



UNIVERSITY OF GOTHENBURG



ACCEPTABILITY OF INTELLIGENT TRANSPORTATION SYSTEMS (ITS) TO VARIOUS GROUPS OF DRIVERS

Master of Science Thesis in Software Engineering and Management

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Göteborg, Sweden, May 2013

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Abstract

The introduction of Intelligent Transportation Systems (ITS) in road vehicles is predicted to enhance traffic safety and mobility considerably. Hence, transport policymakers in most countries are increasingly become interested in possibility of extensive implementation of ITS devices in real traffic environment. Successful deployment of these systems on large-scale mainly depends on potential consumers' willingness to use these technologies. However, the information regarding this willingness is scant. On the other hand, at the current point in development of ITS technologies there has been remarkably little interest shown in segmentation of the market to capture the likely difference in demands and expectations of drivers in various groups of age, gender, country, and so on. Therefore, the acceptability of several ITS applications with high estimated safety potential to different sub-groups of drivers was the main focus of this paper. The study was carried out in two key phases. The first phase encompassed preliminary activities required to be undertaken with the aim of identifying a small number of promising in-vehicle ITS devices that would be assessed for their acceptability. To this end, first it was necessary to identify drivers' needs in actual accident context. This was achieved by case-by-case analysis of the potential sources of accidents elicited by interviewing traffic experts based on their in-depth analysis of crash data. Promising ITS functions were conditioned based on their capability to satisfy drivers' needs. This analysis resulted in the selection of 12 systems for inclusion in the study; Alcohol Detection and Interlocks, Drowsy Driver Warning, Adaptive Front lighting, Night Vision, Intelligent Speed Adaptation, Curve Speed Warning, Adaptive Cruise Control, Forward Collision Mitigation, Intersection Assistant, Lane Change Support, Vehicle Monitoring System, and Electronic License Key. These systems, among several ITS technologies, were assessed to confer the greatest safety benefit to the road user community. In the second phase, the focus was to understand the effect of independent variables pertaining to drivers' background characteristics on their perceived acceptability of various in-vehicle ITS products. This was achieved by executing questionnaire involving a total of 150 car drivers from Iran and Sweden varying in age, gender, and driving characteristics. The results show that on average, the acceptability of ITS applications is rather high. There is evidence to suggest that drivers in diverse groups have different requirements and expectations that have to be met, if ITS technologies are to be acceptable to them. Forward Collision Mitigation system has the highest perceived level of acceptability especially among older drivers. Perceived acceptability of Alcohol Interlocks and Electronic License Key was remarkably low, while these systems are predicted to yield the highest reduction in road trauma and costs. The indications of these findings for the success of ITS have been discussed. A further focus in the second phase was on identification of the significant impediments which would prevent ITS technologies to be accepted by the drivers from their own perspective. Recommendations for enhancing ITS acceptance have been made. The report concludes with suggestions for future work.

Keywords: Intelligent Transportation Systems, ITS, Traffic Safety, Drivers' needs and requirements, Perceived acceptability.

Acknowledgement

First of all I would like to express my appreciation to my supervisor Sven-Arne Andreasson for all his patience, devotion, and help during these months. I was really fortunate to have had him as my counselor. His guidance has been instrumental in accomplishments of this work. Thanks also to my examiner Christian Berger and other members of grading committee for being my opponent. I would like to denote this dissertation to my parents for their great support and encouragement throughout my years of education in IT University of Gothenburg. I appreciate them for all things they have done for me.

Göteborg, May 2013

Elmira Rafiyan

List of Abbreviations

ABS	Anti-lock Braking System
ACC	Adaptive Cruise Control
AFL	Adaptive Front Lighting
Alco-lock	Alcohol Detection and Interlocks
BAC	Blood Alcohol Content
BAS	Brake Assist System
CSW	Curve Speed Warning
DDW	Drowsy Driver Warning
EBA	Electronic Brake Assist
ELK	Electronic License Key
ESC	Electronic Stability Control
FCM	Forward Collision Mitigation
HUD	Heads-Up Display
IA	Intersection Assistant
ISA	Intelligent Speed Adaptation
IT	Information Technology
ITS	Intelligent Transportation Systems
LCS	Lane Change Support
LDW	Lane Departure Warning
NV	Night Vision
PPS	Pedestrian Protection System
RDW	Road Departure Warning
RVC	Road to Vehicle Communication
S&G	Stop and Go
TCS	Traction Control System
TPMS	Tire Pressure Monitoring System
V2V	Vehicle to Vehicle Communication
VMS	Vehicle Monitoring System

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1. INTRODUCTION

This first chapter dedicated to provide the reader with an introduction to the present research. It starts with giving a background to the thesis subject by underlining the need for the utilization of Intelligent Transportation Systems in road vehicles as well as the importance of knowledge on consumers' acceptance of these technologies. Afterwards the identified gaps within the related work which signifies the need for the current study is explained. This is followed by describing aims and objectives of the research in addition to the materials and procedures have been used for task accomplishment. The limitations of the study are also declared. As a final point, the outline of the research along with a graphical depiction of the work process is presented.

1.1. INTELLIGENT TRANSPORTATION SYSTEMS

Today's transportation is increasingly faced with the negative impacts of road traffic such as safety hazards, congestion, pollution, as well as consumption of energy and space [41]. Of the externalities imposed by road transport, un-safety has become a major concern in recent years. This is of particular importance as the motorization is rapidly expanding, and accordingly travelling on roads is becoming ever more dangerous [37]. For instance, consistent with the World Health Organization's (WHO) global status report on road safety, each year over than 1.2 million people die and around 50 million injured because of traffic accidents around the world [32]. While numerous strategies implemented worldwide (e.g. improved road infrastructures, tougher rules and regulations, etc.) have demonstrated a significant success in cutting the road toll, yet we see the road trauma rate is dramatically increasing in most of the countries [49, 51]. It has been estimated by 2030 traffic related injuries will become the fifth prominent cause of death in the word unless an immediate action is taken [32].

In most cases traffic accidents are because of suboptimal or inappropriate driving behavior [41]. Karabatsou, et al. discuss that driving can be deemed as a difficult and complicated task in which continuous adaptation to a changing traffic situation in the driver's neighborhood is required. As a matter of fact, humans' limitations on their adaptation capacities in the long run may push them into difficult situations where the drivers' regulatory functions (i.e. throttling, braking, changing gear, and steering) are over requested. Accidents are the most apparent symptoms of these difficulties met by the drivers at the wheel. According to the universal definition, any problem encountered by drivers represents a driver's safety need that signifies the lack of something inside the driving system's operation. These needs call for an improvement in driving system in line with its operators' functioning particularly by offering suitable devices known as Intelligent Transportation Systems (ITS) [35].

From the global outlook, it has been recognized that the introduction of ITS in road vehicles is likely to enhance traffic safety and efficiency considerably [41]. Regan et, al. define ITS as a variety of electronic systems, incorporating a number of information processing, communication, control, and sensing technologies, serve to address different aspects of transportation problems [72]. ITS can be used, for example, to improve traffic safety and travel efficiency, decrease congestion, increase road capacity, reduce vehicle emission, and conserve energy [6, 51]. Although the potential of ITS technologies in the environment protection and economic productivity improvement is promising, definitely the greatest benefit they confer is in the enhancement of the road users' safety [6]. ITS safety applications are able to actively collect and process information from surrounding traffic environment, provide the vehicle's operator with the relevant feedback, and take action to eliminate or lessen risk of collision [49].

As Bishop points out, concerning the significant effectiveness of airbags as primary samples of safety features in reduction of road tolls designing more advanced and intelligent systems has made competition among system providers and car manufacturers for increasing their sales [8]. Nowadays the variety of possible driver

support systems proposed and developed is broad, varying from functions that assist the operator in one certain driving sub-task (e.g. speed control) up to very advanced functions in which drivers regulatory functions are entirely automated (e.g. the autopilot) [41]. But whatever the applications are, they have to be effective and adopted by the drivers [35].

1.2. USER ACCEPTANCE – A MAJOR OBSTACLE FOR SUCCESSFUL DEPLOYMENT

From a driving task point of view, if these technologies have to be effective, a number of questions have then to be raised [35]. These questions go further than technical concerns and refer to the possibility of worldwide implementation of the functions [29]. Marchau, et al. discuss that today the technological feasibility of most of the driver assistance solutions is not the case any longer. This has been proven through various experimentations and pilots. Within these and other studies in the realm of intelligent transportation, ITS safety functions further demonstrated to have a significant potential for increasing driving safety and efficiency [41]. For instance, according to Lind, et al. estimations of the safety benefits expected with alcohol interlocks which can prevent drunk driving implies 18% reduction of alcohol related fatalities in Sweden [39].

