ABSTRACT

The enormous impact that road fatalities have in our society has attracted the attention of various official entities and policy makers in the last 15 years. Among motor vehicle accidents, which represent the second most frequent cause of death for people aged from 5-29 (2), motorcycle and moped fatalities account for 17.7% of the total number of road accident fatalities in Europe. Compared to a passenger vehicle, a motorcycle was thirteen times more likely to be involved in a fatal accident for every kilometer travelled (8)(9) and the impact of this phenomenon is clearly negative from the social point of view. This paper will present the SAFERIDER (advanced telematics for enhancing the SAFety and comfort of motorcycle RIDERs) project outline, focusing on the functionalities developed and evaluated Europe wide in simulators and motorcycle demonstrators, testing them on functional, usability and acceptance point of views. SAFERIDER project results prove that Intelligent Technology System in motorcycle might contribute to the significant enhancement of riders’ safety and comfort.

1. SAFERIDER OBJECTIVES

SAFERIDER is a 3-year research project (Jan 2008 – Dec 2010) funded by the 7th Framework-Programme of the European Commission under the DG Information Society & Media. It is aimed at studying the potential of ARAS (Advanced Riding Assistant System) and OBIS (On-Board Information System) functionalities integration on PTW (Powered-Two-Wheelers) for the most crucial functionalities and develop efficient and rider-friendly interfaces and interaction elements for riders comfort and safety (4)(5). Considering the innovative functionalities, five ARAS applications have been developed, namely Speed Alert, Curve Warning, Frontal Collision Warning, Intersection Support and Lane Change Support (4). About OBIS, four applications have been developed, namely eCall, Telediagnostic Services, Navigation & Route Guidance, Weather, and Traffic & Black Spot Warnings (4). They are supported holistically by optimal and concise HMI warning concepts and strategies, supported by haptic, visual and audio elements. The functionalities developed have been integrated upon 3 riding simulators and 8 PTW (Powered Two Wheelers) demonstrators and tested in 6 sites Europe-wide.

2. ARAS FUNCTIONS

**Speed Alert** - This ARAS function aims at warning the rider when the speed exceeds the legal limit and is implemented by integrating and correlating static data (maps) and standard dynamic vehicle data (such as speed) to provide the rider with context-related information about legal speed. The Speed Alert function can be regarded to as an improvement of both comfort and safety while riding. In fact, in case speed remains below a certain threshold (even if exceeding the legal limit) it does not necessary lead to a hazardous situation and thus the Speed Alert function can be regarded to as an information system. However, when speed exceeds the threshold, it could lead to a loss of control of the motorcycle or moped. This approach is reflected in the HMI warning strategy: when the Speed Alert has an informative character, HMI proposals are held unobtrusive, while they are more evident when the rider’s safety is at risk.

**Curve Warning** – A common factor in PTW accidents is the wrong curve approach that could lead to the loss of the motorcycle control. Generally, the risk could be associated to the lack of understanding of geometry or wrong approaching trajectory, including speed value. Thanks to inertial sensors, vehicle information and maps, the Curve Warning functionality (ARAS) elaborates in real time the dynamic trajectory of the PTW during curve approaching phase, detecting if the maneuver is safe or not.

The proposed function is based on the concept of comparing the actual rider maneuver with a safe reference maneuver. The safe reference maneuver should be a feasible one that complies with system dynamics, trajectory constraints and safety criteria in a “human-like” riding style. This maneuver in normal riding condition is supposed to resemble rider’s actual maneuver whereas in emergency situations should produce a feasible motion that steers the vehicle into a safe state.

The emergency reference maneuver may or may not match what the rider is doing and, in the latter case, the required correction and risk level should be assessed to generate a proper warning. In this view the CW module is seen as a co-pilot that computes a maneuver that takes into account both vehicles dynamics and road geometry and mimic human driving style. (see Fig.1 and 2)
Figure 1 - Dotted continuous line is the actual motorcycle speed profile. Gray lines correspond to optimal plan at each estimated motorcycle state.

