Potential of ITS to Improve Safety and Mobility of VRUs

Johan Scholliers[1*], Daniel Bell[2], Andrew Morris[3], Alejandra B. García-Meléndez[4]

1. VTT Technical Research Centre of Finland, .O.Box 1301, 33101 Tampere, Finland,
tel. +358 20 7223642, johan.scholliers@vtt.fi
2. FACTUM Chaloupka & Risser OHG, Austria
3. Loughborough University, United Kingdom
4. CIDAUT Foundation, Spain

Abstract

ITS Applications have in recent years assisted in reducing the number of fatalities in Europe. However, Vulnerable Road Users (VRUs) have not benefited as much as vehicle users. The EU-sponsored VRUITS project assesses the safety and mobility impacts of ITS applications for VRUs, assesses the impacts of current and upcoming ITS applications on the safety and mobility of VRUs, identifies how the usability and efficiency of ITS applications can be improved, and recommends which actions have to be taken at a policy level to improve ITS safety and mobility. This paper describes the results of the first phase of the project, in which the critical scenarios for VRUs are identified starting from accident data analysis, and following a user needs based on focus groups and expert interviews. From this basis, the most promising ITS applications for VRUs are selected according to their potential to address the specific needs of VRUs.

Keywords:

Vulnerable Road Users, safety, mobility.

Introduction

In recent years both technological developments and research activities in the fields of Intelligent Transport Systems (ITS) have primarily focussed on motorised transport to improve on safety and ecological standards by advancing equipment of vehicles and infrastructure. The uptake of ITS applications has assisted in the decrease of road traffic fatalities, particularly amongst passenger car occupants. However, Vulnerable Road Users (VRUs), such as pedestrians, cyclists, motorcyclists and moped riders have not enjoyed the same decrease in fatalities. Together, they account for 68% of the fatalities in urban areas[1]. Motorcyclists account for 16% of fatalities, which is much higher than their contribution to traffic[1]. While some projects have considered VRUs from a safety viewpoint, they often aimed at avoiding or mitigating accidents with VRUs by equipping the vehicle and infrastructure. In the vehicle – infrastructure – human approach of ITS research, VRUs and their needs are not an active part of the "human" element in the ITS approach.

What is needed? The VRU must become an active, integrated element in the ITS, addressing safety, mobility and travel comfort needs of VRUs. The VRUITS project, which is sponsored by the European Commission and started on 1.4.2013, aims at actively integrating the "human" element in the ITS approach by focussing on needs of all relevant stakeholder groups into the development and adaptation process of innovative ITS solutions aimed at improving traffic safety as well as the general mobility of vulnerable road users. The VRUITS project places the VRU road user in the centre, assesses the impact of current and upcoming ITS applications on the safety and mobility of VRUs, identifies how the usability and efficiency of ITS applications can be improved, and recommends which actions have to be taken at a policy level to improve ITS safety and mobility. By applying a multi-disciplinary approach the VRUITS project aims at developing tools to evaluate, field-test and subsequently improve ITS for vulnerable road users.

The first objective of the VRUITS project is to assess societal impacts of selected ITS applications, and to provide recommendations for policy and industry regarding ITS in order to improve the safety and mobility of VRUs. Both ex-ante and ex-post assessment of the applications is performed in order to come to a consolidated set of recommendations.

The second objective is to provide evidence-based recommended practices on how VRUs can be integrated in Intelligent Transport Systems and on how HMI designs can be adapted to meet the needs of VRUs, and test these recommendations in field trials. Starting from usability study of current ITS applications, guidelines will be provided on the improvement of the HMI for specific user groups, such as elderly drivers. A key concept is also the integration of VRUs in cooperative traffic systems, either through one-way (tags) or two-way communication. The performance and usability of different concepts for the communication between road users in safety critical situations will be assessed. Field trials for a select number of applications will take place in the Netherlands (Helmond), with an emphasis on cyclists and PTW riders, and Spain (Valladolid), with an emphasis on pedestrians.

