Improving the safety and mobility of vulnerable road users through ITS applications [VRUITS] D4.1 Usability assessment of selected applications

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Citation: CACCIABUE, P. C. ...et al., 2016. Improving the safety and mobility of vulnerable road users through ITS applications [VRUITS] D4.1 Usability assessment of selected applications. VRUITS 40pp.

Additional Information:

- This is an official report.

Metadata Record: https://dspace.lboro.ac.uk/2134/24072

Version: Published

Publisher: European Commission/VRUITS © VTT

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Deliverable D4.1

Usability assessment of selected applications

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### Deliverable information

<table>
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<td>Project acronym</td>
<td>vruits</td>
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<td>Project title</td>
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<td>WP</td>
<td>WP4 Improving ITS applications for VRUs</td>
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<td>Task</td>
<td>T4.1 HMI Usability assessment of existing ITS applications</td>
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<tr>
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<td>D4.1 Usability assessment of selected applications</td>
</tr>
<tr>
<td>Status</td>
<td>F</td>
</tr>
<tr>
<td>Version number</td>
<td>1.0_FINAL</td>
</tr>
<tr>
<td>Lead Contractor</td>
<td>KITE</td>
</tr>
<tr>
<td>Dissemination level</td>
<td>Public</td>
</tr>
<tr>
<td>Due date</td>
<td>30.03.2014</td>
</tr>
<tr>
<td>Date of preparation</td>
<td>3.4.2014</td>
</tr>
<tr>
<td>Project start and duration</td>
<td>1.4.2013–31.3.2016, 36 months</td>
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## Version history

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<td>17.02.2014</td>
<td>P. C. Cacciabue (KITE)</td>
<td>First draft of contents for D4.1</td>
</tr>
<tr>
<td>0.2</td>
<td>27.02.2014</td>
<td>P. C. Cacciabue (KITE)</td>
<td>Second draft of D4.1</td>
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<tr>
<td>0.3</td>
<td>11.03.2014</td>
<td>P. C. Cacciabue (KITE)</td>
<td>Third draft of D4.1</td>
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<tr>
<td>0.4</td>
<td>18.03.2014</td>
<td>P. C. Cacciabue (KITE)</td>
<td>Version for peer review</td>
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<tr>
<td>1.0</td>
<td>03.04.2014</td>
<td>P. C. Cacciabue (KITE)</td>
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<th>Description</th>
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<tr>
<td>CARE</td>
<td>Community database on Accidents on the Roads in Europe</td>
</tr>
<tr>
<td>FGI</td>
<td>Focus Group Interview</td>
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<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
<tr>
<td>IGW</td>
<td>Interest Group Workshop</td>
</tr>
<tr>
<td>ISA</td>
<td>Intelligent Speed Adaptation</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport Systems</td>
</tr>
<tr>
<td>PPB</td>
<td>Pedestrian Push Button</td>
</tr>
<tr>
<td>PTW</td>
<td>Powered Two Wheeler</td>
</tr>
<tr>
<td>SDP</td>
<td>System Description Paper</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>VRU</td>
<td>Vulnerable Road User</td>
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<td>WS</td>
<td>Workshop</td>
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EXECUTIVE SUMMARY

In recent years ITS applications have assisted in reducing the number of road traffic accident fatalities in Europe. However, Vulnerable Road Users (VRUs) have not benefited to the same extent as vehicle users. The EU-sponsored VRUI TS project assesses the safety and mobility impacts of ITS applications for VRUs. This process involves assessing the impacts of current and upcoming ITS applications on the safety and mobility of VRUs, identifying how the usability and efficiency of ITS applications can be improved and recommending which actions have to be taken at a policy level to accelerate deployment of such ITS.

This deliverable reports the work performed during the second period of activity focusing on a number of selected existing ITS which are already present on the market. In particular, user-acceptance and usability of existing ITS services for VRUs, have been assessed, focusing on comfort/mobility and effectiveness of related information (the HMI) for special user groups, such as elderly subjects.

In Chapter 1 the Project and the objectives of the deliverable are described. The concept of the Vulnerable Road Users and ITS interfaces are then presented.

In chapter 2 the method for evaluation and screening of existing ITS systems is described. The usability assessment has been performed by experts, which were provided a detailed description of several ITS systems for VRUs. Starting from the inventory of ITS systems in D2.1, the most suitable systems for usability assessment were selected. The selection of the ITS systems to be assessed has been conducted following the feedback received from the activity carried out in WP 2. A questionnaire has been developed for the evaluation of interfaces, based on the literature work already carried out in the past.

The selected ITS systems have been studied in detail in order to develop sufficient material to distribute to interviewees together with the questionnaire. This aimed to support the interface usability process even in situations where the actual systems were not available.

The 4 selected systems are mainly dedicated to pedestrians, drivers of PTWs, cyclists and drivers, and are:

- Intelligent pedestrian traffic signal
- Cyclist digital rear-view mirror
- PTW oncoming vehicle information assistance system
- Blind spot detection system

This process led to the development of a substantial amount of material and information (mainly in the form of links to video and on-line demonstrations of ITS) that were made available to interviewees to support their evaluation process.

The complete set of material, i.e., the questionnaire and supporting material, for 4 different ITS have been distributed to a number of interviewees.

In Chapter 3 the VRUI TS questionnaire used for usability is presented and explained together with the data collection findings.

Chapter 4 discusses the actual survey results about ITS usability. A total of 152 individual replies were collected, and each of the system was assessed by 35-42 persons. This data has been collected and analysed, utilising standard statistical tools, mainly SPSS (Statistical Package for the Social Sciences) for data mining and data analysis.
Finally Chapter 5 and 6 a discussion about the results as well as the research conclusions are reported. The overall findings of the investigation revealed that it was possible to discriminate and identify areas of improvement for usability issues on all the four ITS systems under investigation.

