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Guidelines of future directions for safety potential of ADAS and potential cross-continent synergies

Deliverable 4 of Task Force B

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Modifications: Addition of a phrase (in the Methods/ Background section) explaining that the final results of the Delphi study will be presented in the final TFB deliverable, following the reviewer's comments.								

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1 EXECUTIVE SUMMARY

This report involves the synthesis of information and knowledge from the previous TFB deliverables and milestones, namely deliverable B.2 and milestone 3, along with some preliminary results from the Delphi study that is being conducted within the framework of this task force. Furthermore, the report is also based on data from studies related to intelligent transport systems (ITS) presented at recent international conferences and journal publications. Certain aspects of the research in the field of ITS indicate that there is adequate knowledge, whereas there are other aspects in which not much research has been conducted. In a similar way, for specific systems, such as ISA, a great number of studies have taken place whereas for other systems more research needs to be done.

The systems presented in this report are those that were presented in the B.2 deliverable. In addition, systems on which various studies take place in the US and Japan, but not yet in Europe, are also mentioned. More detailed analysis however is provided for the five systems that were studied through the Delphi Study.

This report aims at providing future directions for research in the field of the safety potential of advanced traveller assistance systems, and intelligent transport systems in general. Those future directions are identified through two different points of view. The first is to seek for lack of knowledge and evidence on elements of the impact of – already widely studied – systems on road safety. The second element of the report is to provide future directions for research on more “recent” systems, mainly to identify new systems that could improve road safety and that are already in the research agenda in institutes outside Europe.

Generally, intelligent transport systems are being developed continuously, and their impact on road safety is an important parameter of their evaluation and hence further application. Task Force B aims at providing a rounded and constructed description of the available systems, their anticipated impact on road safety and the needs for further research.

2 INTRODUCTION

Intelligent transport systems (ITS) is a quite recent field in science and as such it demonstrates rapid development (Peirce, Lappin, 2003). Nonetheless, their implementation forms now part of our everyday life. Their contribution on dealing with the consequences of the growth of traffic is anticipated to be important. Generally, an important parameter in the evaluation of ITS is the impact of their use on the users and as a consequence on the elements of the road transportation system.

Generally the invention of the car and other means of transport have enhanced our everyday life, but their development and resulting growth in mobility has been followed by negative consequences. In particular, this growth in mobility has affected road safety, traffic and environmental conditions and has resulted in an increase in accident rates, congestion and environmental pollution. Conventional measures seem to be ineffective for solving these problems. However, intelligent transport systems could be a promising direction towards providing an efficient solution for the reduction of those side-effects of mobility growth, thus setting new standards.

A constraint of the implementation of those systems is the uncertainty of their impact along with the cost of their implementation. The latter is definable and is quite high, whereas the benefits of the use of intelligent transport systems are still abstract. Hence, the procedure of systems evaluation and application seems to be a rather slow one and the question still remains: “Are intelligent transport systems a promising means to the future?”. Furthermore, although there is some evidence of the impact of such systems on road safety, specific elements of this impact have still to be defined. This reports aims at identifying elements of the research on impact of intelligent transport systems on which more studies are required. Furthermore, effort is being made into identifying differences between research that is carried out in and outside Europe in order to indicate “new” systems with a potential in improving road safety.

3 METHODS / BACKGROUND

Three different types of input were provided for the production of the present report. The first involves a short summary based on information provided from previous Task Force B reports, and namely deliverable B.2 “An Inventory of available ADAS and similar technologies according to their safety potentials” and milestone of month 16 “Completion of SWOT analysis for ADAS impact assessments”. The second is preliminary results from the first round of the Delphi study on the impact of the use of intelligent transport systems. It must be noted that the final results of the Delphi study will be presented in the final deliverable of Task Force B, which will present all final results of the conducted research in the TF (also the 2nd round of the study is still underway). The third involves identification of different research directions both in terms of specific systems but also methodologies in institutes outside Europe.

4 OBJECTIVES

The general objective of the Task Force B (*Evaluation of ITS Potential Benefits*) is to provide a critical and thorough review of the experience and literature of the safety potential of ADAS from a macroscopic perspective, assisting thus better definition of the research directions for the other Task Forces of Humanist project - especially Task Forces D and E.

More detailed, objectives and description of the work of the two first task of the Task Force B were listed in Technical Annex as follows:

WP B.1. *Identification and Inventory of ADAS Technologies*
- Production of a structured inventory of available ADAS and similar technologies.
- Classification of available technologies according to their functionalities (e.g. support, control, enforcement), the relevant maturity of technology as well as their safety potential and traffic efficiency.
- Undertake of an extensive literature search and doing interviews with selected researchers
- Use of meta-analyses of results from already available related projects
- Doing assessment of the safety potential of specific ADAS technologies.

WP B.2. *System Evaluation and Safety Impact Assessment from Previous and On-Going Research*
- Gathering of system evaluation and safety impact assessment reports from relevant projects from the 3rd, 4th and 5th Framework Programs
- Critical review and thoroughly analysis of these reports
- Run of a common SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, in order to derive comparable conclusions on the relevant technologies and their clear impacts on safety.
- Identification of the requirements from the Safety point of view

WP B.3. *Review of Application Potential and International Synergies*

This Tasks aims at investigating and uncovering the application potential and safety effects of ADA Systems and technologies, especially as these are reported by international cross-continent experience. Experts from the EU, but also from the US and Japan will be called to participate in a Delphi-type of evaluation process, using formal and structured questionnaires developed specifically for such an evaluation. These questionnaires will be analyzed using the appropriate statistical procedures, and the results will be presented and openly evaluated and discussed during a 2-day workshop. This Task will also concentrate on uncovering possible international synergies and cooperation, to both avoid duplicating work and expanding the knowledge base on ADAS.

WP B.4. Synthesis of Technologies and Safety Potential

The goal of this Task is to organize and synthesize the findings and results from the previous work performed in this Task Force. In this Task, the information collected from the literature and previous projects will be used to develop a list of information items and technologies that are, or could be, made available to the driver. This list will then be compiled into a set of logical information groupings and a multi-attribute analysis will be conducted for each technological item to assess its safety potential. This information will then be filtered through the set of existing standards and, in order to identify a subset of technologies that are most suitable from a safety perspective for development, practical trade assessment will be inferred.

The present deliverable will also provide input for the final deliverable of Task Force B, B.5, which involves the design of a comprehensive cross-referencing lookup Table of available technologies and their safety impacts and potential, and is due on month 30 (end date of Task Force B).

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5 SYNTESIS OF PREVIOUS REPORTS

- **DELIVERABLE B.2**

In this section a short description of the findings of previous reports is presented. In particular, those two reports are Deliverable B.2 and milestone of month 16. In the first an inventory of available ADAS and similar technologies according to their safety potentials was designed and for the second the majority of systems presented in deliverable B.2 were analysed using a common methodology, SWOT analysis.