Methodology

This paper describes the selection of the applications which have the most potential to improve the safety and mobility of VRUs. The selection is based on three pillars:

1) identification of major critical scenarios
2) analysis of the user needs of VRUs

3) inventory of ITS applications

The major critical scenarios for VRUs are studied through an analysis of accident data. The databases available (accident data, hospital data, in-depth studies and conflict studies) were first identified. For the analysis, both international databases (CARE), national databases (United Kingdom, Austria, Finland, Sweden, Spain) as in-depth studies (SafetyNet, Pendant, MAIDS) were selected. From a review of previous studies, a total of up to 14 key scenarios were identified for each VRU group and the subsequent accident analysis was then conducted according to these key scenarios in order to determine which of these was the most commonly occurring.

The user needs analysis for the identified VRU user groups focuses on both objective and subjective indicators such as:

- current mobility patterns
- behaviour, mobility and safety issues, needs, attitudes, prospects,
- ITS-user experiences and
- technology potential

This goal is accomplished by applying Focus Group Discussions and expert interviews based on a comprehensive literature review focussing on both available technologies, VRU groups relevant for the project and topics to be assessed in the course of the empirical phase of the task.

In addition to qualitative data gathered in the course of the focus group discussions 10 international experts at the European level from fields relevant and tangential to the topics of ITS and VRUs are interviewed to gather professional insight on the current state regarding both VRU needs and ITS technology development and implementation.

Together results of both focus groups and 10 expert interviews are providing comprehensive input to the other tasks and consequent work packages in the VRUITS project by connecting project related tasks to actual user needs.

Based on these findings ITS applications which affect VRU safety and mobility are identified, combining results regarding critical situations for vulnerable road users in traffic and the benefits as well as potential issues and hazards of these systems. As a result an inventory, categorizing and prioritizing existing and upcoming ITS services targeted at VRUs, also regarding positive or potentially negative impacts on safety and mobility, allows researchers and stakeholders to close existing gaps for new ITS and provides insight into the potential of existing technologies in this field.

The different ITS applications were then prioritised in a workshop with experts, and 20+ applications were selected for further assessment.

The method, which is used for the safety and mobility assessment, is based on the methodology, which was developed by Kulmala et al.[2], and which has been adapted towards VRU applications, as described by Mans et al.[3] The assessment is performed in two phases: a qualitative phase with all 20+ systems, and a second quantitative phase for a selected number

(7-8) of ITS applications.

Accident Data Analysis and Identification of Critical Scenarios

Analysis of a range of databases has been conducted to identify a number of scenarios for VRU's. The CARE database has been used as the most representative database for EU accidents and data from national databases from Austria, Finland, Spain, Sweden and the UK have been compared to the CARE data for consistency of results and for potential additional information regarding accident situations. Table 1 gives an overview of the databases used for accident analysis.

Table 1 Databases analysed for VRUITS accident analysis

Country	Name	Year(s)	Type	Number of accidents		
				Pedestrians	Cyclists	PTWs
Several	SafetyNet	2004-2008	In-depth	90	-	188
Several	PENDANT	2003-2006	In-depth	67	-	-
Several	MAIDS	1999-2000	In-depth	-	-	921
Austria	Austrian Statistics of Road Accidents Database	2009	Macroscopic	11 192	12 042	15 832
Finland	VALT	2007-2011	Macroscopic & microscopic	2 949	4 308	7 095
Spain	DGT	2009-2011	Macroscopic	-	11 184	77 742
Sweden	STRADA	2008-2012	Macroscopic	61 751	47 392	23 349
UK	STATS19	2010	Macroscopic	25 645	17 185	18 286
EU25*	CARE	1999-2012	Macroscopic	~1 800 000	~1 700 000	~2 900 000