Next to representing the technical possibility and potential of different ITS technologies, a wide range of driver support systems have gradually been introduced to the market on a small scale [8]. Well-known examples are systems that assist the driver in following the leading vehicle with a safe distance (i.e. cruise control), systems in which the driver is warned if he/she has slipped out of a certain speed threshold (i.e. speed alerting), and systems which support the driver in case of impending collision danger with the vehicle ahead (i.e. collision avoidance). There is no doubt in ITS applications' contribution to enhance traffic safety and efficiency. Hence, transport policymakers in most countries are substantially become interested in possibility of rapid deployment of these functions in real traffic environment, as high impacts require extensive utilization [57]. Brackstone and McDonald explain that this deplorability can be mainly specified by measuring the willingness of the future consumers to adopt these systems. However, the information regarding this willingness is scant [9].

Nowadays the category of ITS technologies is rapidly increasing. Therefore, gaining insight into the potential consumers' willingness to buy and use these applications is required [41]. Cairney discusses that knowledge on drivers' views of ITS products could enable system suppliers and vehicle manufacturers to provide or tailor their options in accordance with their intended market demands [11]. It is worthless to invest money and effort in developing systems if the technologies are never purchased or adopted by the consumers [72]. Accordingly, taking in to account that how regular drivers are likely to accept certain types of systems in early stages of designing is a way to lessen the cost of forthcoming development in addition to improving the usability of the produces [30]. Systems that are not acceptable to the road users are not likely to have the intended positive impact on traffic safety and efficiency [51]. However, as Rumar et al. claim, currently, the ultimate contribution of these technologies to enhance road users' safety is assumed uncertain. The reason is because intelligent transportation systems have never been implemented on a large scale in real world transportation for deriving reliable safety changes they may yield in traffic context considering the reduction in crash numbers [53]. Meanwhile, information on acceptability of ITS functions can shed some light on the possible benefits of this technology in real world traffic from a safety point of view [41]. On the other hand, as Cairney indicates, knowledge on users' acceptance of ITS applications can also be beneficial in notifying road authorities of the degree and type of infrastructure related to the road transportation for which they should plan [11].

The acceptability of ITS applications to the future users is therefore a vital issue to think carefully about early in the design and development of these systems [51]. Such understanding can be obtained by studying the consumers' views regarding various functions of these technologies. Acceptability of some ITS applications to the driving public is the main focus of this report. The challenge is how to explore drivers' acceptance.

1.3. LACUNAE TO COMPENSATE FOR IN THE PREVIOUS RESEARCH

Over the last few decades, numerous studies have been carried out to evaluate consumers' views of different ITS technologies. It is not appropriate here to describe all the details and findings that have emerged from these researches. Rather, some key issues that signify the need for the present research are discussed. A brief review of the previous work on acceptability of ITS technologies is presented in chapter 2.

First remarkable thing is that the instruments chosen to assess acceptability have varied considerably across the studies. As the number of investigated or developed ITS functions are too high and it would be unmanageable to include too many systems in a single research, in every research paper on ITS acceptance there was an attempt to select among possible applications that would be evaluated for their acceptance. Some studies have focused broadly on issues of acceptability relating to a single system of research interest (e.g. Harrison et al., 2000), while others have examined drivers' views regarding a sub-set of ITS technologies (e.g. Cairney 1995; Young et al., 2003). Noteworthy is that, there has been remarkably little consideration shown in deciding which systems have to be selected as the basis for assessing the acceptability. In most cases, it seems that the technologies investigated have been chosen either randomly or based on their availability in the market at the time. It is considered important to have an effective selection among several alternatives while measuring users' propensities. One promising approach could be to select systems that are expected to yield the greatest benefit in terms of reducing crash numbers, as such technologies' acceptance would be far more important for the success of ITS.

Besides, reviewing existing literature on acceptability of ITS technologies exposed a further gap with regard to describing the composition of participants in view of their background characteristics. This is of a particular importance since several studies in the information technology domain have revealed the influence of various elements including numerous psychographic, demographic, geographic, and behavioral characteristics on users' acceptance of a computer system [13, 61]. This has also been validated in case of ITS technologies. For instance, variances in perceived acceptability of ITS systems between drivers of different countries have been observed (e.g. Várhelyi, 2001). Unfortunately, at the current point in development of ITS technologies, there appears to be relatively little interest in segmentation of the market to capture different demands and expectations of drivers in various groups of age, gender, country, and so on [40, 51]. It is important to identify these differences and bring them to the attention of system suppliers and vehicle manufacturers when designing and marketing ITS products. In this way, companies can not only direct their advertisements towards the right customers but also adjust their products in accordance with the demands of the specific market segment in which their products are targeted so as to increase their sales and market share [11, 61].

Additionally, notable is the diversity of the methods has been used to measure the acceptability. Several studies have been performed through conducting focus group discussions (e.g. Cairney, 1995) or executing telephone surveys (e.g. Gray 2001) with drivers who had no previous experience with ITS technologies. Other studies have explored drivers' propensities after a short or long duration exposure to the systems in either driver-in-the-loop simulators (e.g. Oxley, 1996) or in equipped vehicles in an actual traffic environment (e.g. Sayer et al., 1995). Although each of the adopted methodologies has its own advantages, but a common thread is that these methods, which are assumed qualitative, compared to quantitative techniques are relatively expensive and as a result usually less participants could get involved. Limitations on respondents' volume may impose the risk of inaccuracy of the findings especially when it comes to generalization of the outcomes [17].

Also noteworthy is that, within the previous research, there has been very little discussion made on actual drivers' concerns about and expectations of emerging technologies that have to be met in order for ITS technologies to be acceptable to them. If the desired benefits of these functions are to be realized to the full, it

is necessary to identify impediments preventing the products from being adopted in the intended direction and rectify them before development [72].

Finally, a common problem in almost every study on ITS acceptance is the lack of any attempt to provide an operational description of acceptability which could enable interpretation of research outcomes and facilitate inter-study comparisons. The further research on acceptability of ITS technologies without establishing a clear understanding of what is meant by acceptability and its determinants, the greater the risk that the effort will go into developing a series of researches which their results could not be interpreted or compared to guide the future work. This is not for claiming that what has been done so far is wrong. Rather, it suggests that comparisons between studies would be facilitated if every researcher were to present from the beginning an operational explanation of acceptability that has been used in that research [51].

The need for the further research

The identified gaps in the previous studies provide the following suggestions for further research:

- An important research priority is to determine an operational strategy that can be used to effectively select a small number of possible systems which would serve as the basis for measuring acceptability.
- Further work needs to be done to establish a better understanding of how individual factors pertaining to drivers' background characteristics (e.g. age, gender, culture, etc.) affect their views of ITS technologies, and what implications this may have for successful implementation of ITS products.
- It is important to carry out this type of research in a more cost-effective way with a larger group of respondents.
- More research is required to identify significant impediments preventing the ITS products from being successfully deployed.
- It is necessary to provide an operational description of acceptability and its underlying constructs as they apply to Intelligent Transportation Systems to facilitate future interpretations and comparisons.

Apart from these matters, as long as ITS technologies evolve over time additional investigation on users' acceptance is needed since societal perceptions change accordingly. In other words, it is probable that attitudes towards ITS applications of those participants in earlier studies are different now from what they were at the time [51].

1.4. PURPOSE OF THE PRESENT STUDY AND RESEARCH PHASES

The study was undertaken to address the identified issues related to the dearth of prior research on acceptability of ITS applications to the road users by;

- Offering an effective strategy for selecting alternative ITS applications so as to measure drivers' views towards them.
- Providing an operational description of ITS acceptance and its underlying factors for use in the present study.
- Promoting an affordable method for conducting the research involving a wider group of participants.
- Analyzing the probable effect of independent variables relevant to drivers' background characteristics on their perceived acceptability of ITS equipment.
- Investigating drivers' concerns and expectations that have to be met, if ITS technologies are to be acceptable to them.

Phases of the research

The focal point of this research was therefore to establish a productive assessment of how various drivers' are likely to accept the most promising ITS technologies. The work was done in two key phases. Phase 1 encompassed preliminary activities needed to be performed in order to identify a promising sub-set of ITS devices that would be assessed for their acceptability among various driver sub-groups. Karabatsou, et al. believe the indispensable step of the work to be taken on the way to achieve such an objective will cope with the identification of the actual needs that drivers have of support in their driving. To a great extent, this can be diagnosed through quantification of driving hazards according to an in-depth analysis of crash cases. These needs will be understood as a consequence of the difficulties faced by the motorists in the operation of the driving system. Comparing these needs with possible ITS technologies makes it possible to deduce conditions where these variables match, with regard to both needs fulfillment and respective capability of the equipment to avoid particular types of crashes [35]. It appears to be relatively little investigation on what kinds of ITS features are actually required for the drivers in order to deal with the general traffic complications [40]. Thus, it was necessary to identify the most common critical situations that are subject to a wide range of traffic accidents and accordingly detect suitable ITS solutions that are most capable of addressing the usual needs of the drivers from a safety point of view.

Phase 2 dedicated to investigate drivers' perceived usefulness and preferences regarding candidate systems from the prior phase of research. The investigation continued by exploring how various characteristics of the drivers might influence their perceived acceptability of an ITS function. A further focus was on identification of the major barriers which would prevent ITS products to be purchased and used by the drivers from their own viewpoint.

