# METHODOLOGY FOR SAFETY AND USABILITY ASSESSMENT OF ITS FOR RIDERS

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**ABSTRACT**: Intelligent Transportation Systems (ITS) applications may have the potential to significantly improve Road Safety of Powered-Two-Wheelers. Nevertheless, it requires targeted and in-depth research to avoid negative consequences, as riding is a very sensitive perceptual and motor task. This paper presented methodologies developed in the framework of the European project SAFERIDER which aims to study the potential of Advanced Rider Assistance Systems/On Bike Information Systems integration on motorcycles for the most crucial functionalities. The proposed methodologies are based upon some of the available studies in the PTW area in addition to automotive area, with the purpose to adapt available tools and techniques coming from driver's behavioural studies to the specific context of the riding activity using ITS.

## 1 CONTEXT

European statistics show that Powered-Two-Wheelers (PTW) road accidents are extremely high, whereas a high percentage of them are fatal. Indeed, motorcycle and moped fatalities account for 19% of the total number of road accident fatalities in 2006, in EU-19 member countries (Annual statistical report, 2008). The implementation of appropriate Advanced Rider Assistance Systems/On Bike Information Systems (ARAS/OBIS) technologies in PTW's might contribute to a significant enhancement of riders' safety. In particular, functionalities from these assistance and informative systems may help reduction of some types of accidents, for example by providing important information on weather conditions, on critical conditions of the road infrastructure, on location of other road users… These assistance can also support the rider by reducing obstructions through intelligent communication interfaces, that will substitute the hazardous and incompatible to PTWs communication and infotainment practices currently used (i.e. use of mobile phones or mobile radio while driving). Thus, the development of Intelligent Transportation Systems (ITS) applications may have the potential to significantly improve road safety. Some ITS applications will need specific development to enable them to be used on PTWs. Nevertheless, they should only be considered when it has been demonstrated that they will not destabilise a motorcycle in a range of conditions and circumstances. Because of PTWs' dynamics, some ITS applications will not be able to be adapted to motorcycles, or may not be cost effective if it would be possible. Thus, the effect on PTW's has a high potential safety benefit, but requires targeted and in-depth research to avoid negative consequences and to be cost-effective. Such technologies should be designed and developed in a way that will not interfere with riding and/or annoy the rider. Indeed, PTWs are very sensitive vehicles (from the vehicle dynamics point of view) and any unexpected change for the rider in motion could lead to loss of control.

# 2 OBJECTIVE

The European project SAFERIDER (« Advanced telematics for enhancing the safety and comfort of motorcycle riders ») aims to study the potential of ARAS/OBIS integration on motorcycles for the most crucial functionalities, and to develop efficient and rider-friendly interfaces and interaction elements for rider's comfort and safety. The overall objective of this project is to learn from the knowledge about ADAS/IVIS applications (Advanced Driver Assistance System/ In-Vehicle Information Systems) developed in automotive area. This experience is useful in terms of methodologies for design and evaluation, and in terms of integrations of the several available functions.

The riding task is a very demanding primary task, with the control of the PTW dynamics and the complex perceptual activity toward external events. It is therefore important that any additional devices are intuitive, very easy to use, self-explanatory, and not interfering with the riding task. These are the main reasons why tools and techniques to investigate systems safety have to consider the rider in the centre of the design process. Riders have to be involved in any stage of the system design in a User perspective. As quoted in ISO 13407:1999 Human-centred design processes for interactive systems, in the automotive area, but also valid in the PTW area, "making system more human-centred has substantial economic and social benefits. System can contribute to protect users from risks for their health and safety, meeting users and organizational needs better".

After the selection of priority information and communication functionalities, according to accident data, user needs and preferences and technological feasibility, the work conducted in the Saferider project intended to develop further functions, to meet the specific use cases requirements. Integration of these functions will be conducted through a common and unified HMI concept, utilising visual, acoustic and haptic elements and integrating them in different subsystems (i.e. on the panel, at a helmet, etc.); allowing each ARAS/OBIS functionality to use the best modality in an integrated and modular way and even supporting HMI personalisation to the user and context of use. The developed prototype will be tested across Europe in riding demonstrators, off-road and on-road, with 3 PTW simulators and 6 PTW vehicles, the developed function and HMI (stand alone but also in combinations), thus proving their reliability, effectiveness, usability and user acceptance in different traffic and weather environments and user different riding and behaviour style as well as socioeconomic and cultural conditions.

