bike communication. To enable the rider to intuitively and quickly capture visual warnings, a light band is mounted onto the upper end of the cockpit, as close as possible to the rider's field of vision. The combination of light intensity, colour and position is to convey information about location and urgency of the hazard to the rider. Additionally, an acoustic warning, in the form of a speech display in the helmet is provided via Bluetooth (Schröder, 2008).

Figure 3.9: Honda's visual attractor (Schröder, 2008).

3.1.6 Head-Up Display

According to SAFERIDER internal report "HMI Elements for ADAS" (Fraunhofer IAO, 2008) head-up displays are already available. At current state the NZI HUD provides two numerical fields and a bar of individually illuminating elements. It is proposed to use the HUD for non-critical information rather than in imminent situations. The HUD has a certain potential of distracting the driver and could interfere with clear vision.

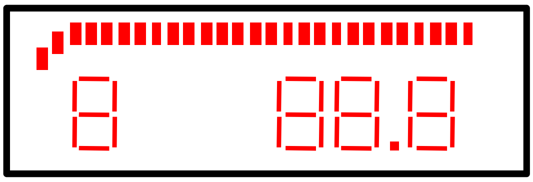


Figure 3.10: Current State of HUD.

The numerical fields can be used to display current speed or desired speed (e.g. for Speed Alert the current speed limit). It should be clearly distinguishable which kind of speed is displayed. The bar on the upper side could be used effectively to display the distance to the hazard (e.g. curve, intersection, preceding car or distance to turn, or maybe the TTC). Thus, when approaching a hazard more and more red fields might be illuminated, symbolizing increasing danger. Basically the bar display is best in displaying changing information with little detail.

3.1.7 Application of Visual Displays

Provided that the visual channel basically has the highest priority to a PTW rider it has to be considered how much visual processing capacity the rider may spend on the HMI devices (Abel, et al., 2007).

Visual warnings are good for:

- Unobtrusive warnings / non-urgent information / self-paced presentation.
- Complex, long, and many messages.
- Discrete and continuous information.
- Spatial information.
- Temporally and spatially free access.

Visual warnings are *not* good for:

- Conveying time-critical information / forced-paced presentation.
- Poor/difficult illumination conditions.
- Configuration with unrestricted driver viewing angle and position (Campbell, et al., 2007).

3.2 Auditory Output

3.2.1 Design of Auditory Outputs

Auditory outputs include both acoustic and speech output. Auditory outputs are most effective if they are reserved for imminent warnings, but they may also be effectively used for safety warnings for certain applications. To be distinguishable the following characteristics should be used to differentiate imminent from safety warnings and alerting tones (Lerner, et al., 1996)

Table 3.3: Characteristics of Auditory Warnings (Lerner, et al., 1996).

Imminent Auditory Display	Safety Auditory Display
high signal (or pattern) repetition rate	low signal (or pattern) repetition rate
high intensity	low intensity
high fundamental frequency	low fundamental frequency
large frequency oscillations within auditory patterns	small frequency oscillations within auditory patterns

There are three different types of auditory warnings:

- Alerting tone: Provides unobtrusive indication of non-critical information presented in the dashboard display.
- Safety auditory display: Used in situations which require corrective action of the rider but which are not time-critical.
- Imminent auditory display: Used for time-critical situations, requiring immediate corrective action of the rider.

Speech displays are intended for the navigation and RG device only, because they are more obtrusive and require more time to be presented and received.

3.2.2 Urgency of Auditory Output

The safety auditory warning should be noticeable, convey rather little urgency and direct the rider’s gaze towards the dashboard display under safe driving conditions. It may also occur quite often and must not be annoying. It is recommended to use an earcon that merely notifies the driver about a new message. This is similar to already existing applications like the notification of a new text message on a mobile phone or a new e-mail on a PC. Appropriate earcons are available from different manufacturers. They can give hints on how to design an earcon suitable for the SAFERIDER context.

The imminent earcons need to convey higher urgency. They shall interrupt the rider in his/her routine and trigger an immediate reaction. This also means that false alarms could be regarded as being more annoying than on the safety level. The sound should be composed of 10 or more harmonically spaced components, at least 4 of which are prominent and in the range of 100 to 4000Hz. For SAFERIDER a classical warning sound that consists of 2 or 3 bursts with a base frequency of around 2000 Hz is therefore proposed as a basis for the safety earcon (Cho et all, 2001). Warning tones of such a type are easy to notice while driving and easy to vary in their impression of urgency.

The imminent earcon could be a continuation of the style of the safety earcon - a single warning tone that is longer and louder than a single burst of the safety tone. Impressions of very high urgency can also be achieved by including higher harmonic and disharmonic frequencies (Sayn, et al., 2007).

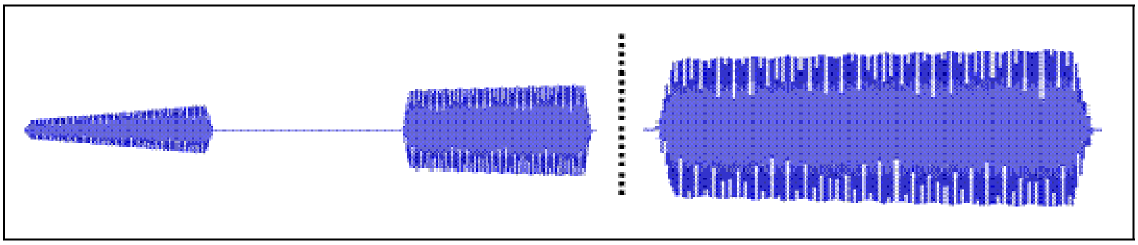


Figure 3.11: Characteristics of safety earcon (left) and imminent earcon (right). (Sayn, et al., 2007).

3.2.3 Auditory Messages Presentation

It is recommended to use helmets that allow presenting the same auditory messages to both ears of the rider. The advantages of this kind of output solution are:

- Lower probability of ignorance.
- Audibility for one-sided hearing-impaired riders.
- Possibility to provide directional information.

Directional auditory information could shorten the time required to detect a hazard. For the application of directional auditory information to PTW there are only two directions available (right or left). However it is recommended not to use directional warnings unless the head position of the rider is clearly recognizable. Potentially confusing scenarios should be avoided, such as providing an auditory warning message to the left ear while the rider's head is turned to the left: in this case, the rider may mistakenly localize the warning's cause as coming from his/her back.