*excluding Germany

For *Pedestrians*, in all databases including the CARE database, it was found that the accident between pedestrians and vehicles with the highest frequency occurs when the pedestrian was crossing the road at mid-block (Figure 1). The accident analyses suggest that in most if not all cases, the environmental conditions are not intuitively detrimental to road-crossing. That is, in the majority of the databases, these accidents tended to occur in fine weather and the road conditions were found to be dry. Also, there was some consistency across databases suggesting that pedestrian accidents tend to occur between 12pm and 6pm. It was found that in the majority of cases, the accidents tended to occur in urban areas on roads with lower speed limits (<50km/h). In the majority of databases including CARE, a passenger car was the most frequent collision partner. Some important parameters could not be determined from analysis of the CARE database and the various in-depth databases. These include vehicle characteristics, vehicle speed pre-collision and pedestrian actions prior to collision.

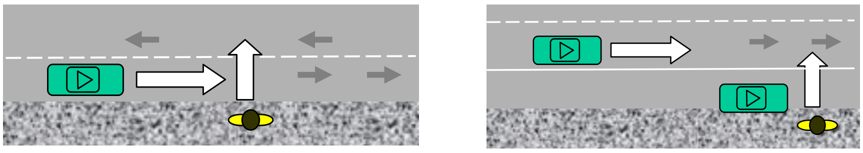

Figure 1 Critical pedestrian scenarios: crossing the street remote from a junction.

For *Cyclists,* the majority of cycling accidents in the accident databases were found to occur at junctions/intersections. One of the most common scenarios involved vehicles pulling out into the path of the on-coming cyclist at an intersection (Figure 2). CARE data suggests that the most common scenario involves both the cyclist and the vehicle heading in the same direction but the vehicle then turns into the cyclist's path. The majority of the accidents occur in fine dry weather during daylight hours. The majority occur in urban areas on roads with relatively low speed limits.

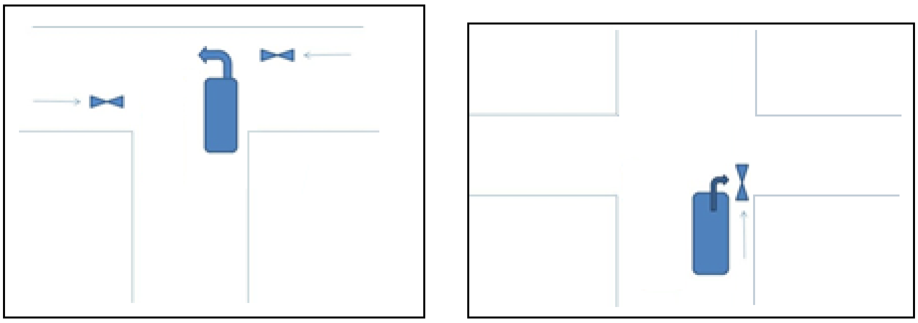

Figure 2 Critical cyclist scenarios: (a) vehicle pulling out into the path of an oncoming cyclist at an intersection; (b) vehicle turning into the cyclist's path

For *Powered Two Wheelers,* the most common scenario in the CARE accident analysis was found to be the PTW being hit by a vehicle (mainly passenger car) initially heading in the same direction and then turning across the path of the PTW. This was not consistent with the national database analyses which suggest that the most common scenario involves vehicles pulling out from intersections into the path of the PTW. Most accidents occurred within urban environments. It is thought that the majority occurred on roads with low speed limits (<50km/h). The majority of accidents occurred in fine and dry weather conditions during daylight hours. The majority occurred during the 'summer months' (May to September).