In order to run these tests, a methodology has been developped according to the following steps :

- To identify tools and techniques among ergonomic literature that are relevant for the task analysis of PTW riding: external observation of behavior using behavioral items grid to gather objective data (visual strategies, posture, speed, riding errors,…).
- To check and to verify applicability of these techniques and tools for PTWs needs and adapting them, as it can be expected that they mostly derive from research in the automotive area
- To develop of a specific tool for the evaluation of rider mental workload (RALI) as it has been done in previous projects for the driving activity with the development of the Driving Activity Load Index (DALI) and behavioral measures (e.g. secondary tasks).
- To define a methodology for real road and driving simulator PTW experimentations.
- The following paragraph developed some of the main variables identified as potentially appropriate for PTW systems evaluation, with discussion about their relevancy in the context of PTW.

# 3 RECOMMENDATIONS FOR TOOLS AND METHODS

In order to assess rider's usability and safety of information and communication technology, parameters to record and to analyse are related to the vehicle (for example, trajectory deviations consequent to the system use), rider's visual strategies (for example, visual demand due to information system display on screen with poor legibility or glare) and overall rider's workload according to the complexity of the situation.

The riding task has been much less studied than the driving task, but there are already some interesting studies we will be referring to investigate this topic.

## *3.1 Performance and riding errors*

### 3.1.1 Objective measures of the motorcycle control

Objectives data from the PTW dynamic are very important from a safety point of view, to be able to understand the level of riding performance in relation with the complexity of the context and the use of systems and the type of riding errors.

In an on-road study of rider behaviour performed at BASt (Haumann et al., 2006) several variables were recorded during the test rides (Speed [m/s], Acceleration [m/s2], Heart frequency [Hz], GPS position, Video recordings, PDT parameters, Steering angle [°], Hand lever and brake pedal operation, Temperature within the helmet [°C], Temperature outside [°C])

Data collection was realised by means of a mobile data recorder mounted in the top case of the motorcycle (see Figure 1).

**Figure 1: Measurement equipment in the topcase of the motorcycle (from Haumann et al., 2006)**

Based upon this previous experiment, it is recommended to use sensors on instrumented PTW to get main variables such as Speed, Acceleration, Brake and Motorbike tilt in field experimental conditions.

### 3.1.2 Physiological measures

Gathering physiological measures of rider workload is complicated by the fact that the device must not interfere with manoeuvring the motorcycle. In an on-road study performed by BASt (Haumann et al., 2006), heart rate was measured by means of a belt which was fastened at the riders breast (see Figure 2). Signals were sent by radio to a digital channel of the data recorder mounted on the topcase. However, this procedure turned out to be problematic for reasons of electronic interferences with the ignition system and the control of the ABS although the antenna directly fixed at the belt.

**Figure 2:Heartrate measurement device for use while riding a motorcycle**

Based upon this previous experiment, it is recommended not to use electrophysiology recording in field experimental conditions.

### 3.1.3 Video recording of rider's behaviour

The analyse of the user's behaviour in general, and more especially analysis of visual strategy (driver, rider, etc.) is one of the most important approach in the context of performance evaluation.