Thus, in sum, this dissertation has four major **objectives**:

- The first one aims at the determination of the actual drivers' needs that call for assistance as they can be directly inferred from in-depth analysis of crash cases.
- The second one addresses the identification and assessment, among potential ITS applications, the most promising solutions that can support drivers or other road users in critical conditions.
- The third one targets drivers' acceptance of various ITS devices that are significantly expected to enhance traffic safety and efficiency as well as their preferences regarding different states of the systems (i.e. informative or automatic). Measuring the acceptability goes further and deeper by studying the effect of various elements relevant to drivers' background characteristics on their preference and choice behavior and the indications this may give rise for success of ITS products.
- Finally, the fourth one concentrates on the impediments preventing ITS technology from being accepted by its eventual users.

Accordingly, the **Research Questions** addressed within this paper can be summarized as follows:

- What needs drivers actually have of support in their driving to deal with the common traffic problems?
- What would be the best fit ITS technologies to meet the common needs of the drivers?
- How acceptable different ITS equipment with high estimated safety potential are likely to be to the drivers?
- How drivers' acceptance of ITS applications may differ with regards to their background characteristics? What indications the differences have for successful deployment of ITS technology?
- What would prevent regular drivers from accepting ITS products?

1.5. METHOD

In view of the methodologies have been used for task accomplishment, this exploratory research can be split into three main parts. The research started with the investigation on the actual needs drivers actually have of assistance in their driving. As mentioned before, these needs can be directly inferred from common safety problems and complications encountered by the drivers at the wheel through an extremely detailed analysis of crash cases. In order to put the analysis forward, it was decided to get benefits of expert judgments. To achieve this goal, qualitative in-depth interviews with accidents reconstruction experts were conducted with a view to establishing a list of potential sources in accident production.

The outcomes of the interview were used as the input to ground the next step of the work which was identification of best promising ITS solutions that can fulfill diagnosed needs from the interview. This part of the work was predominantly base on a comprehensive literature review on various classes of ITS technologies to draw up an evaluation of the capability of the functions to prevent certain types of crashes. As Okoli and Schabram explain, the purpose of this type of review, which is also known as “theoretical background”, is illustrating and synthesizing the content of current knowledge [45]. The results of the literature review were used as the basis for the acceptability assessment.

Finally, questionnaire was applied as the main method for completing the study with the aim of exploring the acceptability of candidate ITS systems with high estimated safety potential from the prior phase of the research to the various drivers’ sub-groups. Alternatives were presented in the questionnaire and the respondents were asked to state their perceived usefulness of each system and choose between its warning states. The questionnaire was continued with a question asking for the most preferred function which the respondent would like to have in his/her own car. The drivers of passenger cars has been surveyed in order to measure their acceptance of different systems and to see whether there is a significant difference among their attitudes concerning both driving and socio-demographic characteristics (e.g. age, gender, country). Considering the kinds of collected data (i.e. quantitative) and the objective of the research, different mathematical statistics procedures were performed to analyze questionnaire results. A final question was asked to uncover participants’ concerns about the emerging systems which would prevent them from using this type of technology.

The materials and procedures used in each part of the study will be explained in details in later parts of this paper.

1.6. LIMITATIONS

The range of ITS systems available on the market is wide. Besides, there are many applications that are being further implemented up to the more advanced level in the near future [40]. Since adequate evaluation of all the systems may be challenging and confusing by regular drivers, this thesis only targets those ITS applications that according to experts’ evaluation have a high potential to enhance traffic safety and efficiency. Furthermore, while measuring the users’ attitude towards proposed alternatives, the greatest emphasis was on applications’ ideal state of development.

It has to be noted that the focus of attention in this investigation has been on acceptability of in-vehicle systems rather than infrastructure-based ITS technologies, as the road users’ community would have very limited or even no choice in deciding with which infrastructure-based technology they would interact.

What has to be clarified is that the greatest motivation behind measuring users’ acceptance of in-vehicle ITS technologies in this study was to get a better understanding of how the individual factors relating to users’ background characteristics may affect the acceptability of these systems rather than estimating the impact of

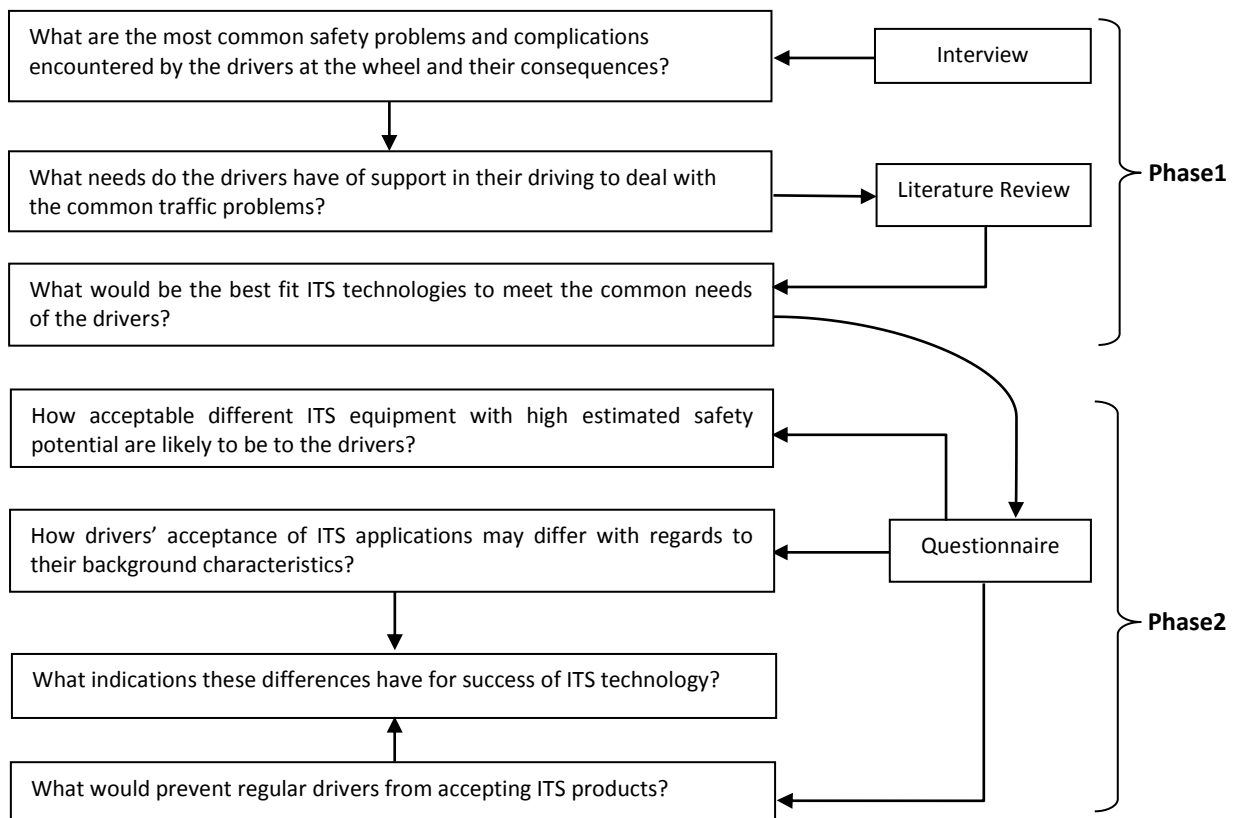
large-scale implementation, designing a specific interface or an integrated application for a particular consumer group, or else finding specific problems within specialized sub-groups (e.g. problems in cultures).

1.7. OVERVIEW OF THE THESIS

To reiterate, the main objective of the present study was to assess various ITS technologies with high estimated safety potential for their acceptability among different driver sub-groups. Three steps must have been taken to meet the research goals. The first part of the study was focused on trying to understand driving deficiencies and actual accidents causations. Traffic experts' interviews were used to answer the questions; WHAT are the most common hazardous driving situations and their repercussions? WHY they are happening? HOW they can be avoided? The elicited problems and complications in the driving system would be seen as a precise sign of the needs drivers have of support in the driving system. Based on the outcomes, at the second step, the associated ITS technologies with the inferred drivers' needs were identified by reviewing available literature. The question addressed in this part was; WHICH types of ITS devices are the best fits to handle common needs of the drivers? The results of this section have been used as the contents of the questionnaire for measuring acceptability in the next step. The main focus at the final step was on exploring the acceptability of candidate ITS applications with high estimated safety potential to various groups of drivers. A further focus was on identifying the impediments preventing this technology to be used by its eventual users. The questions in this part were; HOW acceptable different ITS equipment with high estimated safety potential are likely to be to the drivers? HOW drivers' acceptance of ITS applications may differ with regards to their background characteristics? WHAT implications these differences have for success of ITS technology? WHAT concerns and expectations drivers actually have to accept ITS products?

Below, the explicit research questions for each step of the study and related methodologies are given together with a depiction of the work procedure.

Figure 1. Work procedure.