In general, the results revealed common usability patterns across the four ITS systems. In particular, the Perception of risk avoidance (given by the ITS system) and Communication of Risk (risk warning by the ITS) were rated the best usability properties of the various ITS systems. Providing feed-forward information about incoming hazardous situations and subsequent appropriate perception of risk avoidance are the best properties among all the four ITS systems. Also, the highest rated usability features across all ITS systems were the clarity of the system functions (Explicitness), the way the systems work and operate (Functionality) and the degree of control by the user (User Control).

Some major areas of improvement were revealed also. Firstly, the lowest rated usability features across all four ITS systems were System Monitoring, Flexibility and Consistency. This latter finding could suggest the evidence that all four ITS systems might need more focus on adaptability to road context, consistency of functions in difficult weather conditions and finally a more active monitoring of human behaviour in response to the ITS (where this is applicable). Secondly, Trust in the ITS system, and the perception of Safety Improvement revealed to be weak ITS properties overall. Some work on trust in safety and ITS automation and safety improvement perception (in using such systems) could be brought forward as the aim of the ITS system for VRUs is exactly to increase Safety. In fact, a user attitude of trust in the systems and belief that such systems could improve their safety is a substantial desirable scenario to strive for.

Notably, younger people (<38 years) tended to rate the general usability of the four systems slightly more positively than the older people (>62). Nevertheless the rating is on the same direction for both sub-samples of respondents. Finally, the replies from experts in the sample did not differ from the overall group for the general usability and the for usability scales except for minor differences.
1 INTRODUCTION

1.1 The VRUITS Project

In recent years both technological developments and research activities in the fields of Intelligent Transport Systems (ITS) have primarily focused on motorised transport to improve safety and ecological (environmental) impacts by advancing vehicle equipment 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 (CARE, 2009). Motorcyclists account for 16% of fatalities, which is much higher than their contribution to traffic (CARE 2009). 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.

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 will be 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- how HMI designs can be adapted to meet their needs and test these recommendations in field trials. Starting from a usability study of current ITS applications, guidelines will be provided on the improvement of the HMI for specific user groups, such as elderly drivers.

1.2 Scope and objective of the deliverable

This deliverable describes the work performed in tasks T4.1: HMI usability assessment of existing ITS applications.

The task aims to perform an assessment of user-acceptance and the usability of existing ITS services for VRUs. This focuses on comfort/mobility and the effectiveness of related information (the HMI) for special user groups, such as elderly subjects. The services to be tested are selected in T2.3. T4.1 identifies the need for improvement in safety services for VRUs. For the assessment of effectiveness and friendliness (Usability) of the HMI, well consolidated methods and techniques, derived from the literature, are implemented in relation to Human Centred Design principles.
2. METHOD FOR THE USABILITY ASSESSMENT

2.1 The variety of systems considered and the candidate selection process

An exhaustive process of identifying and documenting systems for consideration in VRUITS project took place in WP2. A total of 144 systems were initially identified in T.2.3. On the basis of this compilation, an inventory of ITS applications targeted to VRUs was made with a total of 14 systems addressing pedestrians, 34 addressing cyclists, 28 for PTWs, and 10 in-vehicle systems which benefit all kind of VRUs.

This inventory of ITS systems was narrowed down to a total number of 22 systems at the First IGW that was prepared by VRUITS partners in Brussels on September 18, 2013. At this Workshop 40 relevant stakeholders selected the applications which have the most potential for VRU safety, mobility and comfort. This formed the basis for the VRUITS project to decide the final set of 22 systems to be evaluated later in this project (Table 1). The selection process and the applications are described in more detail in D2.1.

Table 1. List of ITS selected in WP2 for impact assessment

<table>
<thead>
<tr>
<th>ITS applications</th>
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<tbody>
<tr>
<td>1. Blind Spot Detection</td>
</tr>
<tr>
<td>2. Intelligent Pedestrians Traffic Signal</td>
</tr>
<tr>
<td>3. ISA (Intelligent Speed Adaptation)</td>
</tr>
<tr>
<td>4. Red Light Camera /Average Speed Camera</td>
</tr>
<tr>
<td>5. Intersection Safety</td>
</tr>
<tr>
<td>6. Pedestrian Detection System + Emergency Braking</td>
</tr>
<tr>
<td>7. Navigation systems for VRUs</td>
</tr>
<tr>
<td>8. PTW Oncoming vehicle info system</td>
</tr>
<tr>
<td>9. VRU Beacon System</td>
</tr>
<tr>
<td>10. Cyclist digital bicycle rear-view mirror</td>
</tr>
<tr>
<td>11. Roadside Pedestrian Presence</td>
</tr>
<tr>
<td>12. Urban sensing system</td>
</tr>
<tr>
<td>13. Automatic Bicycle Identification</td>
</tr>
<tr>
<td>14. Night Vision and Warning</td>
</tr>
<tr>
<td>15. Information on vacancy on bicycle racks</td>
</tr>
<tr>
<td>16. Bicycle to car communication</td>
</tr>
<tr>
<td>17. Rider Monitoring System</td>
</tr>
<tr>
<td>18. Crossing Adaptive Lighting</td>
</tr>
<tr>
<td>19. Infotainment</td>
</tr>
<tr>
<td>20. Real-time information systems for public transport</td>
</tr>
<tr>
<td>21. Road weather warning for pedestrians</td>
</tr>
<tr>
<td>22. Advice system for elderly cyclists</td>
</tr>
</tbody>
</table>

Starting from the 22 systems, 14 systems were selected as being potentially relevant for the usability assessment process, based on a comprehensive mapping and evaluation process, which in turn served as basis for the final selection of four applications to present to the interviewed experts.
The 14 systems were chosen based on the following four aspects:

1) Systems whose links provide valuable information on the interface
2) Systems for which a link to on-going or finished projects has been established
3) Systems to be tested in the project pilots
4) Systems for which further resources are provided, and/or more creative initiatives are required in order to get the required information on the HMI

The various systems identified for possible evaluation are shown in Table 2.