3.2.4 Application of Auditory Outputs

Auditory warnings are good for:

- Getting the attention of a driver who is distracted or looking away from a visual warning.
- Time-critical information.
- Low-complexity, high-priority messages.
- Few and short messages.
- Discrete, sequential, or spatially-localized information.

Auditory warnings are *not* good for:

- Frequent warning messages because they are obtrusive and can be annoying.

- Continuous information.
- High complexity/informational messages.
- High-noise environments that can mask auditory warning signals (techniques for mitigating auditory masking may be necessary).

3.3 Tactile and Haptic Output

3.3.1 Tactile Elements

According to Jones (Jones, et al., 2008), the optimal sensitivity is achieved at frequencies between 150 HZ and 300 Hz for all sites of the human body. At lower and higher frequencies the displacement of the skin must be greater to be detected. The amplitude for detecting vibration at any given frequency does, however, vary considerably over the body with the lowest threshold (i.e. highest sensitivity) being measured on the fingertips. In using the skin as a communication channel it is important to know how sensitive people are to changes in vibration frequencies, as frequency appears to be a very natural parameter to use to encode information. But, it is difficult to specify the change in vibrotactile frequency that could be reliably distinguishable by the rider. In the context of a tactile output that presents information to an operator engaged in a number of tasks, it is unclear whether vibration frequency is a useful parameter to vary in order to provide different urgency levels.

A further variable that can be used to encode information in a tactile output is temporal variation in the stimuli presented. This leads to a **rhythmic tactile output**. Three temporal components to vibrotactile stimuli have been studied:

- Burst duration
- Pulse repetition rate
- Number of pulses

When the tactile signal is functioning as a simple alert, people prefer that the duration of the tactile pulses be between 50 and 200 ms, as stimuli of longer durations are perceived as annoying. It is also possible to group vibrotactile pulses of varying durations together so as to create rhythms that encode information (e.g., urgency of message, proximity of vehicle). The capacity to perceive vibrotactile frequency appears to be largely attributable to temporal cues rather than spectral properties, as the human tactile system seems to be relatively insensitive to variations in waveform, in marked contrast to the perception of timbre by the auditory system. Signals such as these could be used to convey cues about traffic flow in a handheld or vehicle-based device. Changes in the intensity or amplitude of vibration can also be used to convey information, such as the proximity of a vehicle to an obstacle during driving. The change in intensity that is reliably discriminated (i.e., the difference threshold) depends on the amplitude of the vibration, but it does not follow Weber's law. It is advisable to vary only one of the variables (i.e., intensity or frequency) when communicating via the skin. Additionally it is possible to provide cue about the location of events in the environment. Spatial cues can also be represented in the pattern of vibrotactile stimulation. In these applications, a series of tactors in the tactile output system are sequentially activated and the pattern of activation represents a specific command: for example, "move to the left". Of the **encoding parameters** available for a vibrotactile stimulus – namely:

- frequency,
- intensity,
- **locus**,
- **duration**, and
- **rhythm**

-the latter three hold the most promise for encoding information in a tactile display. Frequency and intensity appear to be the least exploitable dimensions, primarily because the skin is rather poor at discriminating differences in frequency, and stimuli of the same intensity applied to different loci on the body are perceptually different (Jones, et al., 2008). To determine the desired characteristics there must be extensive testing of the tactile devices, thus granting intuitive comprehension and perceptibility without training (see also section 5). At the moment it is proposed to use constant frequency for tactile cues and vary merely intensity, pulse duration and rhythm (repetition) to distinguish between alerting cue, safety warning and imminent warning. Anyway the locus of the stimulus is given by the kind of tactile device used.

3.3.2 Force Feedback Devices

The use of force feedback devices in vehicles is intrinsically limited since the kinesthetic apparatus of the driver (or rider) is already busy for the required driving maneuvers. Nevertheless in the field of Automotive many research works has been conducted to study the possible integration of force feedback devices into the main driving control interfaces of the vehicle.

In particular a very promising device that has been investigated by several companies (Volkswagen, Continental, Nissan etc.) and research institutes (Moulder, et al, 2008; Abbink, et al, 2008, Kuge, et al, 2006) is the Haptic Feedback Accelerator Pedal (HFAP). Basically an active gas pedal of the car is used to provide intuitive messages to driver. Messages can deal with speed limits, road conditions, energy consumption or possible collision with surrounding objects.

In analogy with this example in the Automotive field, here it is proposed the development of a Haptic Feedback Throttle. The rider will receive intuitive signals suggesting him the proper correction actions for danger avoidance through an actuated throttle handle.

Being aware of the criticality for the user acceptance of such kind of device, it is proposed an approach that will minimize the impact on the vehicle control and driving style. The aim is not to provide an explicit warning signals that are perceived and distinguished by the rider, but rather to communicate suggestions through subconscious cues. The rider will not perceive the haptic cues but he will unconsciously follow the system suggestions.

To fill in the table below it is necessary to conduct at least some initial experiments, in order to define the specific characterization requirements that the environment of a motorcycle implicates.

Table 3.4: Characteristics of vibrotactile and force feedback messages.

	Safety Tactile Warning	**Imminent Tactile Warning**
Force-Feedback Throttle	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available*	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available*
Haptic Handle	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available*	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available*
Haptic Helmet	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available* Rhythm: *not yet available*	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available* Rhythm: *not yet available*
Vibrating Bracelet/Glove	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available* Rhythm: *not yet available*	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available* Rhythm: *not yet available*
Vibrating Seat	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available* Rhythm: *not yet available*	Frequency: *constant?* Intensity: *not yet available* Duration: *not yet available* Rhythm: *not yet available*

3.4 Classification and Encoding of Output

Table 3.5: Classification and Encoding of Displays.