The objective of deliverable B.2 was to provide a critical and thorough review of the experience and literature on the safety potential of ADAS from a macroscopic perspective. A great number of studies – mainly having taken place in Europe – on the impact of intelligent transport systems (not just ADAS) on road safety was collected and the main findings were presented in the report.

The systems described in deliverable B.2 were classified into the following categories:

- intelligent speed adaptation (ISA)
- collision avoidance systems (CAS)
- lateral control systems
- blind spot detection and merging
- side collision avoidance systems
- driver vigilance monitoring
- adaptive cruise control (ACC)
- route guidance and navigation
- vision enhancement
- dynamic control systems (eg esp)
- anti-lock braking system (ABS)
- seatbelt warning
- event data recorder
- emergency notification/emergency call (e-call)
- real-time traffic information
- dynamic traffic management
- traffic monitoring and management
- in-vehicle devices – distraction

For some systems, such as ISA and ACC a great number of studies were identified. On the other hand there were systems such as vision enhancement systems, for which not much research seems to have been conducted. For the latter, further research needs to take place. For each of the system categories, conclusions on the potential impact of the systems, the evidence of this impact as well as the constraints for its application and the lack of knowledge in specific elements of the system impact were identified.

Apart from that further more generalised conclusions were drawn. Most of the studied systems are such that are installed inside the vehicle as an original accessory. Hence, such systems can only be installed to new vehicles and not to the already existing vehicle population. Furthermore, this will result in vehicles equipped with the specific being more expensive. An exception are some variants of the intelligent speed adaptation system, which are available as retrofitting accessory.

Advertisements on new ITS products promise quite a lot and so do the evaluation studies undertaken by car/system manufacturers. However, studies conducted by independent research units clearly demonstrate less evidence on the effects of the use of such systems on the user and society.

For each of the investigated systems, several issues comprise potential future directions in research. Nonetheless, there were specific issues that should be investigated for all systems, and for which not sufficient evidence is available. One element of the research on the impact of the use of ITS on road safety that has not been identified in sufficient detail yet, is the estimation of this impact in relation to the interaction of vehicles being and not being equipped with the investigated system. In addition, there are only a few studies on the interaction of a variety of different systems on driver's workload, the driving task and driving behaviour. Another element of the impact of ITS on road safety that has not been identified efficiently is the phenomenon of overcompensation for adjusting the new driver behaviour and characteristics as affected by the system use on the pre-existing driving style and general character of the driver.

A detailed and structured summary of the potential impact of each of the systems, and the required directions for future research will be the final product of Task Force B, deliverable B.5.

- **MILESTONE M16**

Milestone of Task Force B (month 16) involved the investigation of some of the systems presented in deliverable B.2 using a common methodology. The methodology used was SWOT analysis which stands for Strengths, Weaknesses, Opportunities and Threats. The first two aspects involve the internal features of the system, mainly technological ones. The other two aspects involve external parameters, mainly resulting from the usage of the systems. The analysis was focused on the two external parameters, and the main questions that were asked were:

- What are the opportunities of each system to improve traffic safety (in ideal situation)? **(O)**
- Are there any other positive outcomes of the use of the system (traffic flow, environmental factors? **(O)**
- What are the main concerns of the misuse/misunderstanding of the system in the "individual level"? **(T)**
- What are the main concerns of the misuse/misunderstanding in the "system level" (users, other drivers, pedestrians etc)? **(T)**

Not all systems presented in deliverable B.2 were analysed. The systems examined in this milestone are the following:

- intelligent speed adaptation (ISA)
- Speed Alert System

- collision avoidance systems (CAS)
- lateral control systems
- driver vigilance monitoring
- adaptive cruise control (ACC)
- route guidance and navigation
- vision enhancement
- dynamic control systems
- event data recorder
- emergency call

The potential of the investigated systems along with the concerns of their use were noted. Specific elements for each of the systems should be investigated further, mainly in comprising the threat categories, as there seemed to be indication of the threats rather than evidence in most cases.

The results of SWOT analysis manifested the need for two types of future directions for the safety potential of ADAS. First involves the improvement of safety, which is calculated as the change of parameters (such as speed) that are influencing road safety. There is no, however, quantification of the actual improvement on road safety from direct road safety parameters. Hence, future research should aim at quantifying this effect by linking the change of driving behaviour or error compensation when using intelligent transport systems to risk, accident or severity reduction parameters.

Another future direction of research that is identified is the investigation of the negative effects of the system use, mainly in relation to risk compensation, behavioural adaptation or appropriation, and interaction with other users and non-users. Finally, the different types of use of the system by different driver categories (novice drivers, drivers who are prone to violate the highway code etc) have to be investigated further along with ways of persuading those “problematic” driver categories to accept the system and use it in a correct manner.

6 DELPHI STUDY

- **GENERAL ELEMENTS OF THE DELPHI STUDY**

In this section, the directions of future research will be presented for five specific intelligent transport systems, namely – the anti-lock braking, intelligent speed adaptation, lateral control, enhanced navigation and the intersection warning system. The conclusions are drawn based on data collected through a Delphi study on issues related to the impact of these systems on road safety. In particular within the framework of the Task Force B of HUMANIST a Delphi study is being conducted. The general aim of the study is a better understanding of the relevant parameters of the impact of specific intelligent transport systems mainly on road safety.

The Delphi study is a method from which the opinions of experts are recorded through a structured and specific way. It has proven to be a popular tool for identifying and prioritising issues (Okoli, Pawlowski, 2004) and has been used as such in varied research fields including the field of transportation (Mulder *et al*, 1996) and intelligent transport systems (Marchau, van der Heijden, 1998). The main objective of a Delphi study is to reach consensus amongst participants on the investigated issues (Sackman, 1975). Reaching consensus is not always the objective, and other methods of performing a Delphi study by developing a set of alternative future scenarios have also been introduced (Kendal *et al*, 1992, Tapio, 2002).

The implementation of the Delphi study within HUMANIST involved the use of a questionnaire. The main steps of the study are the following with the presented order:

1. the aims of the study are defined
2. a questionnaire is designed
3. an appropriate sample characteristics is being identified, and the questionnaire is sent to the appropriate experts
4. experts fill-in the questionnaire and send it back (1st Round)
5. data are analysed and "average" answers are calculated
6. questionnaire is redesigned based on the results and respondents comments
7. questionnaire is sent to the respondents of the first round along with their previous answers and the "average" answers
8. experts fill-in the questionnaire and send it back (2nd Round)
9. steps 5-8 are repeated until consensus is reached or if this is not possible, experts whose answers divert from the "average" ones are asked to justify their view

The main elements of such a study are the questionnaire itself and the group of experts to whom it is sent. The questionnaire should be designed carefully in a clear, comprehensive and structured way, with the questions order following a "logical" sequence in order not to create confusion to the respondents. Furthermore, the questionnaire should not be long because the drop-out rate between rounds is usually quite high. It is desirable that the questions are not open, but specific answers are provided to allow for easier grouping of answers and result extraction. In relation to the sample characteristics, experts should be chosen carefully taking into account their expertise on the investigated topics.