Chapter 2 represents a review of the prior research on ITS acceptability. The relevant activities of the first phase of the study, dedicated to select effectively among possible ITS technologies, are documented in Chapter 3. In Chapter 4 the results of the executed questionnaire, aiming to explore the likely acceptability of candidate ITS products to various groups of drivers are presented and discussed. An operational description of acceptability for use in in the current research is also presented. In the final chapter, Chapter 5, the implications of the findings as well as methodological concerns are discussed. Recommendations for enhancing ITS acceptance have been made. The report concludes with suggestions for future work.

2. PREVIOUS RESEARCH ON ITS ACCEPTABILITY

During the past few decades, numerous studies have been carried out to explore the acceptability of in-vehicle ITS applications to the vehicle drivers. However, the adopted methods to measure acceptability have varied noticeably across these researches. While it is beyond the scope of this dissertation to give a full account of all involved steps and findings of these researches, the key findings that have emerged from them are worth nothing here. The emphasis is on those systems which have been the focus of attention in most of the ITS acceptability researches.

Several studies have provided a comprehensive look into the acceptability aspects surrounding a single ITS product. For instance, an increasing number of studies (e.g. Vlassenroot et al., 2012; Sundberg, 2001) have been carried out to explore the acceptability of Intelligent Speed Adaptation (ISA) which is developed to reduce speedy driving. Várhelyi in reviewing the outcomes of several studies into the acceptability of ISA concludes that the acceptability of this class of ITS technology is generally high. Informative functions, which only warn the operator when he/she slips out of the posted speed limit, have been favored over supportive systems, which prevent speeding by limiting the vehicle's speed to the local speed limits [66]. However, after drivers experienced both features, they appeared to become more positive towards limiting systems. This highlights the effect of experience on drivers' perceived level of acceptance. There was also evidence to suggest that drivers' culture may influence their preference and choice behavior, as it was found that Italian and Portuguese drivers, unlike other European drivers, were largely in favor of speed limiting systems rather than informative ones [66].

There has also been a remarkable interest shown in exploring the acceptability of systems which assists the driver in following a leading vehicle with a safe distance, known as Adaptive Cruise Control (ACC). For example, Sayer, et al. examined the acceptability of Adaptive Cruise Control to the Swedish drivers after product exposure in one hour highway driving with an equipped vehicle. In general respondents regarded the system to be very useful, comfortable, and safe [55]. Brackstone and McDonald also in reviewing several researches on acceptability of Adaptive Cruise Control, Forward Collision Warning and Avoidance systems have found reliable evidence to suggest that these systems deemed to be highly acceptable to the consumers [9].

One other system that has attracted the attention of ITS acceptability research community was Seatbelt Reminder system. Well-known example of the work undertaken to gauge users' acceptance of this type of technology is Harrison and colleagues' study, commissioned by Swedish National Road Administration, aiming to develop a method that would be used to evaluate the likely acceptability of the system under consideration to the Swedish drivers, before the product actually became available on the market [28]. An important consideration in the establishment of the assessment method was that it involved participants who were non-seatbelt wearers, since these at-risk drivers were more likely to get benefit by using this system. The assessment method has been tested through conducting a series of focus group discussions. Overall, participants agreed that the device would be of great benefit to road safety and expressed that the system would help them to modify their bad habit of not wearing seatbelt even when the driving vehicle was not fitted with the technology [28].

A number of studies have attempted to assess drivers' attitudes towards a sub-set of ITS technologies. For example, Gray has designed a telephone survey with the intention of eliciting individuals' perceptions towards Forward Collision Warning, Intelligent Speed Alerting, Intelligent Speed Limiting, and Navigation systems [25]. Gray has reported that the majority of the participants in his study perceived all the discussed functions to be effective and strongly supported the implementation of the emerging devices. Speed Alerting systems turned to be the most desired feature that the respondents would like to use if it were available in automobiles. Some of the participants felt that Navigation and Speed Alerting system would distract the vehicle's operator from

the driving task, however the degree to which the participants expressed being distracted by these functions was reduced with age. Most of the drivers expressed that Speed Limiting system is the one system that they would least like to have in their vehicles. Gray's findings indicate that individuals are not likely to embrace systems that are distracting or take over the control of the vehicle [25].

Regan and colleagues using focus groups discussions evaluated the acceptability of several ITS technologies encompassing Intelligent Speed Adaptation, Lane Departure Warning, Alcohol Interlocks, Emergency Signaling, Forward Collision Warning, and Fatigue Monitoring systems to Victorian car drivers. Alike Harrison, et al.'s study, the participants in this study were recruited among those drivers for whom the systems are likely to yield the greatest benefit in terms of safety. In this study, each system's acceptability has been assessed considering participants' views of its usefulness, ease of use, effectiveness, purchase price, and social acceptability. Intelligent Speed Adaptation and Alcohol Interlocks were deemed the least acceptable features among Victorian drivers, while Fatigue Monitoring System had the highest level of perceived acceptability. Regan, et al. in summarizing the results claim that cost to purchase and proven effectiveness are the major factors that determines whether or not a driver would be willing to use ITS technologies [51].

Marchau et al. have examined European drivers' preferences regarding the introduction three systems which were entering the market at the time. The technologies investigated were Adaptive Cruise Control, Intelligent Speed Adaptation, and Navigation systems. Car and commercial vehicle drivers from six European countries, varying in age and gender, were surveyed. Drivers' willingness to buy and use the systems was examined using a measurement method so called conjoint analysis [41]. An important source of advantage with this approach is that it explicitly consider the trade-offs which individuals make among different attributes of a given product. A number of hypothetical profiles were constructed, each described in terms of system characteristics, level of system automation, and price. The profiles were presented to the participants and they were asked to prioritize them. The outcomes showed a great support with regard to the Navigation system from both car and heavy vehicle drivers on urban areas, while the most attractive system on motorways was Adaptive Cruise Control. The most desired attribute in relation to Navigation system was the one that could provide the driver with dynamic information about traffic situations and use this to plan an alternate route for the vehicle's operator. Drivers were not in favor of ISA and ACC systems which take over the control of the vehicle [41].

Noteworthy is the comparable studies which have come up with contradictory results. In some cases, however, similar findings were also observed. For instance, a focus group research has been conducted by Cairney to investigate Australian drivers' acceptance of various ITS technologies encompassing Emergency Signaling, Navigation, Adaptive Cruise Control, Congestion Avoidance, and Vehicle Monitoring systems. These systems have been chosen as they were likely to be available in the market within five to ten years. Vehicle Monitoring System has been found to be highly acceptable and preferred by the respondents while Adaptive Cruise Control was concluded to be the least acceptable function at the end of group discussions. The most important source of dislike was that the participants believed that ACC would cause the driver to be unprepared to handle emergency situations [11]. The second finding contradicts the outcomes of some European and US researches (e.g. Sayer, 1995) in which the respondents' perspective towards ACC were appeared to be rather positive [9]. The inconsistency between these researches may be partly due to the participants' cultural differences, and partly due to the different methodologies that have been used to evaluate the acceptability [51].

A few studies have concentrated specifically on the acceptability of ITS products to the drivers of a certain age group. For instance, acceptability of ITS technologies to the Australian older drivers aged over 65 was examined by Oxley. In this study participants were exposed to a range of ITS functions including Navigation, Emergency Signaling, Night Vision Enhancement, Forward Distance Warning, and Rear Collision Warning systems [46]. These systems were chosen as they predicted to have a significant potential in increasing the safety of this group of drivers. Almost all of the respondents found the systems easy to use and felt safe while using them.

However, a few of the participants believed that Navigation System would be somehow distracting. Night Vision Enhancement system was appeared to be the most acceptable feature of all the systems under investigation, as more than 60 percent of drivers have mentioned that they would like to use this system in their future cars. Oxley concluded that properly designed ITS technologies would find a promising marketplace among older drivers [46].

Another study was also performed by Sixsmith investigating the British elderly drivers' perceptions in relation to in-vehicle ITS devices, which encompassed Emergency Signaling, Navigation, Fatigue Monitoring, and Forward Collision Avoidance systems [58]. The results showed while some respondents were quite positive towards the introduction of discussed products, others raised concerns about the likely difficulties they may encounter using new technologies. On average, participants expressed skepticism about the value of equipment which would startle them with cautionary warnings and take their concentration away from driving. Old female drivers were appeared to be more reluctant to accept ITS functions than males. There was an agreement among the respondents that these systems would be of great benefit to the young and commercial drivers [58]. Unlike participants in Oxley's study, elderly drivers in Sixsmith's research were quite negative towards the introduction of the emerging technologies. Again, this could be because of the differences in their culture as well as the adopted methods to measure acceptability. Drivers in latter example had no prior experience with the systems, whereas in Oxley's study the respondents' opinions were obtained after they had experienced the systems under examination.