	Device	Warning Stage						Comments
		(1) Advice / Status / Navigation	**Code**	**(2) Safety**	**Code**	**(3) Imminent**	**Code**	
V	**Visual Displays**							
VD	Dash-board Display	Icon or complete screen not flashing, unobtrusive colours	VD1	Icon flashing slowly, small size, yellow/amber as primary colour	VD2	Icon flashing quickly, large size, red as primary colour	VD3	
VA	Visual Attractor	----	VA1	----	VA2	bright flashing	VA3	If flashing is not possible bright illumination serves as well
VH	HUD	----	VH1	Numerical Display not flashing	VH2	Numerical Display flashing	VH3	in both cases the bar is used to display the distance to hazard
A	**Auditory Output**							
AA	Acoustic Output	Unobtrusive short signal tone, low intensity, no repetition, low frequencies (alerting tone)	AA1	Low signal repetition, low intensity, low frequencies, low frequency oscillation	AA2	high signal repetition, high intensity, high frequencies, high frequency oscillation	AA3	Different acoustic displays for every application required
AS	Speech Output	maximum 3 words, clear speech, 2 or 3 times repeating, speech rate: 156 words per minute	AS1	----	AS2	----	AS3	
T	**Tactile Output**							
TT	Force-Feedback Throttle	----	TT1	*Characteristics not available*	TT2	*Characteristics not available*	TT3	
THA	Haptic Handle	----	THA1	*Characteristics not available*	THA2	*Characteristics not available*	THA 3	
THL	Haptic Helmet	Low intensity, continuous pulse, no repetition	THL1	Low intensity, long pulse, low repetition rate	THL2	High intensity, short pulse, high repetition rate	THL 3	With two vibrating elements directional information possible
TB	Vibrating Bracelet/ Glove	----	TB1	Low intensity, long pulse, low repetition rate	TB2	High intensity, short pulse, high repetition rate	TB3	
TS	Tactile Seat	----	TS1	Low intensity, long pulse, low repetition rate	TS2	High intensity, short pulse, high repetition rate	TS3	

4 Initial HMI Concept & Strategy

4.1 Main Objectives of the HMI Concept and Strategy

There are four main objectives that can be derived directly from the SAFERIDER project's objectives:

1. To develop an integrated and modular **HMI solution for all applications**, tailored towards motorcyclists' and riders' requirements.
2. To **warn the rider timely** and safely about possible hazards in the near future.
3. To **achieve high acceptance** for rider warnings with **high levels of perceived usefulness and satisfaction**.
4. To keep distraction as low as possible by **developing highly intuitive warning stimuli**.

4.2 Process for HMI Concept Development

The process of HMI conceptualization is governed by the development of three different and independent initial concepts. Each of the three concepts will incorporate information provision strategies for every single ARAS/IVIS subsystem, matching different combinations of auditory, visual, haptic signals to specific riding conditions. The concepts will differ in the kind of the strategy adopted, as they will differently address the key tradeoffs of the warning system, i.e. effectiveness vs. intrusiveness, and consequently user acceptance. The goal of the development process is to derive a final concept from these initial ones, in which effectiveness of the warnings and intrusiveness are balanced. This result is to be obtained by conducting evaluations and tests on the single HMI elements proposed, involving potential users of the system.

The three concepts will be named "State of the Art" (hereafter referred to as "Concept A"), "Acceptance" ("Concept B"), "Effectiveness" ("Concept C"). The proposal for HMI elements to be used is based on:

- **HMI components** that are currently available on the market.(Figure 4.1)
- **WP 1 results**: Accident analysis, user needs / expert opinion, benchmarking, ergonomic inspection of PTW systems.
- **HMI guidelines** for automotive systems: Interpretation for PTW HMI concept.
- **Guidelines for warning design** and their application to ARAS/IVIS systems.
- Potential **use cases** for the application of ARAS/IVIS
- **Expert interviews** to define users' needs and wants.

Figure 4.1: Add-On Devices currently available on the market.

4.2.1 Concept characteristics

The design of an HMI always represents a trade-off between high user acceptance and little false alarms on the one hand and intrusiveness, effectiveness and annoyance on the other hand. In the end a compromise is the result of a process that contains an appreciation of the single values for the specific intention of the development project. If a project aims at increasing safety, it might be necessary to cut back the expectations on user acceptance.

With respect to the trade-off mentioned above, for the design of the HMI system, a development methodology was selected that relates to the morphological boxes broadly used in part design. The advantages of this methodology are simultaneous development of concurrent solutions for a particular design problem and the designers' ability to combine the characteristics of each element with any of the others. This results in increased and extended flexibility during the conceptualization and construction phase.

As previously outlined, three concurrent HMI concepts for the SAFERIDER project will be developed, each addressing a specific objective:

Concept A reverts to already existing output components and ordinary information and communication devices, thus allowing low development costs and short familiarization times, as well as providing the "baseline condition" against which other concepts may be evaluated.

Concept B is designed to achieve the highest possible user acceptance. Inconspicuous and unobtrusive information provision modalities will be applied. As a whole, Concept B should provide information, and especially warnings, with minimal anticipation in time and space, and do this through the less attention-demanding combination of stimuli. The rationale behind this approach is that riders should experience the usefulness of the SAFERIDER system, while not being annoyed by irrelevant or "cry-wolf" messages; be such conditions satisfied, Concept B is expected to trigger high user acceptance.

Concept C is focused on improving motorcycle safety by providing relevant information through intrusive, yet innovative and useful output combinations. As a whole, Concept C should provide information, and especially warning, with the aim of maximizing rider's awareness and understanding of the arising situation of danger. This should be obtained by exploiting multiple perceptual channels, stressing redundancies between modalities in order to avoid any misperception of the presented message. The rationale behind this approach is that riders will correctly interpret any warning message, with sufficient anticipation for preparing possible recovery actions.

The desired result of the development process will be obtained by blending concept B and concept C, according to evaluation and tests outcomes. Concept A will serve as benchmark for novelty, conspicuity, understandability and compatibility, comparing currently available HMI systems to the HMI approach resulting from the SAFERIDER project.

4.3 Basic Features

To achieve a high rider acceptance, it is recommended that the HMI system supports a number of basic features, including

1. On/off-mode.
2. Expert/novice-mode.
3. Multimodality.
4. Adaptability.

The on/off-mode provides the possibility to switch off the safety warnings of a certain system or of all the systems, whereas the imminent warnings cannot be turned off by the rider. This is due to the fact that imminent warnings only occur in cases that lead to great danger for the riders' safety. For riders' comfort they do not play an important role, but in contrast to that increase safety considerably.