A limitation of CARE, and most of the national data, is that they mainly based on police recordings, which have an underreporting of single accidents of pedestrians and cyclists, especially when no major injury occurs. Single pedestrian accidents are not included in the UNECE definition of road accidents. However, according to several studies, single pedestrian

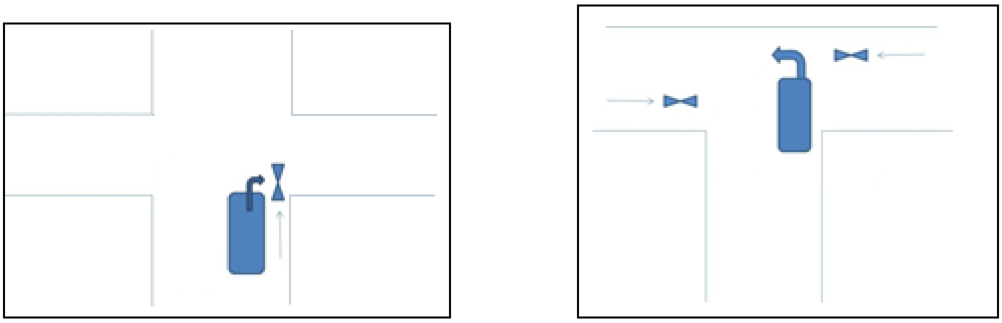

Figure 3 Critical PTW scenarios (a): PTW being hit by a vehicle heading in the same direction and then turning across the path of the PTW; (b) vehicles pulling out from intersections into the path of the PTW

and cyclist accidents are responsible for a significant amount of all societal costs of travel accidents. There has been only performed limited research on the causes of these accidents. Major causes of pedestrian single accidents are pedestrian pathways irregularities and, in countries with severe winter conditions, slipping on ice or snow. Causes of cyclist accidents are problems with handling of bicycles and irregularities in the cycling infrastructure.

User Needs Analysis

By conducting focus group discussions with different user groups in the participating partner countries actual user needs have been identified not only providing insight in the problem areas and critical situations in traffic from a vulnerable road user point of view, but also preliminary identification of systems and functions that are relevant for both, improving traffic safety and general mobility. Interviews with European level experts from the fields of ITS technologies, VRU associations and policies in the fields of traffic and transport helped to integrate a professional expertise on technology potential, relevant scenarios for application and needed research into the assessment of ITS for vulnerable road users.

Based on focus groups with 143 participants from 5 different ITS user groups (adults, parents, adolescents, older road users and powered two-wheelers) in four partner countries (Spain, Finland, Austria, the Netherlands) and expert interviews with 10 international experts from the fields of ITS technology, policy and VRU representation the following aspects have been comprehensively assessed:

- Identification of critical situations for VRUs
- Assessment of needs of different user groups for ITS services & applications.
- Identification and prioritisation of ITS potential and technology prospects in view of VRU safety and mobility

Critical situations for VRUs proved to be usually related to high (car) speeds, high complexity and density of traffic, local weather conditions and maintenance of infrastructure.

System knowledge among focus group participants was on a high level with a high share of standard in-vehicle (car) systems, with known infrastructure based ITS mainly regarding traffic lights and traffic signs. Smartphone-based applications for routing and navigation are already known and regularly used by all involved road user groups for pre-trip and on-trip information. Participants in all countries showed to have experiences on all levels of ITS (mobile applications, in-vehicle, infrastructure) and technologies (informing, intervening, warning) with a high level of experiences especially among car drivers (BSD, ISA, GPS, Cruise Control, etc.).

Main identified benefits and advantages of ITS for VRUs are increased visibility of VRUs (communication, warning, intervention); increased overall traffic flow (automation of processes such as traffic lights, etc.); economic (less fuel consumption) and ecological (less CO2 emissions) aspects; increased comfort in traffic (information).

On the other hand potential adverse effects are a perceived loss of autonomy, distraction (sounds, visuals, interaction with HMI), and potential for overreliance/overconfidence, technical limitations and reliability.

The overall willingness to use ITS for VRUs and the assessment of benefits for traffic safety and general mobility was assessed on a very high level by both experts and focus group participants.

Future technological advances are mainly expected in view of connecting road user groups (communication between VRUs and vehicles); increasing visibility and vision; standardisation of technologies; infrastructural developments and adaptation of legal requirements for broad scale deployment of technologies.