Figure 2 shows how the jerk index (i.e. the initial value of the jerk of each plan) increases (as absolute value) as the vehicle approach the curve. The so far defined risk index also suggests the corrective action and its level of intensity: a greater change in deceleration is required if the riders do not take any action. The warning is issued before the curve and the time to the curve can be tuned by properly setting the thresholds.

Specific HMI elements (acoustic, visual or tactile elements and their combinations) are selected, that can intuitively be assimilated with deceleration causing an intuitive reaction and avoids distraction from the road or curves ahead.

**Frontal Collision Warning** - The function aims at warning the rider when an obstacle has been detected in the headway of the motorbike and it is likely to collide. It is based on the same optimal control problem formulation used in the Curve Warning function with the purpose not only to detect an obstacle, but also evaluate the severity of the encounter.

The FCW evaluates the motorcycle state in order to check whether it is safe. A state is safe for the vehicle if there exists an emergency braking maneuver that prevents collision whatever the former vehicle(s) does.

Therefore an obstacle warning is issued:
- For inappropriate speed when the current vehicle state (velocity) and driver actions are inconsistent with the correct tailing of the vehicles ahead.
- For inappropriate distance, when the current vehicle state (distance) is insufficient to avoid a collision, given the human reaction time, should the vehicle ahead brake unexpectedly.

By producing the alert, the driver’s attention is re-focused on the headway and he/she has time to react adequately. This reaction could be braking or an evasive action.

**Lane Change Support** - This function aims at alerting the rider in case an imminent lane change is critical in terms of a potential collision. In PTW domain, rear view is often limited due to the small size and vibrations of rear view mirrors and the helmet further limits the field of vision and head mobility. Usually vehicles in the blind spot approach with high speed from behind and the rider is not aware of them when starting a lane change manoeuvre. To tackle this issue, the rear/lateral surroundings of the motorcycle are monitored by a radar sensor that provides information about the speed and position of oncoming vehicles. This information is used to assess how critical could be the lane change. In case the rider activates the indicator to perform a lane change, if another vehicle is approaching and it is in the blind spot, the rider is informed about the potential risks by an appropriate HMI.

![Saferider Lane Change System (LCS)](image-url)
3. OBIS FUNCTIONS

e-Call - this function is activated when an accident occurs. Inertial sensors placed both on the vehicle and in the helmet detect the accident in order to activate a remote link with the infrastructure. The e-Call function provides information about location of the crash/fall to the emergency centre, which call back the rider in order to check its conditions. Once the call is established, the emergency centre can be ensured about the conditions or, in alternative, send the emergency rescue team. The e-Call modules receives inputs from on-board vehicle sensors and data, as head impact, from the helmet. In this way, more information are available to the rescue team in order to give the right medical treatments.

Telediagnostic Module - Telediagnosis services provide added value related to safety and security concerns, performance, maintenance and upgrading. It allows the rider to monitor constantly the use and functioning conditions of the vehicle and it offers early warnings about next vehicle services or imminent failure of some vehicle subsystem.

Navigation and Route Guidance (N&RG) - Most of the Navigation and Route Guidance developed so far are addressed to the car occupants. This OBIS function consists of a navigation unit which is dedicated to the rider, especially for novice riders and tourists. It is integrated with several options in order to be more motorcycle-oriented, starting from the 7” display, lane assistance system, and a dedicated interface which include the warnings/information of the overall SAFERIDER functionalities.

Weather traffic & black spot info (WTB) - the Navigation unit is integrated with traffic, weather and black spot functionalities able to inform the rider about potential traffic jam or critical weather conditions that the rider could encounters during the planned route. Traffic and weather information are downloaded from the server via 3G connection. On Black spot side, the Navigation Unit is able to warn the rider about statistically dangerous place: relying on accurate understanding of accidents causation by accident analyses, the system could effectively inform the rider about a potential risk.

4. SYSTEM ARCHITECTURE

The SAFERIDER system architecture is mainly based on the CAN protocol. This allow the different ARAS and OBIS functionalities to share the information provided by sensors and modules in the network (7). The figure below shows the functional architecture developed.