The expert/novice-mode is to provide more visual information transmission to riders that are not used to innovative HMI elements, such as haptic elements. These additional modalities are to support the understandability of the innovative elements for inexperienced drivers.

According to scientific experiments (Lerner, et al., 1996) multimodal information transmission has great influence on perception probability and mental processing of the warning. So it is recommended that all warnings, safety and imminent ones should be presented in a multimodal way. That means that different channels are used to transport information between a technical system and a human.

Adaptability refers to the adaptation of the systems to different riders and their driving style as well as to adaptation to different types of roads. For example, the systems could differ between sportive and cruising drivers and should recognize, whether the PTW finds itself on a rural road or a highway.

4.4 Speed Alert

The Advanced Rider Assistance System Speed Alert alerts the rider when exceeding speed limitation. Due to the fact that exceeding the speed limit does not necessarily result in a hazardous situation the HMI proposals are held unobtrusive and have some of a more informative character. Although speed alert is regarded as informative system, there are two urgency levels to define, depending on the amount of exceeding speed

Because of the fact that inappropriate speed often leads to loss of control of the motorcycle or moped, Speed Alert is more or less applicable in every use case. However, it is most relevant in use cases in which the PTW finds itself on a straight road. In other cases there would be other subsystems applicable such as Curve Warning, Frontal Collision Warning or Intersection Support.

Figure 4.2: Speed Limits.

Table 4.1: Proposed HMI for Speed Alert.

Urgency (Warning Stage)	Concept A (State of the Art)	Concept B (Acceptance)	Concept C (Effectivness)
Safety warning	**V:** VD2 **VA: -** **A: -** **H: -**	**V:** VH2 **VA: -** **A: -** **H:**TT2	**V:** VD2+VH2 **VA: -** **A:** AA2 **H:** TT2
Imminent warning	**V:** VD3 **VA: -** **A:** AA3 **H: -**	**V:** VH3 **VA: -** **A: -** **H:**TT3	**V:** VD3+VH3 **VA: -** **A:** AA3 **H:** TT3

V: = Visual; **VA:** = Visual Attractor; **A:** = Acoustic; **H:** = Haptic

For Speed Alert application the following HMI elements are proposed:

AA3 - Acoustic Output: high signal repetition, high intensity, high frequencies, high frequency oscillation

TT2 - Haptic Throttle: Characteristics not available

TT3 - Haptic Throttle: Characteristics not available

VH2 - Visual Head Up: Numerical Display not flashing

VH3 - Visual Head Up: Numerical Display flashing

VD2 - GNSS Display: Icon flashing slowly, small size, yellow/amber as primary colour

VD3 - GNNS Display: Icon flashing quickly, large size, red as primary colour

Curve Warning

Figure 4.3: Scenario for CW.

The ARAS subsystem Curve Warning gives continuous feedback about possible or not suggestive acceleration, i.e. the system interferes when the rider accelerates in a way that makes it impossible to hold the optimal and safest driving line.

To work efficiently the subsystem requires the rider's acceptance and immediate reaction. That would be safe deceleration and curve negotiating. Imminent warnings appear when the risk of a crash increases and a safe curve negotiating is no longer possible. To cause intuitive reaction and to avoid distraction from the road or curve ahead, HMI elements are selected that can intuitively be assimilated with deceleration. These could be acoustic, visual or tactile elements and their combinations.

For concept C imminent warnings it is proposed to use the HUD with a flashing numerical display of the maximum speed that allows safe curve driving. Instead of VD3, a VD2 display should be additionally used. A VD3 warning might encourage the driver to look at the display instead to the curve ahead.

.

Table 4.2: Proposed HMI for Curve Warning.

Urgency (Warning Stage)	Concept A (State of the Art)	Concept B (Acceptance)	Concept C (Effectivness)
Safety warning	**V:**VD2 **VA:-** **A:** AA2 **H:-**	**V:** VH2 **VA:-** **A:-** **H:** TT2 / THA2	**V:** VH2 + VD2 **VA:-** **A:** AA2 **H:**TT2 / THA2
Imminent warning	**V:** VD3 **VA:-** **A:** AA3 **H:-**	**V:** VH3 **VA:-** **A:** AA3 **H:** TT3 / THA3	**V:** VH3 + VD2 **VA:-** **A:** AA3 **H:** TT3 / THA3

V: = Visual; **VA:** = Visual Attractor; **A:** = Acoustic; **H:** = Haptic

For Curve Warning application the following HMI elements are proposed:

AA2 - Acoustic Output: Low signal repetition, low intensity, low frequencies, low frequency oscillation

AA3 - Acoustic Output: high signal repetition, high intensity, high frequencies, high frequency oscillation

THA2 - Haptic Handle: Characteristics not available

THA3 - Haptic Handle: Characteristics not available

TT2 - Haptic Throttle: Characteristics not available

TT3 - Haptic Throttle: Characteristics not available

VD2 - GNSS Display: Icon flashing slowly, small size, yellow/amber as primary colour

VD3 - GNSS Display: Icon flashing quickly, large size, red as primary colour

VH2 - Visual Head Up: Numerical Display not flashing

VH3 - Visual Head Up: Numerical Display flashing

Frontal Collision Warning

The ARAS subsystem “Frontal Collision Warning” detects objects in the headway of the motorbike. These objects could be other traffic participants like cars or pedestrians. In case of the relative speed between PTW and the detected object being too high, a warning message is produced to alert the driver of a potential collision. The driver’s attention is refocused on the headway and he has time enough to react adequately. This reaction could be braking or an evasive action.

Figure 4.4: Frontal Collision.

Table 4.3: Proposed HMI for Frontal Collision Warning.