Young, et al. have conducted a series of focus group discussions with a view to measuring young novice drivers' acceptance of various ITS products including Intelligent Speed Adaptation, Forward Distance Warning, Fatigue Monitoring, Alcohol Interlocks, Lane Departure Warning, Electronic License, and Seat-belt Remainder systems. Seat-belt Reminder and Alcohol Interlock were found to be generally welcome among this group of drivers, while Fatigue Monitoring and Intelligent Speed Adaptation were deemed the least acceptable ITS functions [72]. With regards to the Fatigue Monitoring and Alcohol Interlock systems, the findings of this study contrasts with the results of Regan and colleagues' study indicating that age does affect the perceived acceptability of ITS technologies.

Summary

In summary, a number of studies have attempted to explore drivers' acceptance of in-vehicle ITS applications. However, the methodologies have been used across these researches have varied significantly from use of focus groups and telephone surveys, including participants that have never interacted with the system, to on-road studies in actual traffic environments. Noteworthy, in almost every paper, is the absence of any operational description of acceptability to guide inter-study comparisons and interpretation of the findings.

Collectively, the outcomes from several researches reviewed here indicate that, in general, the acceptability of ITS applications is pretty high. Intelligent Speed Alerting system appeared to be more acceptable than Speed Limiting systems. However, there is evidence to suggest that drivers' perspectives can change as a consequence of interacting with a technology over the time. Also, several studies have validated that Adaptive Cruise Control, Forward Collision Warning and Avoidance, and Navigation systems are likely to be highly accepted by the driving public. Some researchers have focused explicitly on ITS acceptability to the drivers of a certain age group. It was found, despite elderly drivers have some concerns about the probability of being distracted by the emerging technologies, properly designed systems would find a promising market among drivers of this age group.

The present study

Given the existent knowledge in acceptability of ITS technologies, it would be reasonable to ask why further research is needed. There are a number of scientific explanations for doing so. First of all, it appears to be remarkably little consideration in selecting among alternative systems that have been assessed for their acceptability. In almost every study reviewed in the present chapter, it seems that the instruments discussed to measure drivers' acceptance have been chosen either randomly or based on their availability in the market at the time. To address this issue it was considered important to choose those systems which are expected to yield the greatest reduction in crash numbers, as such applications' acceptance is far more important for the success of ITS technologies. Secondly, in the sphere of information technology, it is assumed that the acceptability of a system can be influenced by different elements such as drivers' demographic characteristics (e.g. age, gender, nationality, etc.). This has also been proven in case of ITS technologies. A pertinent example is Várhelyi's study in which a difference in perceived acceptability of ISA between drivers from northern Europe countries and those from southern Europe was observed [66]. It is clear from the previous research that there has been considerably little discussion on how relevant factors affect the likely acceptability of ITS technologies to the drivers in different groups. For this reason, it is imperative to conduct further research with a view to reaching a deeper understanding of differing perceptions and expectations of drivers in various groups that have to be met, if ITS products are to be acceptable to them. These differences should be brought to the attention of system suppliers and manufacturers when designing and marketing ITS technologies. Thirdly, in view of methodologies have been used to assess acceptability, notable is that in most cases, the adopted method is qualitative. Aside from the advantageous of employing qualitative methods, they assumed to be more costly and timely in comparison to the quantitative methods and consequently usually fewer participants could get involved. Limitations on sample size usually prevent drawing reliable conclusions of the research findings. It is therefore important to carry out this type of research in a more cost-effective way with a larger group of respondents. Fourthly, as mentioned before, failure to accept a product may cause consumers not using the technology in the intended manner. It is obvious from the previous research that there has been relatively little discussion on what drivers' concerns are actually about ITS technologies that may discourage them from using the emerging systems. If the desired benefits of ITS functions are to be realized, it is important to identify and address the impediments preventing the products to be accepted by the eventual users before deployment [72]. Fifthly, a common thread in almost all the reviewed researches is that no operational description of acceptability is provided. This makes comparison and interpretation of research findings very challenging, if not impossible. It was therefore considered necessary to carry out a study on acceptability to address this issue. Finally, further research on users' acceptance of ITS technologies is always needed taking into account that individuals' views of and opinions on acceptability may change over time as the technology evolves. It is probable that attitudes of those drivers who surveyed previously are now different from what they were then.

The remaining chapters in the present report describe a study carried out in which questionnaire were executed to investigate how divers in various groups are likely to accept different ITS equipment with high estimated safety potential.

3. SELECTION OF ITS TECHNOLOGIES

As noted in the first chapter, the main objective of this study was to evaluate the acceptability of various ITS technologies which were considered to confer the greatest benefit to the drivers in terms of safety. Before the evaluation of the acceptance could begin, it was therefore needed to identify a sub-set of intelligent transportation systems that would serve as the contents of the questionnaire to be measured for their acceptability. To this end, first it was necessary to develop a human-centered analysis of drivers' needs for assistance when confronted with actual accident contexts as it could be derived by case-by-case analysis of the potential sources in accident production. Then, the promising ITS functions could be easily conditioned based on their capability in terms of needs fulfillment.

This chapter describes the preliminary activities carried out during the first stage of the work aiming to specify a small number of ITS applications with high estimated safety potential that would be used as the basis for acceptability assessment in the later phase of the study. It first it recalls the motivation behind the determination of accident initiating factors. This is followed by providing an explanation of the materials and procedures used to identify both drivers' needs and ITS technologies to correspond to them. Finally, the selected systems along with their functional descriptions are presented.

3.1. EVALUATION OF DRIVERS' NEEDS AND ITS TECHNOLOGIES TO MEET THEM

Successful deployment of all produces involves a clear understanding of various consumers' demands, views, and needs [56]. Especially when it comes to ITS, focusing on the solution and technology implementation in vehicles without considering actual needs of the drivers have negative impacts on the quality and effectiveness of the systems. It seems that technology is the driving force in most of ITS programs, and consequently there has not been sufficient attention given to the genuine needs of the users. In other words, ITS devices are developed when they are feasible rather than when they are needed [63]. In the absence of basic research with a view to reaching a deep understanding of what drivers' needs actually are, there is a possibility that the development of ITS products will follow a series of priorities that are decided by automobile and electronic professionals. If their priorities do not match the needs of the drivers, there is a risk that most of the effort will go into development of systems which will be never used by the consumers [11, 21]. If these aids have to be efficient, designers and implementers must ensure that the applications are in line with the drivers' needs [21].

From driving hazards to drivers' needs

Regardless of the evident easiness of somewhat automatic procedure where drivers operate, driving a vehicle can be presumed as a difficult and complicated activity that constitutes part of a complex process where drivers' regulatory functions (i.e. throttling, braking, changing gear, and steering) are occasionally over requested. Consequently, considering inevitable limitations on the drivers' adaptation capacities, this may result in driving system malfunctions. Accidents are the proof of this exceeding capacity, each road traffic crash case is a consequence of failures in regulatory functions which generally enable drivers to compensate for driving system deficiencies [35]. These failures represent the drivers' needs for support that ITS electronic aids must address to be efficient [21]. Subsequently, as Karabatsou, et al. claim, one of the finest approaches for gaining insight into the related mechanisms is to investigate these failures, their initiating factors and the specifications of the context in which they may arise. For this reason, comprehensive accident analysis facilitates revealing these operational malfunctions, in association with situational driving context (e.g. road surface or weather condition) and internal driving context (e.g. driver's status) [35].

What is a driver's need?

A driver's need is not such an easy concept to describe, as it can be noticed from the wide range of descriptions to be found in every single dictionary [35]. From a systemic standpoint, a driver safety need is attributed to lack of something inside the driving system operation. Traffic accidents are the explicit symptom of these deficiencies indicating what is deficient to the driver while trying to deal with the complications of the driving task. Consequently, a drivers' need in safety may be seen as a negative aspect of drivers' failure in controlling the vehicle. From an optimistic view, such a need can be used to define an appropriate application to compensate the associated failure. A critical event could be prevented, when its respective need has been fulfilled [21]. Drivers' safety needs must not be confused with eventual wishes that can be stated by the road users (i.e. through surveys, etc.). They have to be derived from in-depth analysis by accident experts of the functional failures drivers experienced in actual accident situations [21, 35].

Accordingly, the study was initiated with an analysis of the potential sources of traffic hazards which threatens the safety of road users. The main objective of such an analysis in the frame of this study is to identify the most relevant ITS functions that can correctly address drivers' needs in terms of safety. This requires a clear and precise description of the context in which the threatening situations arise. In-depth accident studies enable data collection in sufficient details through defining driving dangers on the roads.

The advantages of setting up a list of accident initiating factors and crash scenarios in this study are;

- Specification of traffic accidents causation from a factor-centered stand point.
- Identification of the actual safety needs drivers have of support in their driving by detecting relevant factors which contribute to traffic accidents.
- Analysis of crash scenarios and their reflected safety needs in relation to the various ITS functions base on their capability in avoiding or mitigating the respective hazard.
- Giving the background to the development of the list of promising ITS equipment that would be assessed for their acceptability.

How to determine the needs?