Table 2. ITS systems suitable for HMI evaluation

<table>
<thead>
<tr>
<th>ITS applications</th>
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<tbody>
<tr>
<td>1 Blind Spot Detection</td>
</tr>
<tr>
<td>2 Intelligent Pedestrians Traffic Signal</td>
</tr>
<tr>
<td>3 ISA (Intelligent Speed Adaptation)</td>
</tr>
<tr>
<td>5 Intersection safety</td>
</tr>
<tr>
<td>7 Navigation systems for VRUs</td>
</tr>
<tr>
<td>8 PTW oncoming vehicle info system</td>
</tr>
<tr>
<td>9 VRU beacon system</td>
</tr>
<tr>
<td>10 Cyclist digital rear-view mirror</td>
</tr>
<tr>
<td>11 Roadside Pedestrian Presence</td>
</tr>
<tr>
<td>14 Night Vision and Warning</td>
</tr>
<tr>
<td>16 Bicycle to car communication</td>
</tr>
<tr>
<td>17 Rider Monitoring System</td>
</tr>
<tr>
<td>19 Infotainment</td>
</tr>
<tr>
<td>20 Real-time information system for public transport</td>
</tr>
</tbody>
</table>

Finally 4 systems, out of the 14 already selected as relevant for task 4.1, would be chosen: one system per type of road user (Pedestrians, PTW drivers, Cyclists and car drivers). In order to select the 4 systems, each Task 4.1 participant was requested to provide comments and suggestions by looking more closely at one or more of the 14 previously selected systems. Only those systems for which sufficient descriptions as well as pictures and movies could be gathered remained in the list. 8 systems survived. As only one system supporting Pedestrians and one supporting Cyclists had been selected, they were automatically included in the final list. For the other six, KITE prepared a ranking table to be used by the participants to select the four final ones (Table 3).

Table 3. Ranking table for selecting four ITS

<table>
<thead>
<tr>
<th>PTW oncoming (8)</th>
<th>Pedestrian</th>
<th>Cyclist</th>
<th>In-Vehicle</th>
</tr>
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<tbody>
<tr>
<td>Infotainment (19)</td>
<td>Intelligent Pedestrian Traffic Signal (2)</td>
<td>Cyclist digital rear-view mirror (10)</td>
<td>Intersection Safety (5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Blind Spot Detection/ VRU beacon (1, 9)</td>
</tr>
</tbody>
</table>

On 14.1.2014 the final selection was done by KITE on the basis of the rankings received. The four systems to be assessed were:
• Intelligent pedestrian traffic signal
• Cyclist digital bicycle rear-view mirror
• PTW oncoming vehicle information assistance system
• Night vision and warning or Blind spot detection system

2.2 Material for supporting interviewees

As the experts were not able to actually use the systems they needed to be provided with supporting materials that allowed comprehensive insight into the functions of the applications without any issues in comprehensibility or ambiguity. This would give them adequately insight into the system in order to be able to effectively complete the usability questionnaire.

For the initial set of systems (Table 2) each of the participating partners contributed by screening the available information (mainly through the use of internet searches) for each of the applications in this set.

The two steps in the selection process of materials to support the experts in the usability interviews consisted of:

- Screening of each of the suggested 14 systems (provided by task T2.3) in view of available information material
- Where available collection of video, image and function descriptions based on existing project materials and web searches
- Producing an information brochure for all 14 systems consisting of the found materials and illustrating each application in a comprehensible and concise way

The main goal of the screening process was to produce a document, in the form of an information brochure, which provides concise descriptions of the 14 systems, including available illustrations of both the systems’ functions and their interface design. Ideally these illustrations were supported by video clips showing the functioning of the systems in action. This document in turn was developed to serve as the main factor in the consequent decision making process on which four systems to provide to the experts.

As already pointed out the description of the systems not only needed to present the functions and mechanisms of the applications, but also answer the following questions:

- What is the function/goal/target of the system?
- In which context, traffic situation is it used?
- What is the VRU group targeted by the system?
- Are road user groups actively/passively interacting with the system? Which road user group(s)?
- What are the components of the system? Which technologies are used?
- Which interface is employed?

The final system description/supporting material consisted of a short introductory text outlining the goals and functions as well as the used components of the application. In addition a schematic representation of the system functions or the traffic situation it is applied in was provided. If available, images of the system in action were additionally added. In order to clarify potential remaining ambiguities web links to videos presenting the actual system in action, either in form of (computer) simulations or even in already implemented real-world scenarios broadened the information material.
Issues only occurred in cases where either different applications were available for one system or the systems were only available in an early prototype phase. Especially systems which had been available for several years (i.e.: navigation systems, etc.), or systems which were implemented based on different technologies (i.e.: Intelligent Pedestrian Traffic Signal, see below) led to a need for further discussion on which exact application to choose for the supporting materials. This was especially important as the depicted system needed to provide a representative illustration of the discussed technology. In the case of infotainment systems for instance, there is already a wide variety of solutions available on the market from different manufacturers, not only aimed at car drivers but also at motorcyclists and therefore a wide variety of implementations exist.