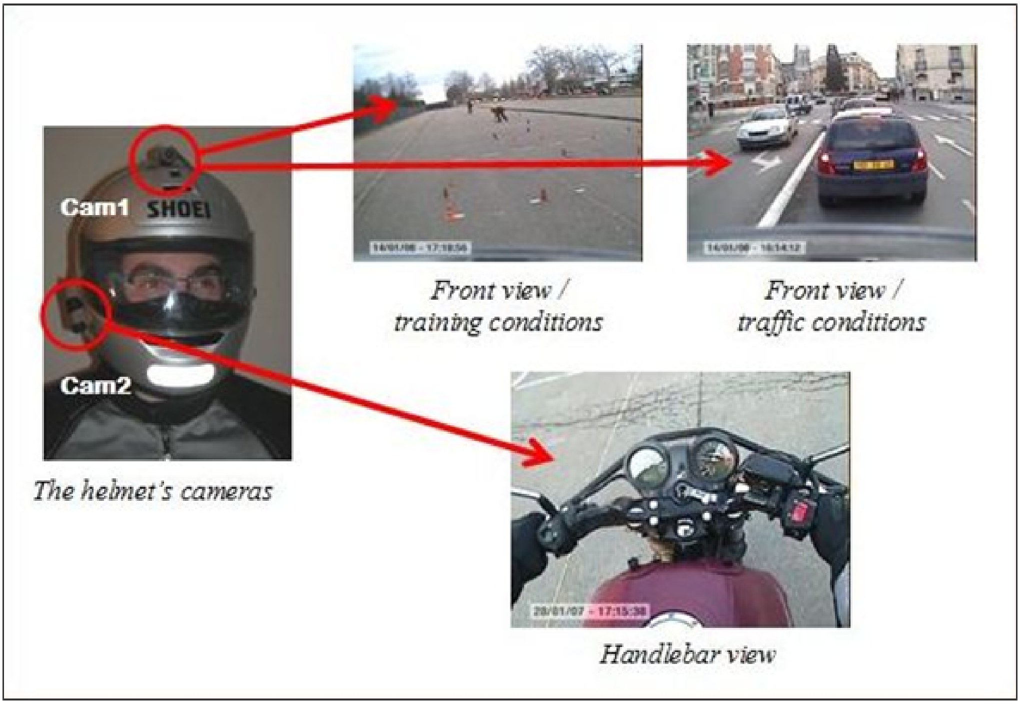



**Figure 3: Cameras mounted on the rider's helmet (Aupetit, S., Riff, J., Buttelli, O, & Espié, S. (2008)**

There is a necessity to combine several cameras in order to have synchronised recordings of various important aspects of the rider's behaviour in addition to road environment context (Figure 3). This combination of views should make it then possible to extract the information needed afterwards through analysis conducted in laboratory, image by image and to define some behavioural patterns linked to the situation, to understand the rider's strategies and to understand the impact of the environment on the rider's behaviour.

To summarise the following recommendations were given concerning the video recording of riders' behaviour at the SAFERIDER on-road tests:

1. To use at least two cameras fixed on the rider's helmet. Camera 1 should record the mobile front view and provide information on viewing strategies, in particular glances to visual sources in the environment. Camera 2 should record the handlebar view and provide information on the control of the vehicle.

2. If possible the use of three additional cameras is recommended. Camera 3 should record the fixed front view, and Camera 4 the fixed back view. Both provide information on the environment make it e.g. possible to rate the difficulty of traffic situations. Finally, camera 5 should record the rider's face and head movements and provide additional information on visual strategies.

### 3.1.4 Measurement of rider workload

In a broad sense, workload can be understood as the amount of capacity an operator invests to perform a certain task on a certain level. In this sense, workload is a construct characterising the interaction between the operator (e.g. a rider) and a task (e.g. safely negotiating a curve with a certain speed) as the amount of capacity spend is within certain limits and his/her control (c.f. Brookhuis & de Waard, 2001). Thus, workload and task performance usually have to be measured in parallel when evaluating an HMI for usability.

**A secondary task measure of the workload : the Peripheral Detection Task**

The Peripheral Detection Task (PDT) is a method which can be considered as an well established instrument in the automotive domain. It can be classified as one of the numerous secondary task techniques proposed to measure driver workload and requires simple manual responses to visual stimuli usually presented by LEDs positioned left to the drivers' normal line of sight. Stimuli are visible for 1 to 2 seconds and are presented with intervals of a few seconds, varying e.g. between 3 and 5 sec. Van Winsum, Martens, and Herland (1999) developed the task mainly based on studies of Miura (1986) and Williams (1985). Miura found that response times to spots of light presented at different horizontal eccentricities on the windscreen during driving increased with traffic density and by this reflected demands of the driving task. Williams demonstrated that with increasing foveal load the accuracy of responses to stimuli presented peripherally decreased.

In the PTW domain, the on-road study by Haumann et al. (2006) aimed at investigating the option of using the PDT for the online measurement of rider workload. To reach this aim, the "automotive" version of the PDT had to be modified under several aspects (see Figure 4). First, the LED had to be fixed within the helmet used by the subjects during the test ride. The angles relative to the line of sight were 3° to the horizontal and 17° to the vertical axis. Second, in order to ensure visibility of the LED also under conditions of inconvenient illumination the brightness of the LED had to be regulated depending on the light shining towards the rider. Third, as the conventional PDT finger switch cannot be operated by the rider when wearing gloves the press button of the horn was converted in order to record riders' manual responses to the visual stimuli presented during the test rides. All other parameters (stimulus presentation times, inter-stimulus intervals) corresponded to those usually implemented in automotive applications.

In the context of the present paper it is not necessary to completely summarise the results achieved by Haumann et al. (2006). However, with respect to the PDT which was, according to our knowledge, for the first time applied in the PTW domain, the most striking result were the high rates of missed signals (30% - 50%). These must be considered as extremely high as compared to results from automotive applications where hit rates about 85 - 90% are a common finding in PDT studies. These high rates of missed signals made it actually impossible to reasonably interpret the response latencies, which are usually used as workload indicators. Moreover, in this study the rate of missed signals turned out to be only moderately sensitive against situational demands and insensitive against HMI characteristics of the two navigation systems investigated.

**Figure 4: Apparatus of the PDT modified for the measurement of rider workload (from [3])**

To summarise, based on these results, it could not be concluded that the PDT is recommendable as a sensitive and efficient instrument for the measurement of rider workload. One reason might be that the baseline level of visual load imposed on a rider is beyond the level where sensitive measures of the PDT can be expected. Another reason was that although precautionary measures were taken to ensure the visibility of the LED there are reasons to believe that numerous signals were missed due to dazzling light. Finally, there were problems with the input device as the push button of the horn converted to record riders' manual responses (see Figure 4) could not be pressed in cases where the clutch lever was held (e.g. when waiting at red traffic lights).