Urgency (Warning Stage)	Concept A (State of the Art)	Concept B (Acceptance)	Concept C (Effectivness)
Safety warning	**V:** VD2 **VA**:- **A:** AA2 **H:**-	**V:** VD2 **VA**:- **A:**- **H:**TB2/THL2 or TB2	**V:** VD2 **VA:**- **A:** AA2 **H:** TS2 / THL2 or TS2 or TB2
Imminent warning	**V:** VD2 or VD3 **VA:**- **A:** AA3 or AA2 **H:**-	**V:**- **VA**: VA3 **A:** AA3 **H:**-	**V:** - **VA:** VA3 **A:** AA3 **H:** TS3 / THL3 or TS3 or THL3

V: = Visual; **VA:** = Visual Attractor; **A:** = Acoustic; **H:** = Haptic

For Frontal Collision Warning application the following HMI elements are proposed:

AA2 - Acoustic Output: Low signal repetition, low intensity, low frequencies, low frequency oscillation

AA3 - Acoustic Output: high signal repetition, high intensity, high frequencies, high frequency oscillation

TB2 - Vibrating Bracelet/Glove: Low intensity, long pulse, low repetition rate

THL2 - Haptic Helmet: Low intensity, long pulse, low repetition rate

THL3 - Haptic Helmet: High intensity, short pulse, high repetition rate

TS2 - Tactile Seat: Low intensity, long pulse, low repetition rate

TS3 - Tactile Seat: High intensity, short pulse, high repetition rateVD2 - Icon flashing slowly, small size, yellow/amber as primary colour

VA3 - Visual Attractor: bright flashing

VD3 - GNSS Display: Icon flashing quickly, large size, red as primary colour

Intersection Support

The "Intersection Support" function is a non-physical device, built-up by the integration of the three previous ARAS:

- Speed Alert
- Curve Warning
- Frontal Collision Warning

Figure 4.5: Intersection.

The system does not contribute any additional functions, nor does it require any further sensing devices. It merely uses the sensors, which are available anyway to provide data to the three basic ARAS. In order to provide an adequate warning to the rider it is proposed to use warnings which are different from those, used for the basic subsystems. Thus, the driver can be made aware of approaching an intersection and of probably present hazards.

Table 4.4: Proposed HMI for Intersection Support.

Urgency (Warning Stage)	Concept A (State of the Art)	Concept B (Acceptance)	Concept C (Effectivness)
Safety warning	**V:** VD1 **VA:-** **A:-** **H:-**	**V:** VD1 **VA:-** **A:-** **H:** THA2	**V:** VD1 **VA:-** **A:** AS1 **H:** THA2
Imminent warning	**V:** VD3 **VA:-** **A:** AA3 **H:-**	**V:-** **VA:** VA3 **A:** AA3 **H:-**	**V:-** **VA:** VA3 **A:** AA3 **H:** TS3 / THL3

V: = Visual; **VA:** = Visual Attractor; **A:** = Acoustic; **H:** = Haptic

Proposed HMI elements for Intersection Support:

AA3 - Acoustic Output: high signal repetition, high intensity, high frequencies, high frequency oscillation

AS1 - Speech Output: maximum 3 words, clear speech, 2 or 3 times repeating, speech rate: 156 words per minute

THA2 - Haptic Handle: Characteristics not available

THL3 - Haptic Helmet: High intensity, short pulse, high repetition rate

TS3 - Tactile Seat: High intensity, short pulse, high repetition rate

VA3 - Visual Attractor: bright flashing

VD1 - GNSS Display: Icon or complete screen not flashing, unobtrusive colours

VD3 - GNSS Display: Icon flashing quickly, large size, red as primary colour

Navigation & Route Guidance

There are already many navigation and route guidance devices available on the market. However, many of them are add-on systems and not integrated in an overall assistance system. Besides, just a few of them are specially designed for PTW use. Most of them are to be primarily used in cars.

The relating objectives for the SAFERIDER project must therefore be:

- Design of an integrated navigation device
- Usage of innovative HMI elements
- Intuitive and rider-centered design

Table 4.5: Proposed HMI for Navigation & Route Guidance.

Urgency (Warning Stage)	Concept A (State of the Art)	Concept B (Acceptance)	Concept C (Effectivness)
----	**V:** VD1 **VA:-** **A:** AS1 **H:-**	**V:** VD1 **VA:-** **A:-** **H:** THL1	**V:** VD1+VH2 **VA:-** **A:** AS1 **H:** THL1

V: = Visual; **VA:** = Visual Attractor; **A:** = Acoustic; **H:** = Haptic

Proposed HMI elements for Navigation and Route Guidance

AS1 - Speech Output: maximum 3 words, clear speech, 2 or 3 times repeating, speech rate: 156 words per minute

THL1 - Haptic Helmet: Low intensity, continuous pulse, no repetition

VD1 - GNSS Display: Icon or complete screen not flashing, unobtrusive colours

VH2 - Visual Head Up: Numerical Display not flashing

Weather, Traffic and Black Spot Warning

As designated in the project presentation (Deliverable No. 10.1), there are additional applications for motorcycles of high value to riders' comfort and to potentially positive influence on traffic safety.

Weather warnings are designed to provide the rider with relevant information concerning the current weather situation and the near future. Relevant to riders could be:

- Current temperature (above/below 4°C)
- Forecast for the area where the PTW currently is (rain, snow, frost)
- Forecast for the area where the PTW goes to (probably combined with navigation)
- Upcoming thunderstorms

Traffic warnings could serve additional information, such as traffic jams, traffic accidents and road closures. Places with high probability of PTW accidents according to statistics are called Black Spots. When approaching such a place, the system advices the rider to drive carefully.

For the HMI concept, however, it makes no difference where the PTW currently is. Thus the warning concept includes merely one warning stage that is applied to every use case.

Table 4.6: Proposed HMI for Weather, Trafic and Black Spot Warning.

Urgency (Warning Stage)	Concept A (State of the Art)	Concept B (Acceptance)	Concept C (Effectivness)
----	**V:** VD1 / VD2 **VA:-** **A:** AA1 **H:-**	**V:** VD1 / VD2 **VA:-** **A:** AA1 **H:-**	**V:** VD1 / VD2 **VA:-** **A:** AS1 **H:-**

V: = Visual; **VA:** = Visual Attractor; **A:** = Acoustic; **H:** = Haptic

Proposed HMI elements for WTB

AA1 - Acoustic Output: Unobtrusive short signal tone, low intensity, no repetition, low frequencies (alerting tone)

AS1 - Speech Output: maximum 3 words, clear speech, 2 or 3 times repeating, speech rate: 156 words per minute

VD1 - GNSS Display: Icon or complete screen not flashing, unobtrusive colours

VD2 - GNSS Display: Icon flashing slowly, small size, yellow/amber as primary colour

eCall

The eCall application is a special IVIS that. applied in emergency situations after a crash. By connecting the motorcycle's cellular radio device with the center for coordinating rescue in case of emergency, the coordinator is enabled to get information about the rider's health and constitution and to initiate further activities.