The **Intelligent pedestrian traffic signal** serves as an example for the supporting materials provided to experts in course of the usability assessment process to illustrate functions, components and interface that were supposed to be evaluated:

```
IPT is a traffic signal control system that uses sensors such as an infra-red camera or microwave detectors to determine the presence of pedestrians and adjusts the traffic signals accordingly. State-of-the-art traffic light management systems use advanced sensors to monitor crossing behaviour of pedestrians.

**Waiting detectors:**
- Pedestrian pushes PPB
- Detectors confirm the presence of pedestrians standing near the crossing
- If pedestrian leaves before the onset of the Walk interval, the call for the pedestrian phase is cancelled.

**Crosswalk detectors (detect pedestrians on crosswalks and...)**
- A pre-set extension is added to the pedestrian clearance
- Late-starting or slow-moving pedestrians have more time to clear the intersection
- Driver waiting time is reduced if the pedestrian crosses in a gap in traffic instead of waiting (U-walk ?)

**Examples**
Both microwave and infrared detectors work by calling the Walk signal when a person enters the detection zone on the curb. The size and shape of the detection zone varies depending on the type of detector used and how it is positioned. A delay can be built in so that persons are detected only if they stay within the detection zone for more than a minimum amount of time

**Video 1:** [http://www.youtube.com/watch?v=avKv0wqlUE](http://www.youtube.com/watch?v=avKv0wqlUE)

**Video 2:** [http://www.traficon.com/information/flashmovie_detail.jsp?id=18](http://www.traficon.com/information/flashmovie_detail.jsp?id=18)
```
Overall no specific issues occurred in the course of the usability interviews to indicate the experts experienced critical uncertainties, in the course of the evaluation process, due to unclear illustrations for the provided systems. Visual elements proved to be an especially important aspect of the provided supporting material as they allowed for easily comprehensible insight into functions and interfaces. As can be seen in Appendix A all of the used systems were presented in the same way, including short descriptions, visual illustrations of the functions and one or more web links to videos presenting the actual application in action.

2.3 The questionnaire

2.3.1 Introduction and Literature review on Usability

The term usability is here defined as “the achieved level of accuracy, efficiency and perceived satisfaction by using a system”. The Usability Questionnaire developed by KITE was intended to assess the level of usability for a selected number of ITS systems.

The Kite Usability Survey is composed of 5 scales.

1. Scale 1: ITS Usability Index. It was developed upon classic referenced usability topics (Stanton and Young, 1999). In particular, nine usability properties (sub-scales) were targeted: system explicitness, functionality, consistency, compatibility, human error potential, flexibility, user control, system monitoring, and informative feedback;
2. *Scale 2: ITS Risk Avoidance* (perception of risk avoidance capability by the ITS system);

3. *Scale 3: Trust* (degree of reliance, confidence and perception of credibility in ITS performance and use)

4. *Scale 4: Safety improvement* (perception of expected safety enhancement by using the system)


The Survey also gathered background information from the experts in order to enable a more refined analysis of the results on the basis of values such as age, gender, knowledge with the use of ITS, frequency of use of ITS, etc.

### 2.3.2 The VRUITS Questionnaire

See Appendix p. 35

### 2.4 Statistical method

Descriptive statistics were applied on all survey results to screen and check data point estimates like sample averages (both checking arithmetical and geometrical means).

Standard errors, standard deviations and sample sizes were also monitored in order to verify that statistical power was acceptable (i.e., detecting a statistical significant result when the null hypothesis is false and the effect is real). Independence of errors and respondent independence was kept under control.

Also data screening (check of scatterplots and sample distribution shapes) to check data consistency was fully applied: check for univariate and multivariate outliers (unusual Z scores or Mahalanobis distances), missing values, data entry errors and sample distribution issues were dealt with.

Data screening allowed removing any inconsistent value leading to potential distributional problems in both univariate and multivariate ANOVA models applied on the Survey.

The use of ANOVA or MANOVA was chosen as one of the most common univariate and multivariate parametric tests (in behavioural research) to test sample differences in the measured dependent variables (e.g., usability index) over the levels of the independent variables chosen (e.g., expertise levels), effect sizes as well as variable associations. For instance, participants’ age and level of expertise were certainly controlled in order to detect any unwanted co-variation in the usability responses over the level of the factor age or expertise of the respondents (selected as experts). Any significant result in this case would have detected a bias in the expert selection.

A decision was also taken to use factorial ANOVAs or MANOVAs to substantially increase statistical power of the analysis and reduce Type I error inflation (the augmented probability of rejecting a true null hypothesis leading to family wise error rate inflation; e.g., the risk of having an ANOVA revealing a significant result when such result is actually a false positive). Also it was chosen to apply Bonferroni tests when applying further tests to check simple main effects or interaction contrasts when omnibus ANOVA or MANOVA was significant (at least with p>.05).
3. Results

3.1 Response ratio

The data was collected over a 2 months period. Participants were asked to study or review (if necessary) the multimedia materials (video clips and documents) about the ITS system. The multimedia materials and the survey were sent by email. The participants were allowed to choose one or more ITS systems to assess. After reading the introductory letter of the Questionnaire the participants filled in the full Questionnaire- the completion of which acted as their assessment of the systems.

A total of 152 individual replies were collected. 100% of the surveys were completed successfully. In particular, the allocation of the four ITS surveys provided homogeneous sub grouping:

- System 1 (Intelligent pedestrian traffic signal) = 35 replies
- System 2 (Cyclist digital bicycle rear-view mirror) = 39 replies
- System 3 (PTW oncoming vehicle information assistance system) = 36 replies
- System 4 (Blind spot detection system) = 42 replies

Average Age Participants was M=48.4, with SD=13.9 (min=25; max=66). Gender composition is equally distributed with 46.7% female and 53.3% male participants.

Nationality sampling spread over 11 different countries. The UK, IT and NL had highest response rates of the total sample.

The job roles of participants ranged from advertising to university roles. Overall, civil servants researchers and managerial roles had the highest contribution to the overall job role composition. Engineers and employees were the second most relevant sub-grouping.

The averages job experience by specific job role highlighted a quite mature set of participants. At least seven job activities had representatives with more than 20 years’ experience in their specific roles. The highest levels of experience were recorded by the following job roles: civil servants, doctors, HF experts, management, self-employed, teachers and University professors.

3.2 ITS Usability results

Mean ITS knowledge (by System)

Average ITS knowledge was rated on a 4-points Likert scale from proficient (4) to minimal competence (1) (see Figure 1). The overall sample of respondents and groupings per ITS system revealed moderate/good knowledge of each ITS system.
The mean ITS knowledge for all four systems respectively was higher than the mid-point rating (2). All systems knowledge was between moderate (2) and good knowledge (3) of systems. Notably this variable reveals the level of expertise and experts available in the sample.