As mentioned above identification of drivers' needs requires an extremely detailed analysis of crash cases, as they can be more or less directly deduced from potential sources involved in accidents occurrence [35]. In order to put the analysis forward, it was decided to get benefits of expert judgment. To achieve this goal, qualitative interviews with a crash reconstructionist who was the head of the traffic police in Tehran, Iran were executed. Interview with traffic specialists was favored as they cope with several accidents day by day. They perform comprehensive analysis of crash cases via cinematic reformation and accurate interrogations with related motorists [35]. Thus, the elicited risk factors can be deemed as actual representatives of drivers' needs that call for safety measures. During the interview, the interviewee was asked to answers the questions of: WHAT are the most hazardous driving situations and their consequences?, WHY they are happening?, HOW they can be avoided?, from his own perspective.

In total, 25 driving risky situations were elicited from the interview. These crash scenarios were analyzed case-by-case and the respective needs to be fulfilled by ITS functions were diagnosed. The identified risk factors indicate strong need that drivers have of support in their driving while attempting to deal with the complexity of the driving task. Problems related to impaired driving, speeding, mechanical malfunctions, tailgating, colliding with obstacles, unsafe lateral movements, restricted visibility, non-conformity to the traffic rules, and vehicle's directional instability were considered by expert judgment to be the main factors initiating accidents. It is not appropriate here to describe all details and findings emerged from this analysis. An inventory list of accident initiating factors and the needs they reflect can be found in Appendix A.

How to determine systems to support drivers' needs?

Once drivers' safety needs have been clearly defined from crash scenarios, still they had to be assessed for the ability of ITS equipment to correspond to them. The capability of the ITS technologies to properly fulfill drivers' needs had to be evaluated by confronting the functionalities of each system with diagnosed difficulties drivers experienced in actual accident contexts. This required a clear and detailed description of the way a particular technology operates. Therefore, a comprehensive review on the exiting literature was done.

A list of 25 ITS applications were assessed for drivers' needs. The information regarding each system and how it can fulfill divers' needs provided in Appendix B.

In order to keep the study on a manageable size and bearing in mind that the number of 25 systems is too high to be evaluated adequately by the respondents, it was decided to choose only the systems which have expected to confer the greatest benefit to the road users from a safety point of view. This list was therefore reviewed by the traffic experts based on their evaluation of what are promising systems to address the most common causes of road crashes. This review resulted in selection of the following in-vehicle ITS technologies for inclusion in the study:

- Alcohol detector and interlocks (Alco-lock)
- Drowsy Driver Warning (DDW)
- Adaptive Front Lighting (AFL)
- Night Vision (NV)
- Intelligent Speed Adaptation (ISA)
- Curve Speed Warning (CSW)
- Adaptive Cruise Control (ACC)
- Forward Collision Mitigation (FCM)
- Intersection Assistant (IA)
- Lane Change Support (LCS)
- Vehicle Monitoring System (VMS)
- Electronic License Key (ELK)

3.2. DESCRIPTION OF CHOSEN SYSTEMS AND THEIR CRASH RELEVANCE

In the paragraphs that follow, a brief functional description of each system and its crash relevance is presented. For more detailed information, the reader is referred to Appendix B.

Alcohol detector and interlocks

Description: The motivation behind the development of Alco-lock systems is to eliminate the risk of intoxicated driving. The primary functions are units incorporated into the start key of the automobile. The operator needs to blow into a narrow plastic pipe connected to a built-in unit that is capable of analyzing the individual's Blood Alcohol Content (BAC). The car will stay immobilized, until the alcohol detector unit determines that the user is fit to drive [6]. Some other systems using biotechnology can also monitor the driver's BAC through his/hers skin in touch with the steering wheel while the car is being used, and if it was necessary, the application will warn the operator to stop. If the user neglects the advice, then the automobile's head-lights will start blinking. Covering the hands with gloves cannot cheat such system. Except alcohol, biological units are capable of detecting illegal drugs [33].

Crash relevance: This system is designed to prevent the occurrence of accidents where intoxication by alcohol or other illicit drugs is the major contributing factors. Regan, et al. estimated the predisposition of the breath-based test interlocks to reduce the number of alcohol related crashes by 96% [51].

Drowsy Driver Warning

Description: Drowsiness detection applications can alert the users whenever they assessed to be sleepy or impaired. The automatic systems can intervene into driving activities and bring the car to a standstill. These functions are able to notice operator's drowsiness or inattention by monitoring both user's (e.g. head and eye movements) and vehicle's (e.g. lateral movement and speed) behavior [6, 8].

Crash relevance: Drowsy driver warning system can address crashes where driver's diminished alertness due to drowsiness or fatigue is the contributing factor. Estimations on expected safety benefit with fatigue monitoring system with wide implementation implies up to 15% reduction of all fatal and injury related crashes on motorways [53].

Adaptive Front Lighting

Description: This systems incorporate one or a number of technologies that serve to optimize driver's and other road users' visibility of the road environment considering vehicle's speed (Speed Adaptive Headlights), the level of the environment's luminance (Automated Headlights), steering wheel angle (Cornering Controlled Headlights), and presence of an oncoming vehicle (Auto-dimming Headlights) by setting the headlights' luminance appropriately without driver's interference [6]. Speed adaptive headlights can regulate the pattern of luminance to befit varying speeds. At low speeds the radiation pattern is adjusted outward and downward to allow an enhanced viewing of the road surroundings and road surface while the beam is projected narrower and longer for higher speeds in order to provide the driver with a greater visibility of farther distances [6, 8]. Moreover, automated headlights are aimed at reducing driver's workload allowing headlamps' auto-light setting. These systems continuously monitor the level of environment luminance and turn the front lights on in case of detecting a minimum threshold of luminance [6]. Further, old-style front lights only illuminate the road path right in front of the vehicle during cornering rather than the intended path. Cornering controlled front lights using the data from steering wheel angle or satellite maps adjust the direction of the auxiliary beams to provide an ideal view of roadway for the driver when he/she turns into a curve [6, 8]. Auto dimming headlights is also an additional feature of intelligent lighting systems that can be also beneficial for other road users since it has the ability of dimming the high-beam headlights in cases where an oncoming or approaching vehicle is detected in order to make sure that the headlights beam will not dazzle other road users [6].

Crash relevance: Intelligent lighting system can reduce the likelihood of accidents in which adverse viewing because of inappropriate set of headlights is the contributing factor. Bayly, et al. reported that adaptive front lighting systems have the verified potential to affect 0.5 percent of all traffic fatalities while the full potential (i.e. in case of large-scale utilization) is 8 percent [6].

Night Vision

Description: Night Vision Devices, using built-in infrared light sources (i.e. active systems) or thermal imaging cameras (i.e. passive systems), provide the user with an improved view of the roadway by projecting a more clear vision than the driver's current field of view. This enhanced visualization of the vehicle's path is further than the visual field that the vehicle's upper beam headlights can provide and has the advantage of not dazzling oncoming traffic flow. The improved image of the surroundings is presented to the driver through a Heads-Up Display (HUD) overlaid on the vehicle's front glass shield [6, 8].

Crash relevance: This system can significantly affect the accidents where adverse visibility due to darkness and bad weather is the contributing factor. According to Lind, et al. estimations on expected safety benefit with night vision systems implies 45% reduction of vulnerable road users including pedestrians and cyclists in Sweden [39].

Intelligent Speed Adaptation

Description: In general ISA refers to any system which helps the drivers to keep the speed of their vehicle based on the government' predefined speed limit in a given area [8]. Three levels of intervention employed for implementing ISA systems: advisory, voluntary, and mandatory. Advisory systems can only warn the user if he/she exceeds the legal speed limit without taking any action in order to limit the speed of the vehicle. Voluntary systems can limit the speed of the vehicle to the prevailing speed limit when it is enable, but they can be disabled by the drivers at any time they want. The highest level of control over the vehicle is related to mandatory systems which ensure that the driver cannot slip out of legal speed limit [12]. The local speed limits can be communicated to the automobiles either via roadside transponders or through GPS technology [6]. A GPS based ISA system incorporates satellite positioning linked to a digital map database that contains information such as maximum driving speed for the road network [8]. The predetermined speed limits can also be obtained using optical recognition technologies (i.e. traffic sign recognition system) [16]. The ideal ISA systems are variable and dynamic systems which are capable for adjusting the speed limit by recognizing certain locations (e.g. school zone, pedestrian crosswalk) or certain conditions (e.g. weather condition, traffic congestion) [6, 12].

Crash relevance: It is assumed that ISA would affect all speed related accidents. Carsten and Tate claim that a mandatory intelligent speed adaptation system expected to reduce 20% of related injury accidents, as well as another 37% of fatal accidents. A dynamic version of mandatory ISA system may result in the reduction of relevant injury accidents up to 36% and 59% of fatal accidents [12].

Curve Speed Warning

Description: This system can be assumed as a specialized type of speed adaptation systems which is precisely designed to prevent the operator from taking a bend with an unsafe speed. For this reason Curve Speed Warning integrates three services: the first service encompasses procedures for detecting oncoming bends on the roadway; the second function provides the driver with information on the safe speed to be pursued which is computed based on the degree of curvature of the coming curve; and the third function imposes automatic speed control of the vehicle so as to achieve a safe speed when the driver dose not react by him/herself [24]. Information about the characteristic of the approaching curves can be drawn from preexistent satellite maps of the road. Future systems may take other parameters, including road pavement and climate condition, into consideration so as to optimize the computation of the safe speed [8].