ITS applications for the critical scenarios and user needs

An inventory of ITS applications targeted to VRUs has been made with a total of 86 systems (14 systems addressing pedestrians, 34 addressing cyclists, 28 for PTWs, and a number of 10 in-vehicle systems which benefit all kind of VRUs). In order to identify the most promising solutions, a workshop with 40 relevant stakeholders was held in Brussels on September 18, 2013. In this workshop, representatives of VRU groups, national and European authorities, infrastructure service providers and ITS-related representatives of organizations and companies contributed their input to the prioritization process. The participants were divided over three different groups (pedestrians, cyclists, or PTW´s) according to their expertise/interests, and ITS solutions for two scenarios, which were identified in the accident analysis and user needs as the most important for the specific group, were discussed. The first scenario corresponds to the most critical safety scenario; the second scenario corresponds to an identified user need for mobility or safety. More specifically the scenarios were:

- Pedestrians: (1) pedestrian crossing the road at mid-block, occluded or not by a parked car; (2) support pedestrians at intersections to increase comfort and remove obstacles/barriers.

- Cyclists: (1) vehicle on a crossroad, pedal cyclist crossing the road from the right or from the left; (2) making cycling from location A to location B easier.
- PTWs: (1) urban junction accidents with cars; (2) urban single motorcycle accidents on straight roads.

After the discussions, participants were asked to select the three applications which have the most potential for VRU safety and rate these ITS solutions based on the questionnaires, according to the following criteria: safety, mobility, technical maturity, deployment potential, acceptance (by VRU, drivers and government authorities), relevance for older people, relevance for people with disabilities, feasibility for children, usability of system interface. A five-point Likert scale was used for each of them. In addition, they were asked about potential negative side effects of the systems selected.

The final selection of systems considered most relevant for the impact assessment was based on the identified user needs and critical scenarios as well as the results of the First Interest Group Workshop leading to a set of 20 applications. The overall selection was established in the course of an iterative process among the project partners integrating external expertise into available project results. Main focus for the final selection of applications was on taking all road user groups into account, improving comfort and general mobility, providing at least an ITS applications with potential adverse effects, for analysis in course of the assessment process, and offering a mix of services close to market and future applications. This resulted in the following list of ITS applications:

1. Blind Spot Detection
2. Intelligent Pedestrians Traffic Signal
3. Intelligent Speed Adaptation (ISA)
4. Red Light Camera /Average Speed Camera
5. Intersection Safety
6. Pedestrian Detection System + Emergency Braking
7. Trip Planning and navigation for VRUs
8. PTW Oncoming vehicle info system
9. VRU Beacon System
10. Rearward looking assistant for cyclists
11. Roadside Pedestrian Presence
12. Urban sensing system
13. Automatic Counting of Bicycles and Pedestrians
14. Night Vision and Warning
15. Information on vacancy on bicycle racks
16. Bicycle to car communication
17. Rider Monitoring System
18. Crossing Adaptive Lighting

19. Infotainment
20. Real-time information systems for public transport
21. Road weather warning for pedestrians
22. Forward obstacle detection for cyclists
23. Green wave for cyclists

Each of these functions still covers a wide range of actual implementations. For assessing the impact of the functions, an existing or possible implementation of the function will be selected, and the details of the implementation, such as HMI, technology used, reaction of the driver or the system will be described in more detail, as basis for the work in WP3.

Discussion

Besides adaptations in the built environment and education and training procedures the deployment of ITS technologies has the potential to enhance safety and mobility of VRUs. However, it is essential for their success, that these systems are tailored to the specific needs of road users. For this reason, the current investigation has begun with the identification of the critical scenarios for VRUs as well as user needs, in order to find the most promising ITS systems to address them, according to a group of experts.

Based on information derived from Focus group discussions, junctions are one of the most relevant critical situations for VRUs, where VRUs are endangered due to being hardly visible or easily overlooked. Moreover situations where cars overtake cyclists or PTWs are especially assessed as being critical due to high traffic speeds and the perceived reckless behaviour of car drivers in some cases.