The average ITS knowledge across the four ITS systems remains higher than the midpoint rating (2) as shown in Table 4 below.

**Table 4. ITS knowledge across the four ITS systems**

<table>
<thead>
<tr>
<th>(across systems)</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITS_knowledge</td>
<td>152</td>
<td>1</td>
<td>4</td>
<td>2.57</td>
<td>0.974</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>152</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mean ITS use (by System)**

Average ITS use was rated on a 4-points Likert scale from never (1) to very frequently (daily) (4) (see Figure 2). The overall sample of respondents and groupings per ITS system approximated a weekly use of the ITS systems overall.
Mean ITS use for all four systems respectively was higher than the mid-point rating (2). All systems knowledge is between monthly (2) and weekly (3) use of the systems. Notably this variable reveals the level of ITS system expertise in the sample.

The average ITS use across the four ITS systems remains higher than the mid-point rating (2) as shown in Table 5 below.

Table 5. Average ITS use across the four ITS systems

<table>
<thead>
<tr>
<th>Descriptive Statistics</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITS_use</td>
<td>136</td>
<td>1</td>
<td>4</td>
<td>2.713</td>
<td>1.0030</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>136</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean use of vehicle (Car-Motorbike-bicycle) of Participants (per System)

The participant use of cars, motorbike and/or bicycles was rated on a 4 points Likert scale from 1 (no) to 4 (very frequent) across all four ITS systems. Figure 3 below revealed a clear constant pattern across all systems. Car was the most common means of transport (a very frequent average rating) followed by bicycle (average rating between sometime and frequent) and finally the use of a motorbike
Mean Usability Index (Scale 1) (by System)

The ITS Usability Index described in section 3.1 and composed of 9 different facets was assessed on a 5 point Likert scale from 1 (disagree strongly) to 5 (agree strongly). The scores of these nine facets were averaged together for each system to give a Mean Usability Scale rating. The higher the Mean Usability Scale rating the better the usability was assessed to be for the first scale in the survey. All four systems respectively received higher than the mid-point rating 3 as shown in Figure 4 below. In fact all ITS systems obtained usability ratings at least above 3 (neutral). These findings suggest a positive (moderate) usability level obtained on all the four ITS systems under investigation.
Further classification of the results into the 9 different facets of the Usability Index revealed a common pattern across the evaluation on the four ITS systems respectively (Figure 5, left hand side for system 1 and 2 and right hand side for system 3 and 4). In particular, (ITS) Explicitness, Functionality and User Control facets were rated the best usability elements of the various ITS systems (assessed on a 5 point Likert scale from 1 (disagree strongly) to 5 (agree strongly)).

The lowest rated usability features (across all ITS systems) were System Monitoring, Flexibility and Consistency. These findings suggest that it was possible to discriminate and identify areas of improvement for usability issues on all the four ITS systems under investigation.

In general it is clear that System Monitoring does not reveal a robust usability feature on any system. No system is designed to provide a supervisory control on human action. Systems do not seem to “know” what users are doing at all times: environmental complexity and human models are less embedded in their functions.
Figure 5. Sub-scales of Usability Index for the selected ITS Systems on a scale from 1 (disagree strongly) to 5 (agree strongly).

Also Flexibility and Consistency seem to require more focus across all the ITS systems. Again environmental and situational complexity in road scenario as well as human behaviour variance is less embedded in their functional specifications.

Notably, informative feedback appears to work better for system 3 and 4 with respect to system 1 and 2.

**Sub-scales of Usability Index (Scale 2, 3, 4 and 5) for System 1, 2, 3 and 4**

The Usability results for Scales 2 (ITS Risk avoidance), 3 (Trust in ITS system), 4 (Safety improvement) and 5 (Risk Communication) revealed specific common usability pattern across the four ITS systems respectively (see Figure 6, left hand side for system 2 and 3 and right hand side for system 4 and 5). In particular, the Perception of risk avoidance (given by the ITS system) and Communication of Risk (situations) were rated the best usability properties of the various ITS systems (all above the mid-point rating of 3 – based on 5 point Likert scale from 1 (disagree strongly) to 5 (agree strongly)). Providing feed-forward information about incoming hazardous situations and getting a feeling of risk avoidance are the best properties among all ITS systems.
Notably, the Trust, in the ITS system, and the perception of Safety Improvement revealed to be ITS properties requiring more attention. Such findings were all rated slightly negatively across all ITS systems (close to disagree slightly (2) evaluations on the 5 point Likert scale).

In general it appears that trust on the various systems, that is, relying on such systems, has to be improved. Also safety is not perceived as directly improvable by using the ITS systems only. Perhaps more integration between ITS systems and the road-VRUs system coupling is required to be studied not only from a technological perspective but also from more of a cultural and sociotechnical point of view.

**Mean Usability Index (Scale 1): All Systems by Age (binned in 3 levels)**

Factorial ANOVA for System by Age on the Usability Scale 1 was performed. The objective was to detect any significant differences on judging usability (nine usability facets of Scale 1 - see section 3.1) across the four ITS systems according to age levels as shown in Figure 7 below.

The main effects of Age and System were significant (F(2, 126)=4.273, p<.02; F(3, 126)=5.131, p<.01) as well as the Age by System interaction (F(6, 126)=2.616, p<.05). Notably, Age, separated binned into 3 levels, revealed that significant differences were between the youngest (below 38 years, M=3.93) versus the oldest in the sample (over 62, M=3.03). Usability was rated to be slightly better by the youngest (Bonferroni, p<.05). Nevertheless, the differences rest on the mid-point rating of the usability scores. Similar results were obtained across the four systems where the last ITS system (System 4 in Figure 7) was rated in usability better (M=3.5) than first two ITS systems (M=3.06 and M=3.07 respectively), Bonferroni, p<.05. However the differences rest on the mid-point rating of the usability scores.
Inspection of the rating profiles (as shown in Figure 8) has shown the same pattern of ratings across age levels and systems: Risk Avoidance and Risk Communication of the ITS systems are positively rated but Trust and Safety Improvement are not (generally below the mid-point rating of 3).