Furthermore, the sample size should be quite high at the beginning of the study as there is a high drop-out rate between rounds. It is also desirable to have a sample group with varied and distinct characteristics in order to avoid biased results.

- **QUESTIONNAIRE DESIGN**

(a) Choice of Investigated Systems

For the design of the Delphi study several specific issues had to be considered. The first issue involved the systems that would be chosen for investigation. The systems to be used in the study should be such that their implementation is anticipated to result into improving road safety. Furthermore, the conduction of a Delphi study is mainly aimed at providing answers to questions that the scientific evidence is not quite concrete or clear, either because of insufficient research or because of contradicting findings. Hence, the majority of chosen systems should be quite “new”. Three “new” systems were chosen for the Delphi study. Furthermore, it would be interesting to test the answers on such systems with more established ones. For this reason two such systems were also chosen demonstrating a different development level. The systems chosen for the Delphi study were the following: Anti-Lock Braking System (ABS), Intelligent Speed Adaptation (ISA), Enhanced Navigation, Lateral Control Warning and Intersection Warning. ABS was chosen as a system that is now part of standard vehicle equipment. ISA was chosen because it is anticipated to improve road safety, and a wide variety of different studies on their impact has taken place. The other three systems are less studied system, but they are similarly anticipated to improve road safety.

These five systems are quite different to each other in terms of their operation and this was an additional parameter for them being chosen for the study. More specifically, ABS is designed to stabilize the vehicle; to keep a car manoeuvrable when braking strongly. Even though this system comprises part of standard equipment nowadays, the number of studies on its impact is not great. Additionally, there are still disagreements on its effect mostly because of users' lack of knowledge on ABS operation and risk compensation.

Intelligent speed adaptation comprises several variants of systems supporting the driver in choosing the appropriate driving speed by either warning the driver if he/she exceeds the legal speed limit (Speed Alert System) or by automatically adjusting driving speed to the legal speed limit (actively intervening ISA). An important number of studies have been undertaken on the impact of intelligent speed adaptation, and this system is developed in a rather efficient stage compared to the other investigated systems (except of course for ABS).

Enhanced navigation systems are consisted by in-vehicle navigation systems combined with real-time information systems. Navigation function will provide location and route guidance input to the driver. It can also have capability to recommend optimal routing based on driver preferences. Enhanced navigation systems may integrate real-time traffic conditions to the calculation of optimal routes. Other included features could be the integration of other ADA systems, for example systems that could adjust the driving speed if the road conditions are changing. Navigation systems are used in several countries either in the form of vehicle equipment or in the form of nomadic devices. Enhanced navigation systems have not yet been developed greatly, and their impact on road system has yet to be investigated.

Lateral control systems assist the driver to keep the vehicle almost in the centre of the lane using on-board vision systems or dedicated lane markings such as magnetic nails or magnetic tapes. The warning could be audio, visual or haptic. The number of studies on the impact of such systems is low.

Last, intersection warning systems enhance driver awareness of the traffic situation at the intersection by providing timely and easily understood warnings of vehicles entering the intersection. Intersection warning systems have not been forwarded yet at the market and are at a quite early stage of development and testing.

(b) Questionnaire structure

The second important element of the questionnaire involves the questions themselves. As indicated the output of this study involves the impact of the use of intelligent transport systems on road safety. Hence, the questionnaire should mainly consist by questions on that topic. Nonetheless, it would be desirable to include issues of general interest on the systems.

Based on the above objectives the questionnaire is divided into four sections. The first section involves general questions on the examined systems such as the type of anticipated impact (road safety, network conditions etc) or the future anticipated penetration rates. These questions give an indication of whether the systems should, and hence are expected to be further developed and introduced into the market. The second section of the questionnaire involves more specific questions on the examined systems and is focused on issues related to road safety. Questions included in this part describe the expected impact of the systems in terms of its duration (short term or long term effects), the unwanted impact of the systems, the parameters that should be indicators of the impact of the system usage on road safety. The third section of the questionnaire involves general conclusive questions and comments such as user categories that are appropriate for each system or system cost. The final section records participants' characteristics.

- **PRESENTATION OF PRELIMINARY RESULTS**

The conduction of the first round of the study seemed to be rather successful as the sample size that could be used (in some questionnaires only a few questions were answered – hence these were excluded from the study) has now reached the number of 60 questionnaires.

During the first round of the study the main difficulty however was found to be attracting experts from outside Europe. There were only two experts answering the questionnaire that were based outside Europe. For this reason an extension was given to the completion of the first round of the Delphi study. During the HUMANIST session that took place in the ITS Congress in San Francisco, a small presentation of the study was made. This attracted additional participants and the sample was slightly increased to 8 experts outside Europe (namely – Canada, US, Australia and Japan).

The results presented in this report are preliminary ones (33 respondents) – due to the extension given, more questionnaires were received, and their analysis is taking now place. Hence, they concern only part of the first round of the Delphi study, which has just been completed. The sample size in this report is 33 respondents, and only participants who work in Europe. The two questionnaires of non-Europe based experts that were received during the first part of the first round of the study were excluded from this analysis to have a more unified sample and be able to demonstrate the opinions of European experts.

(a) Respondents profile

The respondents profile varied significantly in terms of profession, professional background etc. This variation is desirable since it reduces biased results. An important parameter of the respondents profile is their professional background. Different professional backgrounds indicate a different way of approaching research on the systems, where different aspects of them are important. The profile of the respondents in terms of their professional background is illustrated in Figure 1.