Crash relevance: This system is designed to prevent the occurrence of any type of crash that excessive speed while bending is the contributing factor. This system therefor can eliminate the probability of off-path, multi-vehicle, and rollover crashes on curves. Lind et, al. estimated the expected safety benefit with curve speed warning in reduction of all road crashes by 13% in case of large scale deployment [39].

Adaptive Cruise Control

Description: ACC facilitates travelling on roads by releasing the driver from regulating functions to keep an appropriate headway distance in sparse traffic flows. ACC takes the preset speed till its detector radars notice a leading vehicle. The fitted automobile gradually changes the speed via active throttling and braking so as to adapt to the speed of the vehicle in front of it while maintaining the preset following distance. As soon as the trajectory determined to not be obscured, the device will spontaneously make the vehicle to reaccelerate and move at the preselected speed [8, 48]. Typical cruise controls function at speeds greater than 40 kilometers per hour and are not suitable for using in crowded traffic situations. The new generation of ACC which is also known as low speed ACC or stop-and-go has been specifically developed for driving in metropolitan areas and

overcrowded traffic flows. Such systems are able to keep following the stream of the traffic immediately and decelerate the car until it comes to a standstill [8, 48].

Crash relevance: ACC assist the driver in keeping safe distance from leading vehicles and therefore can prevent the occurrence of rear-end conflicts due to tailgating [6]. This system can also reduce the risk of driving in monotonous and tiresome environments. As Abele and colleagues claim, the probability of rear-end collisions with ACC would be reduced by 25%. The authors also discuss that ACC and its functional enlargement (i.e. stop-and-go), apart from their safety benefit, have a significant potential to increase road capacity by reducing traffic congestion [1].

Forward Collision Mitigation

Description: Collision warning systems are capable of assisting the drivers to evade approaching threats by alerting them whenever an object is assessed to be a hazardous obstacle on the trajectory. The prevention systems provide a supplementary avoidance feature which intervenes with the driving task by automatic braking and deceleration in cases where the driver does not respond properly or the crash determined to be unavoidable. These systems considering the speed and directional movement of various objects on the road path determine the potential dangers. Collision avoidance systems can be seen as specific types of ACC with limited performance [58]. Some systems can also spontaneously tense seatbelts in a pre-collision situation [8]. Forward collision warning systems can also facilitate safe distance keeping from leading vehicles. The more advanced types of forward collision warning and prevention systems can not only detect the probability of colliding with vehicle ahead but also the probability of colliding with other generic obstacles such as pedestrians and cyclists [51].

Crash relevance: This system have a remarkable potential to reduce the risk of rear-end, head-on, and object crashes. Forward collision warning systems were expected to be effective at reducing all rear-end crashes by up to 57% [6].

Intersection Assistant

Description: Intersection assistant systems serve to support the driver in situation assessments and avoid collisions in critical intersecting conditions. As the traffic crossing at most of the intersections are obscured by obstacles like other vehicles or buildings, vehicle's built-in conventional sensors singly are not effective enough for detecting threatening conditions at intersections. Thus, the ideal way for detecting other vehicles in the range of intersections is corporative wireless communication technologies (i.e. Vehicle-to-Vehicle and Road-Vehicle-Communication) combined with satellite positioning and digital map. Once vehicles approach a junction, they exchange relevant information such as their speed and location through communication. The system processes the input data and reacts correspondingly. Data is represented via on-board displays to inform driver about existence of other vehicles passing through the intersection. In conflict situations, IA warns the driver to stop for the hazardous stream of traffic or intervenes directly into the brake, if the driver neglects warning [7].

Crash relevance: This system is designed for reducing the risk of multi-vehicle conflicts at intersections where excessive speed, inattention, or obstructed view may be contributing factors. In a simulator evaluation of the effects of IA, Benmimoun and Chen reported about 20% reduction in all multi-vehicle accidents at intersections in case of system-wide deployment [7].

Lane Change Support

Description: Lane change support systems serve to assist the operator during lane changings on the road network by monitoring adjacent lanes of traffic and warning the driver to impending hazards. Various radars and sensors are engaged to monitor vehicle’s lateral blind space, and alert the driver to identified dangers in the blind spots. Warnings are presented to the user through visual symbols or auditory messages [6]. More advanced systems, employing longer range radars, may also track the road ahead to detect fast approaching vehicles which may pose head-on collision threats in lane changes. Avoidance systems can prevent unsafe lane changings through automatic corrective counter steering [8].

Crash relevance: LCS can reduce the likelihood of Side-swipe or head-on conflicts in overtaking and lane changing maneuvers [6]. According to Lind, et al. lateral collision avoidance systems have the potential to affect 20% of side-swipe fatalities in Sweden [39].

Vehicle Status Monitoring Systems

Description: These systems are a number of independent services that constantly monitor the behavior of various components of the vehicle and alert the user to any abnormalities instantly. For example, problems related to vehicle’s engine, tires, brakes, ABS, and so on can be diagnosed by VMS [26]. A pertinent example of vehicle monitoring systems is Tire Pressure Monitoring System (TPMS) which is specifically designed to provide the driver with the relevant information on the condition of the vehicle’s tires [2].

Crash relevance: This system can minimize the probability of accidents attributed to malfunctions or problems in vehicle system (e.g. tire defects). The effectiveness of various vehicle diagnostic systems has been calculated separately. For example, consistent with eSafety forum report, wide implementation of TPMS in Germany can reduce crashes related to tire malfunctions by up to 35% [22].

Electronic license key

Description: Electronic license key is designed to enhance road safety by stopping unlicensed drivers from operating a vehicle. Driver’s license in the form of a smart card will be used to start the engine. A variety of information such as drivers’ medical details can be stored on these electronic devices. Future electronic licenses may also be capable of monitoring and recording the activities of the drivers to see whether or not they violate traffic rules [6].

Crash relevance: According to Regan, et al electronic license key can decrease the number of accident which unlicensed drivers are involved down to 95 percent [51].

Table 1 represents a brief description of the driver’s needs deduced from driving risks and how ITS technologies satisfy these needs.

Table 1. Summary of drivers’ needs and the capability of ITS technologies to fulfill them.

Risky situation	Respective safety need	Relevant ITS	Need fulfillment
Drinking and driving	Stop a drunk driver from using a vehicle.	Alcohol detector and interlocks	-Warn the user if he/she is assessed to be drunk. -Immobilize vehicle to stop the intoxicated driver from using the car.
Driver’s sleepiness or fatigue	Stop a sleepy or tired driver from driving by taking precautionary actions.	Drowsy Driver Detection	- Warn the driver in case of driving with impaired alertness.
Inappropriate set of headlights	Increase the driver’s and other road users’ view of the road environment ahead and on curves by setting the headlights’ luminance appropriately	Adaptive Front Lighting	-Provide a better viewing of the road surroundings that suits various speeds by adjusting the pattern of luminance. -Improve the visibility of the road environment by adapting the brightness of the front lights according to the level of ambient luminance.

	without driver input.		<ul style="list-style-type: none"> -Increase the visibility of the vehicle's path on curves by directing the additional lighting to the right or left side of the car depending on the direction of the approaching bend. -Enhance the visibility of the other road users by auto-dimming high beam headlamps when oncoming traffic flow is detected.
Bad visibility conditions (fog, rain, darkness, etc.)	Enhance the visibility of the roads with adverse viewing scenes.	Night Vision	<ul style="list-style-type: none"> -Provide the driver with an enhanced view of the road in poor visibility situations including darkness or bad weather conditions.
Exceeding the speed limit	Keep the speed of the vehicle based on the predefined speed limit in a given area.	Intelligent Speed Adaptation	<ul style="list-style-type: none"> -Warn the driver when he/she slips out of the local speed limit. -Adapt speed of the vehicle consistent with the legal speed limit in a certain area.
Inappropriate speed on bends	Prevent the operator from taking a bend with an unsafe speed.	Curve Speed Warning	<ul style="list-style-type: none"> -Determine the coming curve's radius. -Recommend a safe speed threshold for the approaching curve. -Warn the driver to a dangerous speed. -Avoid an impending hazard by imposing speed control when the driver does not respond appropriately.
Collisions with other vehicles- Tailgating	Avoid colliding with dangerous obstacles on the vehicle's forward path by taking precautionary actions.	Forward Collision Mitigation	<ul style="list-style-type: none"> -Detect common obstacles such as pedestrians, cyclists, vehicles, or other stationary or moving objects on the road path ahead. -Alert the driver to an impending collision. -Intervene with the driving task if the driver was not responding.
Driving in monotonous and tiresome environments- Tailgating	Release the driver from regulating functions to keep a safe distance in both sparse and congested traffic flows.	Adaptive Cruise Control	<ul style="list-style-type: none"> -Detect a slower vehicle ahead. -Adjust to the speed of leading vehicle while keeping the preset headway distance. -Reset to the predefined speed when the traffic clears.
Failure to yield right of way at intersections	Support the driver in the situation assessments and avoid collisions in critical intersecting conditions.	Intersection Assistant	<ul style="list-style-type: none"> -Provide the driver with information regarding presence of other vehicles in the approaching junction. -Warn the driver if a conflict situation is recognized. -Avoid collisions by intervening with driving tasks if the driver is not responding.
Overtaking and lane changing maneuvers	Prevent unsafe lane changes by recognizing risks in adjacent lanes of traffic.	Lane Change Support	<ul style="list-style-type: none"> -Spot surrounding vehicles that may present hazards when overtaking. -Warn the driver to the impending risks. -Prevent crashes in overtaking or lane changing maneuvers.
Mechanical malfunction	Monitor different systems of the vehicle in order to alert the driver to potential malfunctions or problems.	Vehicle Monitoring System	<ul style="list-style-type: none"> -Provide the driver with information on the status of different sub-systems of the vehicle. -Warn the driver if any potential malfunctions were detected.
Unlicensed driving	Stop an unlicensed driver from operating a vehicle.	Electronic License Key	<ul style="list-style-type: none"> Prevent starting the vehicle if the driver does not hold a valid driver's license.