In particular, a factorial ANOVA for System by Age on the specific Trust sub-scale was performed. The objective was to detect any significant differences on rating Trust across the four ITS systems according to age levels.

Omnibus factorial ANOVA main and interaction effects revealed no significant difference by age levels across ITS systems over the Trust sub-scale (ANOVAs, p>.05). Age and Trust in systems did not reveal specific significant patterns. The only significant trend is that Trust is low in the ITS systems (as shown by the rating in Figure 8 below).
Deliverable D4.1
Usability assessment of selected applications

Figure 8. Mean Usability Index (Scale 2, 3, 4 and 5): All Systems by Age on a rating scale from 1 to 5

Mean Usability Index (Scale 1): All Systems by Expertise (binned in 3 levels)

Expert level (a linear combination of ITS knowledge and use ratings on a 4-point scale – see background information) was tested for significant differences in rating the Usability Index of Scale 1 for each specific ITS system assessed. The patterns of results are described in Figure 9 below.

A Factorial ANOVA main and interaction effects revealed no significant difference by ITS Expert levels (across all ITS systems) over the Usability Index of Scale 1 (Expert main effect of ANOVA p>.05). The higher experts in the sample did not show differences in ratings ITS usability across the systems. The only emerging trend is that the pattern, according to Figure 9, revealed a clear tendency for ITS systems 3 and 4 to have slightly higher ratings and such finding confirmed some previous findings in this document: ITS system 3 and 4 were rated slightly better in usability (at least in Scale 1 of the survey) than ITS system 1 and 2.
Mean Usability Index (Scale 2, 3, 4 and 5): All Systems by Expertise (binned/classified by 3 levels)

The rating profiles for Usability Scale 2, 3, 4 and 5 (as shown in Figure 10) provided similar patterns of ratings across Expert levels and systems: Risk Avoidance and Risk Communication are slightly more positively rated. Trust and Safety Improvement remains generally below the mid-point rating of 3. At visual inspection no specific difference seems to emerge across levels of expertise.

Applying a factorial MANOVA with Expert and System effects over the Scale 2, 3, 4 and 5 the Wilks’ Lambda F values were all significant (all at least p<.02) for all main effects (the interaction was not significant). Notably the following individual univariate ANOVAs were significant for the scales Risk Avoidance and Risk Communication respectively in the System and Expert main effects (F(3, 116)=4.386, p<.001 and F(2, 116)= 4.155, p<.02 for Risk Avoidance ; F(3, 116)=3.324, p<.03 and F(2, 116)=4.181, p<.02 for Risk Communication). Trust and Safety improvement did not reveal appreciable differences.

Nevertheless the Experts in the sample did not differentiated across any of the four Usability scales significantly except for a minimal difference in ratings on the Risk Avoidance scale with the group of moderate experts (multiple comparison Bonferroni p. <.05).

These final findings seem to suggest that the overall sample of VRUIITS respondent is more than representative and make valid ratings and assessments in terms of usability elements for ITS systems.
Figure 10. Rating profiles for Usability Scale 2, 3, 4 and 5 on a rating scale from 1 to 5
4. DISCUSSION

In this deliverable we described the selection of four different ITS systems aiming at improving safety for pedestrians, cyclist, motor cycles and drivers of PTWs. The usability was assessed by experts through questionnaires, and extensive information was provided to them regarding the functions and the user interface. This method was selected since the majority of the functions is only limitedly available (on a selected set of vehicles or in a limited geographical area), making it difficult to demonstrate the functions in real life to a large set of experts. The questionnaire and supporting material were filled out by 152 participants from different EU countries.

The selection of the four ITS systems was conducted based on the availability of materials to establish a multimedia material kit that could be used for the usability review by the participants. The selection also aimed to select one system per user type: pedestrians, cyclist, motor cycles and drivers of PTWs.

The participants were allowed to evaluate one or more systems. This might have caused a bias in the response because participants that were highly motivated or more prone to like technology were likely to have evaluated more ITS systems. Moreover the participants themselves could choose the system(s) that they wanted to evaluate. This might have led to a selection bias, i.e., participants might relate more to systems they have previously experienced themselves or to systems that relates to a modality of transport that they frequently use (e.g., cyclist will be more prone to evaluate the bike review mirror). On the other hand it might be an advantage that every participant could select the system that they most strongly related to.

Participants received documentation on paper and web links to videos for each of the four systems. The participants did not report issues in judging the usability of the systems based on the information provided. Pictures and videos proved especially useful for comprehending the systems’ functioning and interfaces. Although this paper review of the system was possible and also most feasible given the large number of participants and countries that are included in the response, not having physical interaction with the system during driving/cycling might be disadvantageous for the validity of the results.

Looking at the distribution of participants across the countries it is clear participants were not distributed equally across Europe. Most of the participants were from Italy (35%) then the UK (17%) and the Netherlands (12%). It is unclear if the validity of the results were affected by this. Also from looking at the modalities of transport the participants reported using there appears to be a lower prevalence of motorbike usage compared to other transport modalities. People driving motorbikes might have a different perspective on systems designed to warn the car drivers of their presence.
5. **CONCLUSIONS**

The overall findings of the investigation revealed that it was possible to discriminate and identify areas of improvement for usability issues on all the four ITS systems under investigation.

5.1 **Positive Usability features for the ITS systems**

In general, the results revealed common usability patterns across the four ITS systems. In particular, the *Perception of risk avoidance* (given by the ITS system) and *Communication of Risk* (risk warning by the ITS) were rated the best usability properties of the various ITS systems. Providing feed-forward information about incoming hazardous situations and subsequent appropriate perception of risk avoidance are the best properties among all the four ITS systems. Also, the highest rated usability features across all ITS systems were the clarity of the system functions (*Explicitness*), the way the systems work and operate (*Functionality*) and the degree of control by the user (*User Control*).