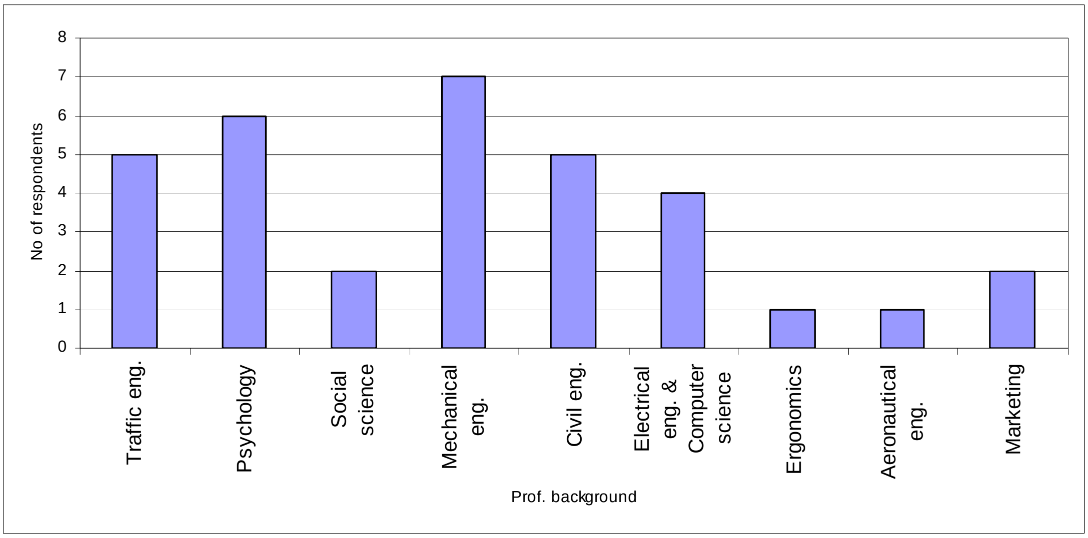

Figure 1. Professional background of the respondents

The professional background of respondents varies significantly. The majority of respondents have an engineering background, with 67% of the respondents comprising this category. Additionally, 6 respondents, 18% of the sample, have a background in psychology. The respondents' profiles also include social science, ergonomics and marketing. Another important characteristic of the respondents involves their expertise on the systems. This expertise is illustrated in two dimensions. The first dimension involves the respondents' knowledge on the systems, hence the way they have been familiarised with them in terms of research. The second dimension describes their experience on the systems, and hence the type of usage of the system. The expertise of the respondents, which is recorded for each of the investigated systems separately, is illustrated in Table 3.

Table 3. Respondents' experience on the investigated systems (no of respondents)

Experience/Systems	ISA	ABS	Intersection Warning	Enhanced Navigation	Lateral Warning
Specialist/Expert	2	3	4	5	4
Knowledge Resulting from minor research	8	8	6	15	8
Knowledge Resulting from reading technical literature	24	19	18	18	21
No knowledge	1	5	5	0	3
Personal experience (system user)	6	21	2	14	2
Laboratory experience (use it only in tests)	9	5	9	11	10
No experience	19	9	21	9	20

Once again the profile of respondents varies in terms of their knowledge and experience on the systems. The majority of respondents have gained their expertise on systems from technical literature rather than testing with the exception of the enhanced navigation system for which a significant number of respondents has performed minor research. In terms of the experience on systems, as expected, the majority of respondents are a user of the anti-lock braking systems as this comprises part of standard vehicle equipment nowadays. There is no experience recorded for the majority of the respondents on the intelligent speed adaptation, intersection warning and lateral warning systems since these are the least developed ones.

(b) Importance of systems

The idenitified importance of the investigated systems as recorded from experts' opinions could demonstrate whether further investment on the systems should take place. Hence, if their impact on road safety is not expected to be substantial, research should take place but for other systems with more potentials. The view of the respondents on the importance of the systems in terms of the anticipated impact is depicted from two questions the first involves the impact of system use on five issues which are road safety, traffic conditions, environmental conditions, driver comfort and user integration into the road system. The systems were rated for each of these issues from highly negative to highly positive. The total score of the systems is illustrated in Figure 2.

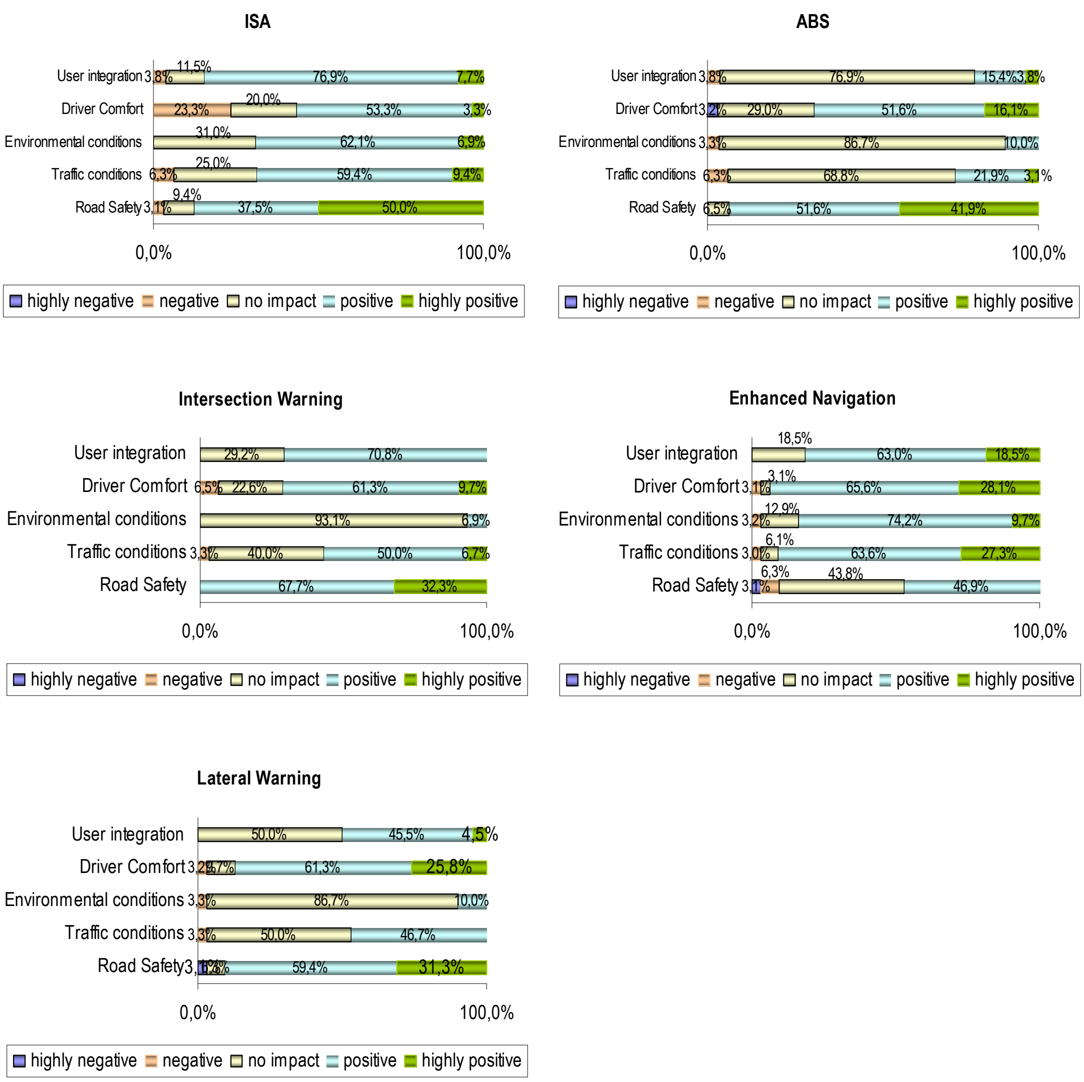

Figure 2. Expert rating on the impact of systems on specific parameters

An important conclusion is that all five systems are expected to improve road safety, with ABS and the intelligent speed adaptation system being the most promising in that direction. Additionally, all systems score differently in each of the impact categories. For example the most promising in terms of road safety is the intelligent speed adaptation system whereas in terms of improving traffic conditions the most promising one is the enhanced navigation system. Furthermore, most systems score also low (i.e. between negative impact and no impact) in some of the impact categories.