The preliminary eCall functionalities are:

1. Motorcycle crash detection
2. Vehicle data sending
3. Connection setup
4. (not yet available)
5. (not yet available)

A speech connection appears to be the only reasonable human-machine interaction. Provided that the helmet could be equipped with a microphone and speakers and could get connected to the cellular phone module on the motorbike via Bluetooth, the establishment of a phone call is possible even if the crashed motorcycle is out of rider's reach. Therefore the proposed HMI element for the eCall system is a Bluetooth headset, preferably integrated into the helmet

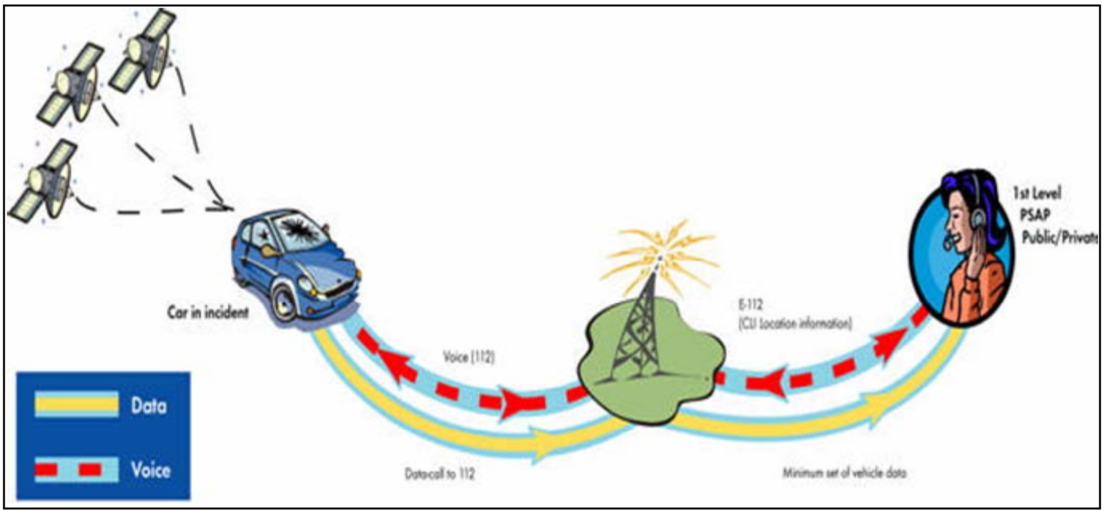


Figure 4.6: Schematic representation of the eCall system (European Commission, 2007).

The figure shows a car in incident instead of a powered two-wheeler. However, the application is the same.

4.5 Telediagnostic Service

The system monitors constantly the use and functioning conditions of the vehicle and offer early warnings about the next vehicle service or imminent failure of some vehicle subsystem.

The target is to provide functionalities which increase safety, security, anti-theft and performance and alleviate remote motorcycle diagnostics. At the time, it is not yet clear what interaction between rider and telediagnostic service looks like. Thus no particular HMI proposal is given, but in case of interaction it is proposed to use primarily the dashboard display for outputs. Only for concept C and additional acoustic cue might be provided. TDS is desired to provide additional value to the final customer, by monitoring constantly use and functioning conditions of the vehicle and offer early warnings about the next vehicle service or imminent failure of any vehicle subsystem. The developed OBS is able to perform remote telediagnostic of the most critical operational parameters of the PTW. These parameters are related to: security concerns, performance, maintenance and upgrading

5 Testing Proposals

5.1 Overall Testing Strategy

For the testing it is proposed to follow a certain strategic procedure in order keep overview over all testing activities and to be able to coordinate them. All testing activities are proposed to be divided into the three categories:

1. Finding/optimization of display characteristics (parameters)
2. Concept Comparison
3. Application assignment (finding the best fitting application)

In addition to these categories it is proposed to conduct a larger number of experiments on the field of tactile elements as mentioned in section 5.2. The testing strategy is formulated in the following sections by using the haptic helmet as an example.

5.1.1 Display Characteristics

To find out the characteristics a tactile element must provide to ensure conspicuity, compatibility and short times-to-response, it is necessary to conduct experiments with various types of riders and motorcycles in different environments. Yet, this is a topic that predominantly concerns helmet manufacturers. Therefore it is refused to give concrete testing proposals for optimizing the display characteristics.

5.1.2 Concept Comparison

It is recommended to test the concepts (A, B, C) against each other for particular ARAS/IVIS applications, for which it is unclear which concept would serve best.

Table 5.1: Recommended Concept Benchmark Tests.

	Concept A	Concept B	Concept C
SA	(xxx)	xxx	xxx
CSW		xxx	xxx
FCW		xxx	xxx
ISS	xxx	xxx	xxx
NRG			
WTB			

Table 5.1 says that, for example for Speed Alert there is a comparative test proposed that includes every concept proposal A, B and C. Whereas B and C are definitely required, concept A could optionally be dismissed. The result of these tests might be a optimal combination of concept components, providing an integrated yet modular built-up HMI system.

5.1.3 Application Assignment

For a deeper understanding of psychological processes activated by the warnings of an HMI element and achievable compatibility it might serve well to examine a single output device, finding out which ARAS/IVIS application fits best. For the NZI haptic helmet a test is proposed to be conducted covering the following fields of application:

- Speed Alert
- Curve Warning
- Frontal Collision Warning
- Navigation and Route Guidance

The tests might be conducted into a driving simulator or on the road with approximately five to ten test persons. Their reaction must be captured properly in order to determine the appropriate application. After driving a test way the test persons might be requested for their estimation concerning the meaning of received signals. Additionally the times-to-response should be measured and compared to each other. In the table below an initial test plan is proposed.

Table 5.2: Preliminary test plan for haptic helmet.