For each module described in the functional architecture, the final hardware architecture has been developed and integrated in order to create a flexible and modular network for the demonstrators.

5. HMI

In order to provide the rider with the proper warning in every riding condition, several HMI devices have been developed and tested in SAFERIDER project. The HMI concept explored is mainly based on haptic devices able to provide information by the touch sensory channel to the riders. The main advantage is to leave visual attention to the road while warning is produced.

Haptic Glove – it is a special motorcycle glove capable of transmitting warnings to the user through vibro-tactile cues. On the left hand, the rider wears a traditional motorcycle glove while the right hand glove is equipped with an electronics and vibration motors. The glove is equipped with 4-haptic motors placed on the
upper, bottom, left and right side of the wrist. The communication between the glove and the system is done via Bluetooth.

**Smart Helmet** – this HMI is able to provide audio, visual and vibration warning to the rider. All the information for the different type of warning are exchanged with the system via Bluetooth communication. The acoustic information transmitted through loudspeakers located in each side of the helmet cheek pads while the visual are produced by an head-up display and the visual information are overlapped to the global visual field. Finally, the Smart Helmet can give vibration feedback by means of two vibration motors located one inside the left cheek pad and the other inside the right cheek pad.

**7” Display** - The 7” display with touch functionality can be used for output as well as for input by the rider. The standard screen of the display is split out into three main parts: at the top the ARAS alarms are represented, below is the place for OBIS and the middle is dedicated to the navigation function (see Fig.5).

**Haptic Handle** - it is a device able to warn the rider by changing its shape and providing pressure feedback to the rider. The feedback provided to the rider consists in a shape variation of the surface of the handle, generating pressure variations in specific points of the palm of rider’s hand. The intensity of the feedback is fixed, but it is possible to change frequency and duration of the pressure stimulus.

**Vibrating Seat** - This HMI provide haptic warning to the rider by means of controlled pulsed vibration under the PTW seat. The vibration is obtained through an electrical motor and a rotating eccentric mass controlled by a microcontroller connected through serial connection to the SAFERIDER system. The intensity of the vibrations is fixed and constant, but the frequency of activation, the relative phase, the duty cycle and the duration time of each motor can be programmed by controlling the activation of the electrical motor.

**Visual Attractor on rear mirror** - This is a specific HMI dedicated to the LCS, providing warnings by means of two LED’s placed on the left side rear view mirror. When a car is driving in the Blind Spot Zone or is approaching to PTW a yellow LED is informing the driver that it isn’t safe to do a lane change. If the driver starts the Lane Change by activating the left side blinker, another LED is flashing red to alert the driver not to change the lane.

**Haptic Throttle** - it warns the rider by applying force feedback on the gas throttle handle. Such system allows modifying the torque that calls back the throttle. It thereby implicitly suggests the rider to react by releasing the gas throttle and thus to decelerate or not further accelerate.

### 6. SIMULATOR ACTIVITIES

The context of the riding simulator is relevant for testing the first stages of the development of the system prototype. This context is useful to evaluate some criteria such as physical and practical aspects linked to the calibration of the HMI sub-system and feedbacks. The SAFERIDER system has been developed and checked on three simulators (France, Italy and Greece). In the one located in the University of Padova, Engineering Faculty, some integration phases, the relevant hardware (basically HMI devices and ARAS hardware and software) have been developed and validated before the installation on Yamaha demonstrator. Various HMI configurations have been developed in order to give a common line for the other simulators and for the on-road demonstrators.

![Fig. 8 – Padova University (Italy) motorcycle simulator](image)

### 7. YAMAHA DEMONSTRATOR

The activities performed on demonstrators provided impressive results, with many components integrated within 8 vehicles in the whole project. The demonstrators are very heterogeneous, starting from scooter to big motorcycle. In particular, Yamaha Tenéré is basically ARAS oriented, with FCW, CW and LCS functionalities installed. Furthermore, Adaptive Light is installed on it. On HMI side, the warning feedbacks to the rider are provided via visual display, haptic handlebar, external mirror, haptic helmet, in-helmet audio and haptic glove. Pictures below show the Yamaha demonstrator and some of the electronic units installed on it.