The intelligent speed adaptation system is the only one for which one parameter (driver comfort) is expected to be affected negatively by a significant number of experts. This indicates that further research should take place in that direction in order to identify a more efficient operation of the system in terms of driver comfort.

Another question which demonstrates the importance of the systems involved the rating of the systems in total. Participants were asked to put the five systems in an order of preference (with the most preferable system scoring 1 and the least 5), and the results of this question are illustrated in Figure 3.

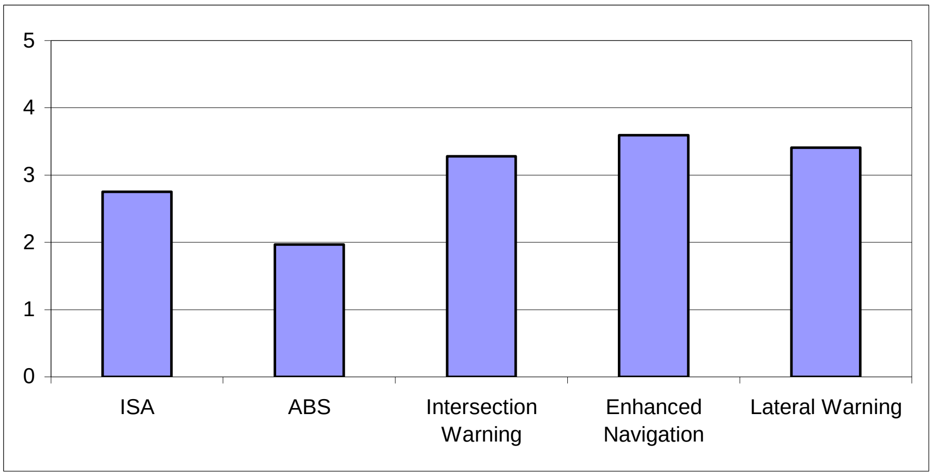

Figure 3. Placement of systems in an order of importance

The total rating of the systems indicates that the most preferable system between the respondents is the ABS and the least is the enhanced navigation one. This conclusion proves to be compatible with the picture that is described through the impact results as illustrated in Figure 2. It seems that for the total rating respondents perceive the impact on road safety as the most important factor. There is a range of parameters for the total ranking of the systems such as development level, system reliability and user acceptability issues. A study that took place indicated that drivers are not very willing to have ISA - at least without any trial. More specifically, in Sweden, the findings of a study indicated that the use of even mandatory ISA may alter driver opinion and could make drivers' attitudes more positive towards using them (Mankkinen *et al.*, 2001).

Another question that illustrated the preference of the respondents on the examined systems and also the level of their development involves whether those systems should be part of standard vehicle equipment. The results of this question are illustrated in Table 4.

Table 4. Systems that you consider to be part of standard vehicle equipment (no of respondents)

Development/Systems	ISA	ABS	Intersection Warning	Enhanced Navigation	Lateral Warning
In their current level of development	6	32	1	12	3
Following a few more impact studies	11	0	7	10	10
With some further development	9	1	24	9	18
Would not want the system in their car	7	0	1	2	2

The results indicate that there is a significant number of experts 20% (the participants who did not give a positive answer to this question) who do not think that intelligent speed adaptation should be part of standard vehicle equipment, whereas only a small percentage 3% (1 respondent) for intersection warning and 6% (2 respondents) for enhanced navigation and lateral control believe that those systems should not be part of standard vehicle equipment. This percentage for ISA (20%) which does not agree with the total ratings of the system could reflect speculation on the user acceptability rates. Results of a Finnish survey (Penttinen, 2003) indicated the preference of users on incident and real-time information systems. Although intelligent speed adaptation was one of the examined systems, it scored much lower on user preferences. According to the respondents' answers, although the anti-lock braking system is already part of the standard vehicle equipment (in most vehicles) 2 respondents indicate that more research needs to be done on those systems. The least developed and tested system according to the respondents views is the intersection warning one, with the lateral warning system following.

The investigated systems with the exception of the intelligent speed adaptation were identified by experts as systems that should be part of standard vehicle equipment. For the intersection warning, the enhanced navigation and the lateral warning systems more studies need to take place, hence they form potential systems for future research.

(c) Gaps in knowledge

The questionnaire provides conclusions on certain aspects around the impact of the systems, on the preferences of the experts but also on our knowledge on the investigated systems. A question that indicates the direction of future research involves the types of studies that should take place for the further testing of the systems. In order to extract such conclusions two questions were asked. The first described the appropriateness of the studies and the possible answers were "not relevant", "slightly relevant", "relevant" and "important", and the results are illustrated in Table 5.

Table 5. Appropriate types of studies for each system

	Real traffic	Test track	Simulator	Laboratory	Questionnaire
ISA	**Yes**	**Yes**	**-**	**No**	**-**
ABS	**Yes**	**Yes**	**-**	**No**	**No**
Intersection Warning	**Yes**	**Yes**	**Yes**	**No**	**No**
Enhanced Navigation	**Yes**	**-**	**No**	**No**	**Yes**
Lateral Control	**Yes**	**Yes**	**-**	**No**	**No**

Generally, real traffic studies are appropriate for the estimation of the impact of the use of the examined intelligent transport systems whereas laboratory studies are not as relevant. Simulator studies also scored quite high for the intersection warning systems. Finally, for the investigation of enhanced navigation systems questionnaire studies also scored quite high.

The second question involved the amount of evidence that is available for each type of study. The answers to this question are illustrated in Figure 4, only for the types of studies that were rated as relevant from the respondents.