Step	Scenario	Measurements	Results
1	The rider has no previous knowledge about the applications and about the HMI element. The pillion rider triggers the warnings/messages, sequentially changing the application after 5-10 warning displays. This test step might be conducted on public roads.	• Evaluation of gesture and mimic of the rider • Evaluation of rider reaction and compatibility with the particular application adopted by the pillion.	Subjective Assessment of rider behaviour under the influence of haptic signals provided by the helmet.
2	Previous to step 2, the rider gets information about the application the signals refer to, i.e. the rider knows whether an alert concerns curve warning, route guidance or other.	• Visual angle • TTR • PTW acceleration • PTW inclination	Measureable objective results for determining the best fitting application

5.2 Testing Tactile HMI Elements

To ensure a high degree of perception reliability of the tactile devices Force-Feedback Throttle, Haptic Handle, Haptic Helmet and Vibrating Bracelet/Glove, it is necessary to find out the required characteristics that serve best for PTW use. Therefore, tests are proposed to be conducted:

1. Characterization tests with every single tactile element
2. Benchmark tests between the particular tactile elements to be able to compare them.

The tests should consider the particular environment of a motorbike, especially the high levels of noise and vibration. Tactile warnings must be clearly perceivable under all weather and road conditions. It is recommended to completely fill in the values in : Characteristics of vibrotactile and force feedback .

In order to investigate the ability of the Haptic Helmet to serve as directional information supply and to find out for which ARAS it is suited best, it is proposed that a test at the Fraunhofer IAO is conducted. Further objectives of these tests might concern user acceptance and efficiency measurements.

6 Literature

Abel Heinz-Bernhard [et al.] Adaptivität und Multimodalität - Merkmale der zukünftigen Mensch-Maschine-Schnittstelle [Article] // ATZ elektronik. - Wiesbaden : Springer Automotive Media / GWV Fachverlage GmbH, March 2007.

Abbink, D.A.; Boer, E.R.; Mulder, M., "Motivation for continuous haptic gas pedal feedback to support car following,"Intelligent Vehicles Symposium, 2008 IEEE , vol., no., pp.283-290, 4-6 June 2008

Beier SENSATION HMI Concept [Report]. - Stuttgart : Studienarbeit Universität Stuttgart, unknown year.

Campbell John L. [et al.] Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. - Washington, DC : National Highway Traffic Safety Administration, 2007.

Continental, Force Feedback Pedal (FFP), http://www.contionline.com/generator/www/de/en/cas/cas/themes/products/powertrain_and_chassis/chassis_control_systems/ffp_2004_en.html

Cho, M., K.Ku, Y. Shi, and Kanagawa. 2001. A Human Interface Design of Multiple Collision Warning System

DIN EN ISO 15005:2002 Straßenfahrzeuge - Ergonomische Aspekte von Fahrerinformations- und -assistenzsystemen - Grundsätze und Prüfverfahren des Dialogmanagements. - Brussels : CEN - European Committee for Standardization.

DIN EN ISO 15006:2006 Straßenfahrzeuge - Ergonomische Aspekte von Fahrerinformations- und -assistenzsystemen - Anforderungen und Konformitätsverfahren für die Ausgabe auditiver Informationen im Fahrzeug. - Brussels : CEN - European Committee for Standardization.

DIN EN ISO 15008:2003 Straßenfahrzeuge - Ergonomische Aspekte von Fahrerinformations- und Assistenzsystemen - Anforderungen und Bewertungsmethoden der visuellen Informationsdarstellung im Fahrzeug. - Brussels : CEN - European Committee for Standardization.

European Commission eCall Support [Online] // eCall Toolbox. - ERTICO - ITS Europe, 2007. - December 9, 2008, http://ec.europa.eu/information_society/activities/intelligentcar/technologies/tech_07/index_de.htm

European Commission Updated European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems // Official Journal of the European Union. - Brussel : EC, 2006.

Fraunhofer IAO HMI Elements for Advanced Driver Assistance Systems [Report]. - [s.l.] : SAFERIDER Project, 2008.

Green Paul [et al.] Suggested Human Factors Design Guidelines for Driver Information Systems [Report]. - Ann Arbor, Michigan : National Highway Traffic Safety Administration, 1993.

Jones Lynette A. and Sarter Nadine B. Tactile Displays: Guidance for their Design and Application [Article] // Human Factors: The Journal of the Human Factors and Ergonomics Society. - Cambirdge, MA : Human Factors and Ergonomics Society, February 2008. - 1 : Vol. 50.

Kuge, N., Yamamura, T., Boer, E.R., Ward, N.J., Manser, M.P., Study on driver's car following abilities based on an active haptic support function. Society of Automotive Engineers International. SAE Technical Paper 2006-01-0344, 2006.

Lerner N. D. [et al.] Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices. - Springfield, Virginia 22161 : National Technical Information Service, 1996.

Mulder, M., Van Paassen, M.M., Abbink, D.A., Haptic gas pedal feedback. *Ergonomics*, Vol. 51, No. 11. (November 2008), pp. 1710-1720.

Nissan, ECO Pedal,
http://www.nissan-global.com/EN/NEWS/2008/_STORY/080804-02-e.html

Sayn A. [et al.] SAFESPOT - Conceptualization of On-Board Information System and Extended HMI. - 2007.

Schröder Caterina ATZonline [Online] // Nachrichten. - Springer Automotive Media / GWV Fachverlage GmbH, November 11, 2008. - December 08, 2008. - http://www.atzonline.de/index.php;do=show/alloc=1/lng=de/id=8690/site=a4e/sid=833472320493e1c455e9ee285884705.

Stevens A. [et al.] Design Guidelines for Safety of In-Vehicle Information System [Report]. - [s.l.] : TRL & DTLR, 2002.

United Nations Economic Commission for Europe Guidelines for the Design and Installation of Information and Communication Systems in Motor Vehicles. - [s.l.] : Inland Transport Committee, 1998.

Wogalter Michael S., Conzola Vincent C. and Smith-Jackson Tonya L. Research-based guidelines for warning design and evaluation [Report]. - Blacksburg, USA : Elsevier Science Ltd., 2002.

7 Appendix

A Results of Expert Interview

Introduction

The interviews were conducted in September and October 2008. The 5 participants covered driving instructors, motorcycle racers, and other experts on the PTW field. The interviews were partly face-to-face or in form of a questionnaire.