5.2 **ITS Usability features in need of improvement**

Some major areas of improvement were revealed also. Firstly, the lowest rated usability features across all four ITS systems were *System Monitoring*, *Flexibility* and *Consistency*. This latter finding suggests the evidence that all four ITS systems might need more focus on adaptability to road context, consistency of functions in difficult weather conditions and finally a more active monitoring of human behaviour in response to the ITS (where this is applicable). Secondly, Trust in the ITS system, and the perception of Safety Improvement revealed to be weak ITS properties overall. Some work on trust in safety and ITS automation and safety improvement perception (in using such systems) could be brought forward as the aim of the ITS system for VRUs is exactly to increase Safety. In fact, a user attitude of trust in the systems and belief that such systems could improve their safety is a substantial desirable scenario to strive for.

5.3 **No age or expertise bias**

- Specific analyses were carried out to study any spurious (undesirable) effect of age and expertise (and relative interactions) on the usability ratings by the sample of participants (considered experts on the ITS systems). In general the effects for age and level of expertise revealed no substantial influence on the ratings for all four ITS systems. These findings suggested that the overall sample of participants were representative and not a biased sample of experts. This also suggested to certain respects (at this exploratory level at the very least) that that the questionnaire was quite suitable for assessing usability of ITS systems.

- Notably, younger people (<38 years) tended to rate the general usability of the four systems slightly more positively than the older people (>62). Nevertheless the rating is on the same direction for both sub-samples of respondents. Finally experts in the sample did not differ from the overall group for the general usability and the for usability scales except for minor differences.
REFERENCES

CARE (2009), EU roads accident database.
Appendix A. Material provided to the interviewees for each system

**Intelligent pedestrian traffic signal**

IPT is a traffic signal control system that uses sensors such as an infra-red camera or microwave detectors to determine the presence of pedestrians and adjusts the traffic signals accordingly. State-of-the-art traffic light management systems use advanced sensors to monitor crossing behaviour of pedestrians.

**Waiting detectors:**
- Pedestrian pushes PPB
- Detectors confirm the presence of pedestrians standing near the crossing
- If pedestrian leaves before the onset of the Walk interval, the call for the ped phase is cancelled.

**Crosswalk detectors** (detect peds in crosswalk and…)
- A pre-set extension is added to the ped clearance
- Late-starting or slow-moving pedestrians have more time to clear the intersection
- Driver waiting time is reduced if the pedestrian crosses in a gap in traffic instead of waiting (J-walk ?)

**Examples**
Both microwave and infrared detectors work by calling the Walk signal when a person enters the detection zone on the curb. The size and shape of the detection zone varies depending on the type of detector used and how it is positioned. A delay can be built in so that persons are detected only if they stay within the detection zone for more than a minimum amount of time

Video: [http://www.youtube.com/watch?v=avKv0wnIUE](http://www.youtube.com/watch?v=avKv0wnIUE)

**Cyclist digital bicycle rear-view mirror**

Combination of camera and wireless technologies for cyclists allows the integration of monitors and Smartphones to increase peripheral vision and hindsight without having to turn back or look around. 

Web links:
- Several U-tube video can be seen. As examples [http://www.youtube.com/watch?v=FmSpCO-6Mvo](http://www.youtube.com/watch?v=FmSpCO-6Mvo)
- [http://www.youtube.com/watch?v=rv0wgSPb_v0](http://www.youtube.com/watch?v=rv0wgSPb_v0)
PTW - Oncoming Vehicle Information Assistance System

This system exchanges vehicle information between automobiles and motorcycles, such as position, direction and speed. Motorcycle riders can view information about vehicles near them on a display, and can receive information through an in-helmet audio system. Drivers can view information on the status of motorcycles in their vicinity and receive warnings on their navigation system display.


Motorcycle and Automobile Communication Technology

Oncoming Vehicle Information Assistance System

This system exchanges vehicle information between automobiles and motorcycles, such as position, direction, and speed. Motorcycle riders can view information about vehicles near them on a display, and can receive information through an in-helmet audio system. Drivers can view information on the status of motorcycles in their vicinity and receive warnings on their navigation system display.

Intersection Stop & Go Assistance System

- **Motorcycles** -
  This system analyzes images from the camera mounted on the front of the motorcycle to detect stop signs and either line markings or road markings. If the rider does not slow down when approaching an intersection, a warning appears on the motorcycle’s display screen, and an audio warning sounds in the rider’s helmet, prompting the rider to decelerate.

  In addition, once the motorcycle has come to a stop, the Inter-Vehicle Communication System detects the position of any approaching vehicles, assisting the rider in determining whether it is safe to proceed through the intersection.

- **Automobiles** -
  Information on intersections that are without traffic signals is gathered from car navigation system data. Images from the vehicle’s cameras are analyzed to detect stop lines and stop signs. Based on the vehicle’s speed and distance to the stop line the system determines whether the vehicle is traveling at a speed that will enable it to stop by the time it reaches the stop line. If the vehicle is exceeding the appropriate speed, the system issues an audio warning while signaling the driver to slow down with a sensory warning via the application of gentle, intermittent braking.

  Once the automobile has come to a stop, the Inter-Vehicle Communication System detects the position of any approaching vehicles and assists the driver in determining whether it is safe to proceed through the intersection.

![Intersection Stop & Go Assistance System](image-url)
In-Vehicle vision and monitoring - Blind Spot Detection system

The new functions on board of several vehicles can help to prevent collisions with pedestrians and vehicles in front in city traffic, defuse dangerous situations.
The aim is to develop active (video-based) driver assistance systems which detect dangerous situations involving early awareness of vulnerable road users (pedestrians, cyclist), allowing the possibility to warn the driver or to automatically control the vehicle (e.g. braking).