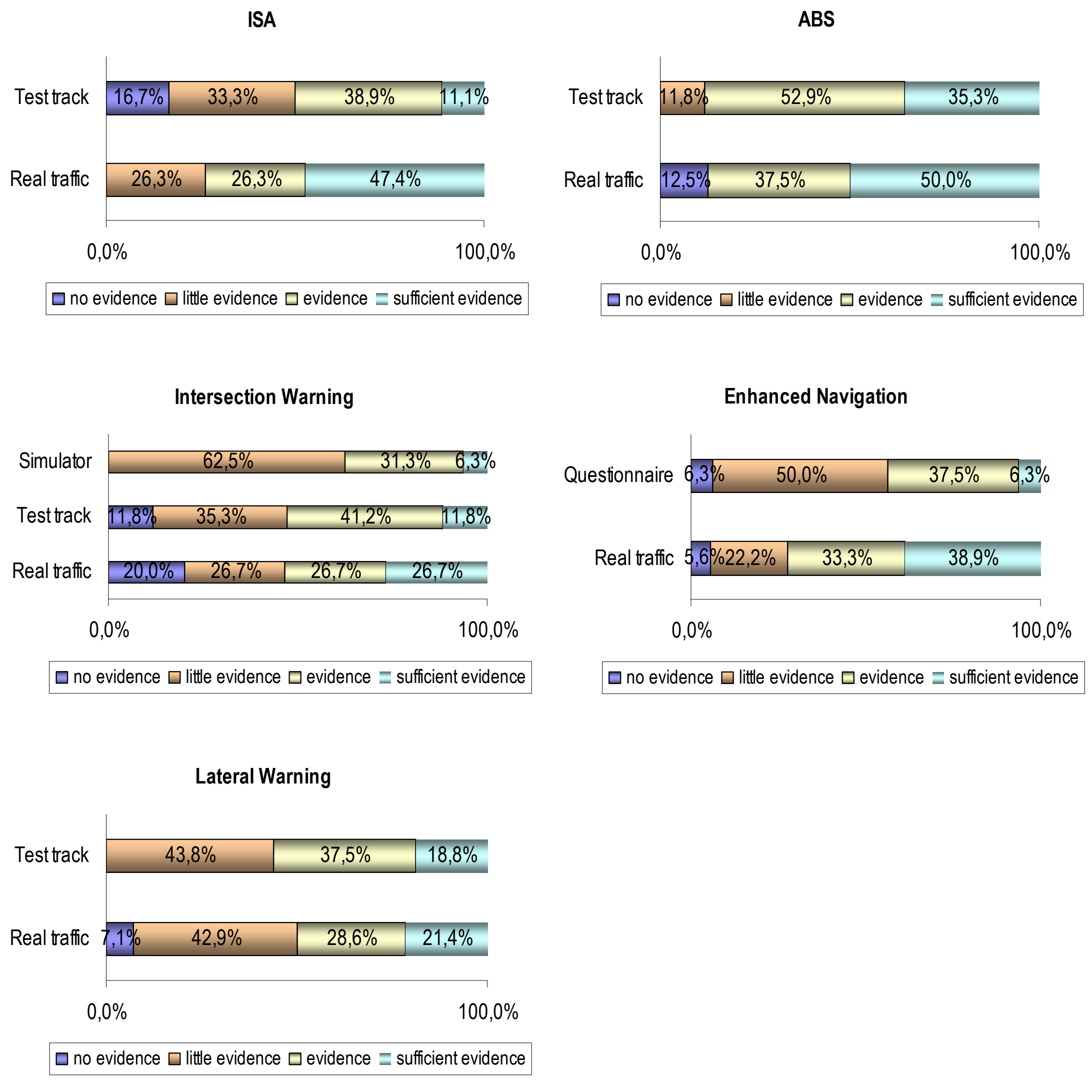

Figure 4. Evidence that is available on the impact of the examined systems

The results indicate that for the investigation of the impact on road safety the majority of respondents believe that there is sufficient amount of evidence for the use of ABS and also a good amount of evidence for ISA, mainly for real traffic studies. However, further research should take place for the other three systems, intersection warning, enhanced navigation and lateral warning.

Another way of identifying adequacy and gaps in knowledge and directions for future research is to calculate the number of the "no opinion" responses in each of the questions. A rough counting indicated that the relationship between the penetration rates and the anticipated impact is an issue that has not been covered. This is quite important, and manifests the need of the development of simulation programs that could be used as a tool to represent networks with vehicles that are equipped with such systems and to be able to simulate different penetration rates. A key element of such simulation tools is that the interaction between system users and non-users has to be represented, and hence (as it was not yet) it has first to be identified.

Additionally, a significant number of experts had no opinion on a question describing the unwanted/side effects of the systems. Hence, the unwanted effects of the system use should be investigated further.

There seems to be adequate knowledge on the type of studies that is appropriate for each system. An interesting result is that in contrast with the other systems there is not sufficient knowledge on the amount of evidence that is available from each type of examined study for the anti-lock braking system. Although it now forms part of standard vehicle equipment, experts are not familiar with the research that was done on it.

7 CROSS-CONTINENT RESEARCH

This section of the report is based on the findings that have been presented in research studies that were presented and published in recent international conferences and scientific journals. Furthermore, data on the research that is taking place outside Europe was also extracted from web-sites of specific institutes and organisations.

- **ASIA**

A great number of studies on the impact of intelligent transport systems is done in Asia. There is a wide variety of investigated topics including the impact of in-vehicle management speed devices and longitudinal control systems. Studies take place on the impact on road safety, traffic conditions (congestion etc) (Chang and Chen, 2005) and on the environment (air pollution, energy consumption) (Tsubota *et al*, 2004). Furthermore, a wide variety of systems is also investigated ranging from “simpler” in-vehicle or infrastructure systems such as Adaptive Cruise Control, Intelligent Speed Adaptation, drowsiness detection and other warning systems (Yamanaka and Mitani, 2005) to more complex ones such as cooperative systems based on vehicle-infrastructure communication or vehicle-vehicle communication. Examples include the research on the implementation of Automated Highway Systems (AHS) (Seto and Inoue, 1999), systems providing real-time information on traffic congestion with vehicle-vehicle communication.

Furthermore, a substantial part of research taking place in Asia involves the incorporation of the impact of the use of intelligent traffic systems on the driver/user/vehicle behaviour into simulation models.

- **AUSTRALIA**

In Australia there are 3-4 main fields of research dealing with the impact of intelligent transport systems. Advanced Traveller Assistance Systems are a popular topic of research. More specifically, the way that the use of such systems influences the trip characteristics of the users is investigated in great depth. Several studies deal with the incorporation of the driver behaviour – adaptation of trip characteristics to real-time information – into simulation models. For this purpose microscopic models based on autonomous agents are mainly used and the concept of “Belief Desire Intention” (BDI) is applied (Dia and Purchase, 1999; Dia 2002).

Research is also conducted on the incorporation of driver behaviour into traffic microsimulation models. A recent example representing scenarios in which the prevailing traffic condition is congestion due to an incident and during which real-time information is provided to the drivers. Driver behaviour in merging traffic scenarios is monitored and then incorporated in the traffic simulation model SITRAS (Hidas, 2005).

The impact of intelligent transport systems – and mainly Advanced Traveller Assistance Systems – on the environment is a topic of research in Australia. In particular, the way such systems improve the air pollution but also reduce the energy consumption by increasing mean speed and reducing travel time is dealt with in many studies.

One topic of research that is popular in Europe and is encountered in Australian literature is the investigation of in-vehicle cruise control systems. Several big projects that were conducted recently such as the TAC SafetyCar project (Regan *et al*, 2002), dealt with the impact of cruise control systems on the user and hence on road safety. In the TAC SafetyCar study, the use of Intelligent Speed Adaptation and Forward Collision Warning was investigated, using appropriately equipped vehicles. A previous study looked at the impact of manual speed alerting and conventional cruise control.

- **UNITED STATES AND CANADA**

A main difference from the studies taking now place in the US in comparison to Europe, is that whereas in Europe there is great focus on longitudinal control devices such as Adaptive Cruise Control and Intelligent Speed Adaptation, this is not the case in the US anymore. In the US there are only a few recent studies on such cruise control devices. In Canada, however this is still a topic of research. A recent study involves the behavioural adaptation of drivers when using Adaptive Cruise Control (Rudin-Brown and Parker, 2004).