First of all, it has to be mentioned that the results of the interviews are not representative for the motorcycle market, because only qualified experts with a lot of driving experience were interviewed. But due to their extraordinary experience, the results could provide some hints on what riders would accept and considered reasonable. Further, it might serve as a guideline for user expectations and requirements, though the participants are not experts on the field of rider assistance systems.

Generally it has to be stated, that at the moment there is no expectation of any tactile/haptic HMI devices among the experts. However, many of them could imagine the application of such innovative elements, if proper cognition is proved by extensive testing.

Furthermore, the experts were aware of a certain overload of the visual information presentation mode. This comes, due to increasing traffic volume and more and more visual information provided by both, the PTW system and the environment.

The summarized results of the interview are stated in the next sections and are separated by the particular assistance systems investigated within the SAFERIDER project.

Table 7.1: Introduction of Experts.

Driving Instructors	Two driving instructors were consulted representing both, longtime practical experience and theoretical background concerning the driving of PTW driver education.
Motorcycle racer	A female motorcycle racer and enthusiastic PTW driver was consulted to represent the liberal part of the riders.
Other Experts	Other experts were a journalist of the “Motorrad” magazine, covering exclusive PTW topics. In particular, the expert belonged to the travel-department and makes up to 30,000 km per year on PTW. A second expert was an associate of ADAC e.V., the greatest German automobile association, who is responsible for PTW testing and riders’ helpdesk and makes between 10,000 and 30,000 PTW-km per year.

1. Curve Warning

By the experts, the functionality of the ARAS subsystem "Curve Warning" is considered as crucial for increasing PTW riders' safety. They anticipate it to work properly and provide early and reliable warnings. According to their common opinion, an acoustic warning would be appropriate in combination with a flashing icon in the dashboard display. The acoustic warning has to provide a warning tone that sounds imminent, and therefore concentrates the rider's attention to the way ahead. Visual information provided in the dashboard display is evaluated as redundant, due to the worse visibility and its distraction causing manner. Some experts mention that also visual warnings in a head-up display could cause a certain distraction or interfere with foresight. When approaching the curve, a speed notice should be given, that indicates the maximum speed for safe curve negotiating.

Some experts can imagine tactile/haptic displays capable to be perceived and interpreted intuitively (especially force-feedback handle or haptic handle), whereas some others denied the application of tactile devices completely. This might be caused by insufficient imagination of the achievable quality of tactile information transmission or by personal attitude.

Result: **Audiovisual warnings** are preferred by experts.

2. Speed Alert

"Speed Alert" is considered as non-crucial subsystem, i.e. there are no direct hazard and no need of immediate corrective action. Therefore, the experts uniformly proposed a single visual hint either in the dashboard or in a head-up display that could attract the rider's attention combined with an additional acoustic cue. They claim the provision of the current speed limit, as it is included in some up-to-date navigation devices. Expectedly, the proposal of driving instructors is more rigidly and consists of an acoustic signal with increasing intrusiveness until the desired speed limit is respected. However they suggest a relatively broad tolerance of approximately 5 to 8 km/h above the speed limit, where no "Speed Alert"-warnings are produced. Displaying the speed limit is necessary, too.

Result: Except driving instructors, all experts prefer a merely **visual warning** in the dashboard display that is more or less unobtrusive. Driving instructors call for **acoustic** signals.

3. Frontal Collision Warning

The subsystem "Frontal Collision Warning" is the one, which causes opinions spreading most among experts. Although uniformly considered essential, the expectations towards the HMI and warning design diverge. Below, three different cases of "Frontal Collision Warning" and the proposals associated with them are described:

Case 1: Early Warning and possible corrective action

In this case an acoustic warning is preferred by the experts. It should be very intrusive, cause immediate concentration of the attention to the road ahead, and signalize great danger. It should be supported by an informational visual hint in the dashboard display, to give the rider the possibility to subsequently control and evaluate his/her behavior.

Case 2: Late Warning, crash unavoidable

In this case it is not possible for experts to give a clear statement or propose any particular HMI devices. What they expressed is that a warning in this case should prepare the rider for the imminent and unavoidable crash situation and cause the right behavior (e.g. loosen contact to PTW, turn the PTW sideways by using the rear wheel brake). But it is added that there is no correct behavior suitable for all crash situations.

At the current state, the second case is more or less insignificant because contribution to increasing PTW riders' safety is low. Therefore the results of the interview are summarized as follows.

Result: Experts expect an intrusive **audiovisual** warning, signalizing to pay greatest attention to the headway.

4. Intersection Support

As for the subsystem "Intersection Support" there is no detailed information available at the moment concerning configuration and mechanisms it is hard to get clear statements. What experts expressed were rather wishes and unclear requirements towards "Intersection Support". Most of them fancied a screen displaying the intersection and providing additional information, such as applicable traffic rules, other traffic participants and distance to intersection. When the intersection is reached, some experts proposed an additional acoustic cue to ensure the rider's concentration to the intersection scene.

5. Black Spot Warning

Experts' opinions have in common that this feature is very helpful to improving PTW and road safety. However, to meet riders' requirements and to achieve great acceptance "Black Spot Warnings" should stay unobtrusive and should have an informational character. Thus, a simple visual display in the form of a symbol in the dashboard display would be adequate. An acoustic cue could indicate the presence of a warning in a visual display.

Result: **Visual** warning preferred, to keep it unobtrusive.

6. Navigation, Route Guidance, Weather and Traffic Information

Because of the fact that each of these systems is not applicable to an imminent hazard situation, and therefore has no direct influence on PTW riders' safety it is clear and consequent that the experts expressed their request for unobtrusive, intuitive and easy to handle devices. For navigation devices some experts requested speech input and output. Speech input would distribute safe manipulation while driving, but leads to great technical requirements. Driving instructors claim for devices that cannot be operated while driving the PTW (unless it provides speech input). For the output of navigation and route guidance devices, the audiovisual mode is preferred, although haptic/tactile devices seem to be possible if directional guidance is feasible. Weather and traffic information should, according to experts, be provided merely visual in the dashboard.

Result: For navigation and route guidance experts prefer the traditional modes of information transmission, i.e. **audiovisual** mode. Some can imagine tactile directional guidance.