![Fig. 9 – Yamaha’s SAFERIDER demonstrator](image)
8. PILOT TESTS

The SAFERIDER project planned and carried out a series of pilots focused on the evaluation of the new and innovative rider support systems from different points of view. On the one hand, the technical correctness of the system outputs had to undergo a test. On the other hand, the user-centred view had to be adopted. This includes the reactions a system may provoke from the rider. Especially when speaking about systems capable of transmitting warnings to the rider and, hence, intend to provoke a reaction, it is important to check whether the system output provokes the desired reaction or not. Besides, the user-centred view covers the usability and attractiveness of the system perceived by the users. It deals with attributes the riders associate to the system and to riding with the system (including feelings of safety and enjoyment). Finally, the riders’ acceptance of the system plays a decisive role in the system evaluation; it is strongly linked to the rider’s intention to use the system, as well as the willingness to own the system and to spend money for acquiring it. Including the users’ opinions is therefore an extremely important aspect when evaluating a new system and when preparing its entrance to the market.

Yamaha demonstrator has been used to test CW, FCW and LCS. CW has been tested in a urban circuit around the Yamaha building in Gerno di Lesmo (Italy). The track has a length of roughly 6 km and is representative of real urban road condition with normal traffic conditions during the test. FCW pilot tests have been conducted on the Motodromo international circuit located in Castelletto di Branduzzo (Italy). This circuit is used every week for motorcycle racing school and different kind of races. In this case the straight portion of the circuit was used to place a car on the road (the obstacle) and check the system behaviour.

The LCS pilot tests have been conducted in Stuttgart, in private circuit by Porsche Engineering. All Test Pilots on ARAS and OBIS have been performed based on four parameters: rider’s reaction to warning, usability, workload and user acceptance.

The riders’ reactions to the system output are crucial in the evaluation of the safety potential of the system. The rider behaviour in front of a defined warning is evaluated by analysing the objective parameters obtained from the riding data logger. A wrong reaction to the system output can imply negative effects on riding safety, contrary to what is intended by the system. The user-friendliness of a system plays an important role when evaluating new technologies, since they are supposed to be intuitive and easy-to-use and thus not to disturb the rider. Criteria which determine the usability within the SAFERIDER pilots are the understanding of the system registered in the final interview.

A system to be used when riding, should of course not have negative consequences on the riding quality. Therefore, it is also important that it does not increase the workload of the rider. In order to investigate if the system use has an effect on workload, the Rider Activity Load Index (RALI(6)) has been developed for and applied within the SAFERIDER pilot tests.

Finally, as previously indicated, the market penetration and the actual use of the new ARAS and OBIS will strongly be influenced by the riders’ acceptance of those systems. In fact, the acceptance is directly linked to the intention to use the systems. This concept is covered by the SAFERIDER questionnaire too.

9. RESULTS & CONCLUSIONS

The overall results from SAFERIDER pilot tests have been positive. Taking into account that the systems have been recently developed and their first implementation on the bikes have been tested, the test results give encouraging first insights into the potential of the SAFERIDER systems.

They show the appropriateness of the system functions and help to further develop and optimize the systems, based on the test outcomes. SAFERIDER project, launched in January 2008, and closed in November 2010 obtained good results from simulator activity, in which several tests with users were planned, as well as the results coming from demonstrator activity. Among demonstrators, the activities done with Yamaha demonstrator equipped with CW, FCW and LCS have a particular relevance.

Since PTW accident statistics shown by literature are considerably high, SAFERIDER intended to contribute to eSafety Action Plan (1) by introducing active safety and information systems within PTW domain. The development and implementation of relevant ARAS and OBIS functionality might contribute to the significant enhancement of riders’ safety and comfort.

The work results lay the basis of a future implementation of ITS functionalities which don’t exist in the global market yet.

10. ACKNOWLEDGMENTS

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11. REFERENCES