Systems that are quite popular within the research field are warning devices, also lateral warning as in Europe, but also intersection warning systems – mainly in cooperative systems, Advanced Traveller Information Systems and Automated Highway Systems (AHS) (Hall and Caliskan, 1999; Tan *et al*, 2000; Bose and Ioannou 2003).

Intersection warning systems were one of the systems investigated in the Delphi Study within the framework of Task Force B, and the results illustrated that it is a system that is anticipated to improve road safety, but for which 24 out of 33 respondents noted that further development is needed. In most US studies, intersection warning systems are investigated as cooperative systems, and part of their operation involves infrastructure adapting to the traveller needs (ie adaptive signal control systems). Subsequently, once research on intersection warning systems commences in Europe, there will be already substantial evidence available from similar studies in the US.

Another type of warning systems that is investigated in the US is warning systems, mainly indicating to the user the need to lower his/her speed under the prevailing conditions (weather, traffic, road geometry) through Variable Message Signs (VMS) or other information systems (Peeta *et al*, 2000;Bertini *et al* ,2006). These type of systems are quite basic ones, but it seems that their importance is highly rated.

Automated Highway Systems are systems that have not been yet introduced in the European research field, but seem to be quite popular in the US, forming the new “trend” in investigated systems. With such systems, vehicles are intended to move automatically and form platoons “artificially”, resulting in a better exploitation of the road capacity within the prevailing flow conditions.

In Canada, a substantial number of studies involve the use of Advanced Traveller Information Systems. The main type of studies encountered investigated the needs of the travellers and their impact for specific road networks. A study on the impact of in-vehicle information system providing information on intersections took place distinguishing between young and elder drivers. Furthermore, there is interest in the several means of speed management.

Last, generally Advanced Traveller Information Systems (ATIS) and mainly VMS are systems that are quite popular in the US. Their impact not so much on road safety, but mainly on trip characteristics and traffic conditions is investigated in great detail. In particular, the investigations taking place involve impact of the use of ATIS on the user, hence on a microscopic level, taking into account the effect of the system on the trip characteristics – namely departure time, transportation mean and route choice. This impact is then applied to an aggregated and hence macroscopic level estimating the impact of the driver decisions on the traffic conditions of the road network.

Furthermore, the investigation of representing the driver behaviour and vehicle movement that results from the use of intelligent traffic systems through behavioural and traffic (mainly) simulation modelling forms a significant part of the research that is carried out in the US. This comprises another important difference with the research on ITS in Europe. The representation of the practical part of the use of intelligent transport systems through a generalised theoretical way is rather neglected.

8 DISCUSSION AND CONCLUSIONS

- **GENERAL**

The objective of this report was twofold. First, an attempt was made to identify the needs of future research on the field of the impact of Intelligent Transport Systems. Second, the different fields in which research is being conducted internationally have been described. This can indicate the potential fields for international synergies and cooperation, to avoid duplicating work and expanding the knowledge base on ADAS.

To achieve these two objectives several sub-actions took place.

➢ First, an overview of two previous HUMANIST reports – namely deliverable B.2 "An Inventory of available ADAS and similar technologies according to their safety potentials" and milestone of month 16 "Completion of SWOT analysis for ADAS impact assessments", took place.

➢ Second, a Delphi Study mainly concentrated on the impact of intelligent transport systems on road safety was conducted. Preliminary results of this study were presented from which the importance of the investigated systems is identified and gaps in existing knowledge on the impact of ITS are spotted.

➢ Last, an overview of recent projects and studies taking place in institutes and organisations outside Europe took place. The aim of this action was to identify directions of future research and also whether similar research to this being conducted in Europe is conducted elsewhere in order to encourage future cooperation.

- **FUTURE DIRECTIONS FOR EXISTING RESEARCH IN EUROPE**

➢ Quantification of unwanted effects arising from system use
➢ Further investigation on behavioural adaptation and driver appropriation
➢ Identification of relationship between impact of ITS and road safety
➢ Investigation of ways to represent the direct impact of the use of ITS on road safety, using accident/risk parameters
➢ Incorporation of the driver behaviour when using ITS into driver behaviour and traffic simulation models
➢ Further research on impact of ITS on driver behaviour (and hence road safety) distinguishing between different driver groups
➢ Further research on specific systems such as lateral or intersection warning systems, vision enhancement systems etc
➢ Further research on impact of Advanced Traveller Information Systems providing real-time information on traffic conditions on driver behaviour

- **NEW TOPICS OF RESEARCH IN EUROPE**

- Investigation of Automated Highway Systems (AHS)
- Investigation of Cooperative systems (vehicle-infrastructure or vehicle-vehicle communication)
- Investigation of the potential application of variable message signs or in-vehicle information systems as warning systems aiming at the improvement of road safety. These systems will provide real-time information on unexpected congestion due to incident occurrence, weather conditions or road geometry advising drivers to reduce speed.

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Main websites that were visited:

ITS JAPAN: http://www.its-jp.org/english/

ITS America: http://www.itsa.org/

ITS AUSTRALIA: http://www.its-australia.com.au/

ITS CANADA: www.itscanada.ca/

http://www.path.berkeley.edu/

Other websites that were visited included University and Research Centre web-sites and TRB ref: http://rip.trb.org/browse/dproject.asp?n=6549.

Proceedings of the recent ITS World Congress and Transportation Research Board Conference were also used as a source of research studies.

APPENDIX A – Delphi Introduction for participants

1. MAIN GOAL AND GENERAL DESCRIPTION

This activity takes place within the framework of the HUMANIST NoE, and more specifically of Task Force B "Evaluation of Potential ITS Benefits", under the "International Synergies" activity (WP B.3). Main goal of this activity is to identify certain issues in relation to the impact of Intelligent Transport Systems, mainly in terms of road safety. Other issues such as the impact on traffic and environmental conditions are also dealt with.

As a means to achieve the goal of the activity, a Delphi study is conducted with the use of a questionnaire. Hence the procedure is as follows: a questionnaire is sent to experts, who fill it in and send it back. The results are then being processed; and a slight redesign of questionnaire might also take place as a result of the answers or comments of participants. The questionnaire is sent again to each participant along with his/her previous answers and the results of the survey (average answers). Participants are asked to fill-in the questionnaire again and send it back. The same procedure is repeated and usually stops when there is group consensus or else when respondents do not change their answers between rounds ***(expected no of rounds: 2)***. In the case of answers out of the average range respondents are asked to justify their view.

The questionnaire itself is divided into the following four parts – a copy of which is presented in Annex I – involving:

1. General questions on the examined systems.
2. More specific questions on the examined systems in terms of Road Safety only.
3. General conclusive questions and comments
4. Questions on the participants' characteristics.

The Intelligent Transport Systems examined within this study are five and are:

1. Intelligent Speed Adaptation (ISA)
2. Anti Block System (ABS)
3. Intersection Warning
4. Enhanced navigation
5. Lateral control

The questions in the first, second and third part of the questionnaire will involve each of the five systems and respondents are asked to answer each question based on their knowledge and hence expectations. More specifically, aim of the study is not to find the absolute truth for the issues represented in the questionnaire, but to identify the views of the people who are responsible for the research, implementation or use of such systems. Hence, one should consider each question as if it started as "WHAT DO YOU EXPECT ….".