**The RALI subjective evaluation of the workload**

The subjective evaluation of the workload is a method consisting in formalizing the own driver or rider judgment about the workload he experienced: this approach considered as "subjective" has been developed according to various methods such as the S.W.A.T. - Subjective Workload Assessment Technique, the NASA TLX - Task Load Index, etc.

This type of tools allows evaluation, rather than measurement, by establishing relative comparison of mental workload induced by various situations, such as, for example, a reference situation to be compared with situation with an implemented system.

The mental workload is multidimensional and, among other things, depends upon the type of task. An efficient tool called the NASA-TLX, NASA-Task Load Index, set up by the NASA for the evaluation of pilot's workload, has been used for many decades to evaluate subjective mental workload of operators A modified version of the NASA TLX has been proposed by INRETS (Pauzié & Pachiaudi , 1997) in order to adapt it to the driving task. As the objective is to evaluate the workload during a well-defined task, namely the driving task when using an in-vehicle system, the tool has to focus on the specific dimensions inducing potential workload for this task. This tool was called the DALI for "Driving Activity Load Index".

The NASA TLX assumes that the workload is influenced by mental demand, physical demand, temporal demand, performance, frustration level and effort. After assessing the magnitude of each of the six factors on a scale, the individual performs pair wise comparisons between these six factors, in order to determine the higher source of workload factor for each pair. A composite note quantifying the level of workload is set up by using both factor rating and relative weights computed from the comparison phase.

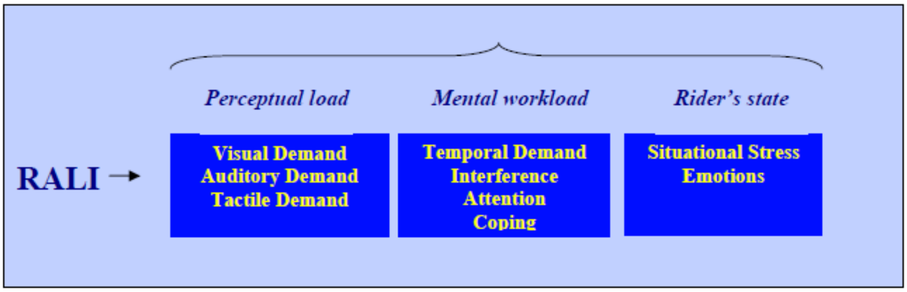
The basic principle of the DALI is the same than the NASA-TLX, with a scale rating procedure for six pre-defined factors, followed by a weighing procedure in order to combine the six individual scales into a global score. The main difference lies in the choice of the main factors composing the workload score. The dimensions for the DALI are: Effort of attention, Visual demand, Auditory demand, Temporal demand, Interference & Situational stress.

After discussion with experts in the area of riding, we propose to adapt this tool to the riding context, the same way it has been done for the NASA-TLX being adapted to the driving context. The RALI "Riding Activity Load Index" will have the following factors: Visual

Demand, Auditory Demand, Temporal Demand, System Interference, Effort Of Attention, Situation Own Coping, Situational Stress, Emotions Handling Vehicle. Two main factors have been added, typically inducing workload for rider:

"SITUATION OWN COPING" for "To evaluate the workload induced for coping with the other vehicles, especially the automotives ones, and with the complexity of the environment such as surface of the road, angle of a curve,…" and

"EMOTIONS HANDLING VEHICLE" for "To evaluate the level of negative emotions linked to the control and the handling of the motorbike."




It is recommended to use the Riding Activity Load Index in order to evaluate the rider's workload while using implemented system on the PTW in comparison with a reference situation with no use of system.

# 4 CONCLUSION

It can be considered that methodology for the evaluation of system safety and usability has been widely studied in the automotive area. Research has to be conducted in order to have the equivalent background in the area of the PTW. Indeed, very few studies have been devoted to this issue.

Methodology proposed in the framework of the Saferider project is based upon some of the available studies in the PTW area, in addition to available tools and techniques coming from driver’s behavioural studies adapted to the specific context of the riding activity.

Some of the described methods are very innovative, such as the evaluation of the rider’s workload RALI that has been developed in the framework of this project. So, they deserve to be further tested or eventually completed by additional techniques, according to the type and the objective of experiment, and the conditions of the context.

There is no objective of exhaustiveness in the described set of methods, the objective is rather to build up the first step of a concrete and operational approach to conduct system evaluation in riding context.

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