Data obtained from Focus Group discussions indicated that the visibility of VRUs is generally perceived as a major factor in view of traffic safety, especially in connection with heavy traffic and high speed situations. Correspondingly technologies and systems enhancing the detectability and visibility of VRUs are considered to have high potential to increase the traffic safety of VRUs.

Previous research has pointed out that ITS technologies capable of distinguishing between different types of VRUs and of rapidly deploying tailored countermeasures (such as active braking or airbags) to reduce injuries in the event of a crash offer considerable safety potential[4]. A detailed study on the potential of Pedestrian Detection Systems /Emergency Braking, suggests that 40% of fatalities and 25-30% of severe injuries suffered by pedestrians can be avoided[5]. Similarly, Blind Spot Detection systems are seen as promising, especially to avoid truck-cyclist crashes.

Cooperative systems, based on simple beacons carried by VRUs, or two-directional devices allowing communication between PTWs and vehicles, are seen as having a great potential. In this sense, the multitude of sensors and communication interfaces smart phones deliver, together with their rising penetration, could provide a good opportunity to improve the visibility of VRUs in complex/urban environments. Indeed, focus group discussions revealed that smartphone-based applications (for routing and navigation) are regularly used by all involved road user groups.

Regarding PTWs the potential for vehicle-to-PTW communication systems to address motorcycle conspicuity issues has been previously recognised[6], though one issue to tackle is the need to reach the necessary penetration to achieve efficiency of cooperative systems. However, while on the one hand systems supporting visibility or communication between PTW's and cars are considered very positive, on the other hand ITS interfering with the riding task or those perceived to take away the autonomy from the rider are seen as very sceptical. Training and education are considered to be of major importance in this group with ITS having mainly adverse effects on riding behaviour. This is in line with the research of Beanland et al.[7], who found that riders believe that innovations should focus on protective equipment, rather than systems that prevent crashes; since they believe crash prevention is better addressed through rider training.

In this sense, Huth & Gelau[8] found that the social norm and the interface design are powerful predictors of the acceptance of Advanced Rider Assistance Systems (ARAS), while the extent of perceived safety when riding without support did not have any predictive value in their study. Thus, these authors found that the specific social influence of peers confirmed for the acceptance of ADAS[9] had proven to have a strong influence on the acceptance of ARAS in their study. This finding revealed the impact that preconceptions regarding the support systems, which might be present in rider circles, may have on the acceptance of the ARAS by an individual. Accordingly, it lends importance to promoting a favorable attitude towards such solutions amongst motorcycle riders, with the particular aim of avoiding a distinctly negative social norm[8]. According to PTW´s participants in focus group discussions, there are not really specific ITS solutions for motorcycles. Several researchers have reflected this need for assistive systems to be developed specifically for PTWs[6,7]. The need of a better understanding of people´s attitudes and opinions about ITS applications has been highlighted as an important area for further research[4], especially given the rapid rate at which ITS applications are becoming available. As Van der Laan et al.[10] stated, it is counterproductive to invest in developing new technologies if the systems are never purchased or if they are purchased but never used. In other words, these systems can only enhance users´ safety and mobility if they use them. For this reason, acceptance is a decisive aspect to be considered in the development process of such systems. In the present study on user needs, overall willingness to use ITS for VRUs and the assessment of benefits for traffic safety and general mobility was assessed on a very high level by both experts and focus group participants. Actual acceptance was found to be mainly related to the following factors: Price/affordability, usability/implementation, availability, standardization across different platforms and manufacturers, reliability, and privacy.

On the other hand, too high vehicle situational speeds have been repeatedly found to be a very important factor in fatal pedestrian collisions. It is well known that even small decreases in vehicle travelling speeds prevent a large number of pedestrian fatalities. For this reason, Intelligent Speed Adaptation as well as automated speed enforcement has significant potential to reduce the injury consequences of VRUs crashes. Red Light Cameras are seen as a safety enhancing technology, and with great deployment potential. However, promoting a change in attitudes and behaviour is suggested in addition to the installation of the Red Light Cameras. In this regard, enforcement should be accompanied by educational measures in order to modify intentions to break the law.