The questions are designed in such a way as to be comprehensive and clear, however in case of confusion do not hesitate to contact us for further clarifications. Estimated time for filling in the questionnaire: 15-20 minutes. If in need of further information, please contact Ioanna Spyropoulou: iospyrop@central.ntua.gr

2. SYSTEM DEFINITION

ISA → Intelligent Speed Adaptation is a range of speed control applications, from external speed recommendations to automatic speed reduction (limitation) function, integrated within traffic control systems.

ABS → Anti-Lock Braking System is a system quite widely used currently. They are designed to stabilize the vehicle; to keep a car manoeuvrable when braking strongly.

Intersection Warning Systems → The purpose of such systems is to enhance driver awareness of the traffic situation at the intersection by providing timely and easily understood warnings of vehicles entering the intersection.

Enhanced navigation → Such systems are consisted by in-vehicle navigation systems combined with real-time information systems. Navigation function will provide location and route guidance input to the driver. It can also have capability to recommend optimal routing based on driver preferences. Enhanced navigation systems may integrate real-time traffic conditions to the calculation of optimal routes. Other included features could be the integration of other ADA systems and for example adjust the driving speed if the road conditions are changing.

Lateral control systems → The system always assists the driver to keep the vehicle almost in the centre of the lane using on-board vision systems or dedicated lane markings such as magnetic nails or magnetic tapes.

APPENDIX B – Delphi Questionnaire

FIRST PART: SYSTEM IMPACT

(Please note that your answers describe your expectations, hence answers do not express absolute knowledge)

1) Impact of system use:

0→ highly negative, 1→ negative, 2 → no impact, 3 → positive, 4 → highly positive, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Road Safety					
(b) Traffic conditions					
(c) Environmental conditions					
(d) Driver Comfort					
(e) User integration into the					

road network system					

2) Penetration rates by year:

0→ 0%, 1→ 1%-25%, 2→ 26%-50%, 3→ 51%-75%, 4 → 76%-100%, NO FILL→ no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) 2006					
(b) 2010					
(c) 2030					

3) Relationship between penetration rates and impact rate ***(please note that by impact both positive or negative impact is implied)*****:**
No relation of penetration rates and impact
Unit increase → Impact of one user only upon himself
Increase & decrease → impact increases with penetration rate and after a value decreases
Increase & stable → impact increases with penetration rate and after a value remains stable
Increase → impact increases with increase in penetration rate

0→ no relationship, 1 → unit increase, 2 → increase & decrease, 3→ increase & stable, 4→ increase, NO FILL→ no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Road Safety					
(b) Traffic conditions					
(c) Environmental conditions					

SECOND PART: SYSTEM ROAD SAFETY IMPACT

(no other type of impact should be taken into account)

(Please note that your answers describe your expectations, hence do not express absolute knowledge)

4) Impact of system in relation to system use on:
If:
The system affects driver behaviour and hence has an impact only when turned on the answer is → with system use only
The impact on driver behaviour is evident if the user has already used the system but even when the system is not turned on, the answer is → even without system use

The impact decreases with the time using the system → Short-term
The impact does not decrease with the time using the system → Long-term

Tick your answers (NO FILL → no opinion)	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(1) SYSTEM on/off					
(a) With system use only					

(b) Even without system use					
(2) DURATION					
(a) Short-term					
(b) Long-term					

5) Side effects from the use of the systems arise from:

Y → YES, N → NO, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Systems are not efficient enough (technology-wise)					
(b) Users will misuse them on purpose					
(c) Users will misuse them because of lack on training					
(d) Side effects from non-users					
(e) Side effects from environment					
(f) No side effects					
(g) Other, please specify					

6) Side effects of system use are:

Y → YES, N → NO, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Increased workload					
(b) Driver distraction					
(c) Over reliance/confidence on the system					
(d) More aggressive driving behaviour					
(e) Other, please specify					

7) Parameters that should be the indicators of the impact on road safety:

0 → not relevant, 1 → slightly relevant, 2→ relevant, 3 → important, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Speed parameters					
(b) Acceleration/deceleration parameters					
(c) Time headways					
(d) Reaction times					
(e) Lateral position					
(f) Near accident calls					
(g) Workload					
(h) Driver attention/distraction					

(j) Accident rates					
(k) Stress					
(l) Other, please specify					

8) Which element of driving will change; and hence affect road safety:

0 → no change, 1 → slight change, 2 → change, 3 → important change, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Change in speed					
(b) Trajectory control					
(c) Change in attention					
(d) Anticipation of risky conditions-preparation for dealing them					
(e) Improved driving behaviour (automatic by the system i.e. safe headways with ACC)					
(f) Improved driving behaviour (non-automatic, as a consequence having used the system)					
(g) Less need to be concentrated – small loss of concentration compensated by the system					
(h) Range of driver errors can be dealt with automatically					
(i) Other, please specify					

9) Appropriate types of studies for each system:

0 → not relevant, 1 → slightly relevant, 2 →relevant, 3 → important, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Real network studies					
(b) Test track studies					
(c) Simulator studies					
(d) Laboratory studies					
(e) Questionnaire studies					
(f) Other, please specify					

10) Amount of evidence available on the impact of the systems arising from the types of studies:

0 → no evidence, 1 →little evidence, 2 →evidence, 3 → sufficient evidence, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Real network studies					
(b) Test track studies					
(c) Simulator studies					

(d) Laboratory studies					
(e) Questionnaire studies					
(f) Other, please specify					

THIRD PART: GENERAL QUESTIONS & COMMENTS

(Please note that your answers describe your expectations, hence do not express absolute knowledge)

11) Which of the following user categories need the system:

0 → no need, 1 → slight need, 2 → need, 3 → crucial need, NO FILL → no opinion	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Any type of driver					
(b) Individual driver					
(c) Commuter					
(d) Tourist					
(e) HGV (heavy goods vehicle driver/professional driver)					
(f) Public transport driver (within the road network)					
(g) Taxi driver					
(h) Old driver					
(i) Novice driver					
(k) Other, please specify					

12) Place the systems in an order in terms of their importance:

Rate from 1 to 5	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**

13) Systems that you consider should be part of the standard vehicle equipment:

Tick your answers (NO FILL → no opinion)	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) In their current level of development					
(b) Following a few more impact studies					
(c) With some further development					

14) Estimate the cost of systems that:

Cost in EUROS (else, please state the currency used), (NO FILL → no opinion)	**ISA**	**ABS**	**Intersection warning**	**Enhanced navigation**	**Lateral control**
(a) Will be introduced in the market					
(b) The general public will be willing to pay					
(c) You would be willing to pay					

15) Do you think that there are certain questions that if answered the impact of systems can be estimated qualitatively OR quantitatively (ie the impact of a system is a function of a,b,c….)?

16) Please provide us with any additional comments on the questionnaire.