Safety Shield Systems:
http://www.safetyshieldsystems.com/cycle-safety-shield/
Video:
http://vimeo.com/76958675
Appendix B. VRUITS Usability Questionnaire

The VRUITS Usability Survey

Dear Participant,

The usability and satisfaction of any ITS technology is paramount to deliver an effective and safe service to any VRU. The following Survey is intended for system assessments and understanding of various usability issues of the ITS technologies targeted within the VRUITS Project.

We kindly request your collaboration in reading and compiling this survey in all its sections. This first section is about background information, the second section addresses common usability dimensions and the third one refers to risk perception and confidence in systems. The Survey is fully anonymous, and all data is confidential and will not be disclosed according to the Project guidelines.

Generally, the first response that comes to your mind is the best choice.

Thanks in advance to participate to Survey!
Back Ground Information

Age: __________
Gender: M ( ) F( )
Do you suffer from any kind of reduced mobility? Yes ( ) No ( )
If yes, please specify which ones: ________________________________
Job role/function: ________________________________
Job experience: years ( )
Knowledge on ITS: Proficient ( ) Good knowledge( ) Moderate( ) Minimal competence ( )
Frequency of use of ITS: 1= never; 2= sometimes (monthly); 3= frequently (weekly); 4= very frequently (daily); 5= for tests only; Other: ________
Do you drive a car? 1=no 2=sometimes 3=frequently 4=very frequently
Do you ride a motorbike? 1=no 2=sometimes 3=frequently 4=very frequently
Do you cycle? 1=no 2=sometimes 3=frequently 4=very frequently
### ITS Usability

Please, answer the questions below by selecting for each item the letter that best reflects your opinion.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disagree Strongly</td>
<td>Disagree Slightly</td>
<td>Neutral</td>
<td>Agree Slightly</td>
<td>Agree Strongly</td>
</tr>
<tr>
<td>1.</td>
<td>The status of the system is always clear</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>2.</td>
<td>Audio/Visual messages are clear and useful to guide towards the right action</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>3.</td>
<td>The system does not contain any unnecessary or misleading information</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>4.</td>
<td>There is enough guidance (e.g., information support) to reduce the effort for the users</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>5.</td>
<td>The way the system works is consistent at all times</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>6.</td>
<td>Adverse weather conditions (e.g., rain, frost, fog, direct sunlight ...) can affect the way the system works or it is used</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>7.</td>
<td>The situations (actions, messages, feedbacks) presented by the system are clear and self-explanatory</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>8.</td>
<td>The system use notations and conventions that are 100% clear independently of cultural or social differences of possible users</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>9.</td>
<td>The potential of user errors (slips or mistakes) in using the system is very small</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>10.</td>
<td>The system is designed to be very adaptable to any user actions or inactions</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>11.</td>
<td>User actions that result in “deviations” from what is prompted by the system are taken into account. The system can prompt further corrections</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>12.</td>
<td>The users of the system are always in control of any actions in the process</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>
13. The system seems to “know” perfectly what users are doing at all times

14. The system messages are effective to guide towards a fast recovery from critical situations

15. There is always a clear feedback to indicate what has been achieved

Have you experienced any relevant usability problem while operating the system? (yes)  (no)
If YES, please expand below:

________________________________________________________________________________________________________________________

________________________________________________________________________________________________________________________

________________________________________________________________________________________________________________________
# ITS Risk Avoidance, Communication, Trust and Safety perception

Please, answer the questions below by selecting for each item the letter that best reflects your opinion.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disagree Strongly</strong></td>
<td><strong>Disagree Slightly</strong></td>
<td><strong>Neutral</strong></td>
<td><strong>Agree Slightly</strong></td>
<td><strong>Agree Strongly</strong></td>
<td></td>
</tr>
</tbody>
</table>

1. The system increases my awareness on the proper actions to do
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

2. I trust the system signals and prompts even when I am not sure how it works
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

3. The risks of having a road incident is reduced by simply using the system
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

4. I am prompted on risks primarily by:
   - a. Visual warnings ( )
   - b. Audio warnings ( )
   - c. Verbal/written warnings ( )
   - d. Other (please specify__________________)

5. I easily know if the system is activated and operative
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

6. I easily know if the system is working properly
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

7. I am safer if I could receive prompts and warnings earlier
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

8. The system increases my awareness on the actions to avoid
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

9. I believe this system keeps me 100% safe all the time
   - A: Disagree Strongly
   - B: Disagree Slightly
   - C: Neutral
   - D: Agree Slightly
   - E: Agree Strongly

10. I am safer if the system could be more intuitive and simpler to use
    - A: Disagree Strongly
    - B: Disagree Slightly
    - C: Neutral
    - D: Agree Slightly
    - E: Agree Strongly
### Deliverable D4.1
Usability assessment of selected applications

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<tbody>
<tr>
<td><strong>11.</strong> I believe this system could be dangerous if it is not working properly</td>
<td>A</td>
<td>B</td>
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<td><strong>12.</strong> I think a person exposed for the first time to this system would...</td>
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<tr>
<td>a. ...rely on it with no hesitation (  )</td>
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<td>b. ...rely on it partially and controlling other external signals (e.g., other road user behaviours) (  )</td>
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<td>c. ...not rely directly on the system. The new user would need to test it different times before trusting it completely (  )</td>
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<td><strong>13.</strong> The system increases my awareness on the possible risks I am exposed to</td>
<td>A</td>
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<td><strong>14.</strong> The risk of having a road incident is not reduced by simply using the system</td>
<td>A</td>
<td>B</td>
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<td><strong>15.</strong> I am safer if the system could send me more info on what is happening around me</td>
<td>A</td>
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<td><strong>16.</strong> I believe this system keeps me 100% safe only when it is working properly</td>
<td>A</td>
<td>B</td>
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<td><strong>17.</strong> I easily know if the system is not functioning</td>
<td>A</td>
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