Systems aiming at infotainment, applications that are not primarily focusing on the driving, riding, or walking task, have the negative potential of distracting road users. Moreover the general usage of systems while being part of the traffic system and the mere interaction with different HMIs could increase the cognitive load of the user and negatively affect his behaviour. Therefore both usability and potential effects on different user groups need to be assessed comprehensively to develop and adapt ITS, which have the potential to increase VRU safety and improve general mobility and comfort.

Single VRU accidents, especially pedestrians and cyclists, are underreported in traffic accident databases. There is only little research performed on the scenarios of these accidents, and there are only little ITS applications attempting to avoid these accidents. Two of these applications: road weather warning for pedestrians and a forward obstacle detection system for cyclists are included in the final list of ITS applications.

Conclusions

The paper reported on the findings of the first phase of the VRUITS project, which has as first objective to provide recommendations regarding ITS applications to improve the safety and mobility of Vulnerable Road Users. The most potential applications were selected starting from an identification of the most critical scenarios through analysis of various accident databases; through identification of user needs through focus groups with VRUs and experts interviews; and through an inventory of ITS applications. The applications were prioritised by VRU experts in a workshop. Based on this prioritisation, and by forming a mix of services addressing the different VRU groups, through a mix of current and upcoming services, the list of ITS applications which will be assessed further is selected.

During the next phase of the VRUITS project, the impact of the applications on safety and mobility will be analysed qualitatively and quantitatively, and based on this assessment recommendations will be formulated towards policy makers and ITS industry for the improvement of VRU safety and mobility.

Acknowledgements

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 321 586.

References

1. CARE (2009), CARE, EU roads accident database
2. Kulmala, R. (2010), Ex-ante assessment of the safety effects of intelligent transport systems, *Accident Analysis and Prevention 42* (2010), pp 1359-1369.
3. Mans, D., Giannelos, I., van Noort, M., Silla, A., Leden, L., Johansson, C., (2014), Impacts of ITS on Vulnerable Road Users 10th Conference on ITS in Europe, 16-19 June 2014, Helsinki, Finland
4. Regan, M. ,Oxley, J., Godley, S., & Tingvall, C. (2001). *Intelligent Transport Systems: Safety and Human Factors Issues*. Victoria: Royal Automobile Club of Victoria.
5. Källhamer J. (2009), Pedestrian Injury Mitigation by autonomous braking; Autoliv Research.
6. Baylay, M., Regan, M., & Hosking, S. (2006). *Inteligent Transport Systems and Motorcycle Safety* (Monash University Accident Research Centre Report 260). MUARC: Clayton, Australia.
7. Beanland, V., Lenné, M.G., Fuessl, E., Oberlader, M., Joshi, S., Bellet, A., Robger, l., Leden, L., Spyropoulou, I., Yannis, G., Roebroeck, H., Carvalhais, J., & Underwood, G. (2013). Acceptability of rider assistive systems for powered two-wheelers. *Transportation Research Part F, 19*, 63-76.
8. Huth, H., & Helau, G. (2013). Predicting the acceptance of advanced rider assistance systems. *Accident Analysis and prevention, 50,* 51-58.
9. Arndt, S., & Engeln, A. (2008). *Prädiktoren der Akzeptanz von Fahrerassistenzsystemen.* In: Schade, J., Engeln, A. (Eds.), Fortschritte der Verkehrspsychologie, vol. 45: DGP-Kongress für Verkehrspsychologie. Deutscher Psychologen Verlag, pp. 313–337, doi:10.1007/978-3-531-90949-3 16.
10. Van Der Laan, J.D., Heino, A., & De Waard, d. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation *Research Part C: Emerging Technologies, 5(1),* 1-10.