4. ACCEPTABILITY ASSESSMENT

The present chapter outlines the activities undertaken to assess the acceptability of candidate ITS technologies from the prior phase of the research. First the issue pertaining to the lack of an operational description of acceptability and its underlying constructs, which is usually disregarded in researches examining ITS technologies' acceptance, is addressed. This is followed by a brief description of the method and procedure used to evaluate the acceptability. Finally, the results of the executed survey are presented and discussed.

4.1. WHAT IS MEANT BY ACCEPTABILITY?

As mentioned in the first chapter, with the rapid advances in computing, information, and communication technologies in recent years the emphasis in the field of Intelligent Transportation Systems has been shifted from technological feasibility concerns to one that is focused on the users. If the desired benefits of ITS applications are to be realized, the products must be accepted by the eventual users [51]. Steele indicates that road users are the driving force behind the demand for such technologies, and their acceptance level of ITS will assess the degree of its failure or success [60]. The acceptability of intelligent transportation systems is therefore a vital issue that has to be addressed early in the design and development [51]. Acceptability of some ITS applications to the various sub-groups of drivers is the main focus in this chapter. But before the evaluation of acceptance could begin, it is necessary to understand what is meant by acceptability and the entities that make it up.

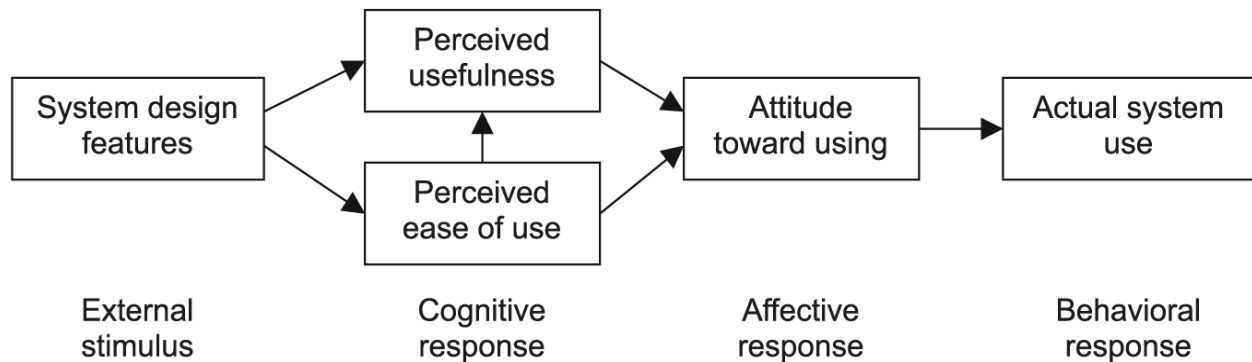
In the realm of ITS research, the concept of acceptability is often taken for granted. While it seems that everyone knows what acceptability is and all admit that it is important, yet we see there is inconsistency among studies as to what is meant by acceptability and how it should be measured [51]. It is perhaps appropriate to claim that there are as many questionnaires and procedures to evaluate drivers' acceptance of ITS product as there are papers of acceptability [64]. This is probably expected given the wide range of entities making up acceptability as well as the variety of ITS technologies. Without establishing a clear understanding of acceptability and its underlying constructs that have been used to measure the consumers' acceptance of ITS products, inter-study comparisons would be challenging, if not impossible. If every research group were to present from the beginning an operational explanation of acceptability, then the interpretation of the findings and inter-study comparisons would be facilitated [51]. Therefore, a definition of acceptability as it applies for the purpose of the present study is provided.

Over the last decade a number of competing theoretical models and frameworks have been proposed to explain and forecast the user acceptance of Information Technology (IT) based products [67]. Surprisingly, almost neither of these works is mentioned in studies investigating the acceptability of ITS applications. The broad research conducted on IT acceptance has resulted in identification of a diverse set of acceptability determinants ranging from individual aspects of technology (e.g. utility, usability, effectiveness, reliability) to psychological (e.g. subjective norm, personality, behavior) and sociological (e.g. age, gender, work type, level of education) characteristics of the users [67]. It is beyond the general scope of the present research to determine all of the possible constructs, the relationship among them, and their relevant contribution to the acceptability of ITS technologies. Furthermore, many of the determinants that are purported to influence user acceptance have not been proven for their validity over consumers and technologies [51].

One of the most primitive and powerful models which has been validated repeatedly is the Technology Acceptance Model (TAM) [67]. The conceptual framework suggested by TAM is depicted in Figure 2. In this model, Davis suggests that a potential consumer's attitude towards a particular technology is assumed to be the key element for determining whether he or she will actually accept or reject it. The attitude toward using an application, itself, is a function of two main factors encompassing usefulness and ease of use [15]. Davis

describes perceived usefulness or utility as the extent to which a prospective user believes that adopting a given technology would improve his or her task performance. Perceived ease of use or usability is defined as the extent to which a user believes that interacting with an application would be effortless [14]. In this model, perceived utility is hypothesized to be affected by perceived usability. System design features, in turn, have a causal effect on both perceived usefulness and usability. Subsequently, it can be presumed that system characteristics indirectly influence users' attitudes toward system usage as well as their actual usage behaviors [15].

Figure 2. Technology Acceptance Model. (Davis, 1993, p.476)



According to the results of a field study conducted by Davis to test his hypothesized model, it was found that perceived usefulness is fifty times more influential than perceived ease of use in determining consumers' acceptance of a computer system. This indicates that users of a particular application may be willing to endure its poorly designed interface so as to get advantage of the system's functionality which enables them to accomplish their task with a greater performance. Contradictory, no amount of usability can encourage people to utilize a system which does not serve a useful purpose [15]. Besides, as Chau claims considering the effect of time and user experience, it can be argued that usability has no strong or direct influence on users' intentions or perceptions of long-term utility. In other words, as consumers' reference frame moved further than instant task at hand, matters relating to usability came to be less important [13]. This has also been shown within other studies in the realm of ITS. For instance, Brackstone and McDonald have reviewed several researches on Adaptive Cruise Control acceptability and concluded that respondents' perspectives can change once they gain experience with the system [9]. This is not for suggesting that providing user friendly interfaces is not important for the consumers to accept a given technology, but what is more important for them is what the system can do to make their life easier or safer [11]. Taking this into account and considering the scope of the present study, which targets more general aspects of ITS acceptance rather than testing the acceptability of various graphical user interfaces, perceived ease of use was not regarded for measuring users' attitudes toward candidate systems.

4.2. GENERAL PROCEDURE

This section describes the procedure used in conducting the survey including the design and development of the questionnaire as well as the criteria for selecting and dividing the participants into various groups of research interest.

4.2.1. DESIGN AND DEVELOPMENT OF THE QUESTIONNAIRE

The questionnaire was designed at the final stage since constructing the questions needed identifying and finalizing the ITS technologies to be examined in advance. This method was favored over the other research

methods as the ideal means for addressing the objectives of the present study. The questionnaire is an effective and efficient way to gather information from large sample sizes. Through questionnaire data can be obtained in less time and with lower cost than it would take for conducting individual interviews or tests with advanced prototypes [17]. This is not to say that person-to-person field testing with advanced prototypes is unimportant, but they may be more suitable for the usability testing which is the focus of acceptability assessment later in system development [51]. Furthermore, advanced prototypes for all the technologies under examination were not easily available. Thus, apart from being less costly and time-consuming than the other tools, questionnaire seemed to be more appropriate to meet the research goals.

Once the questionnaire constructed, a rating task has been formulated by which the participants were asked to indicate their perceived usefulness regarding various systems under investigation. Using a rating scale was preferred to a choice task, since it demonstrates the desirability level of an alternative while a choice only shows that an alternative is favoured over another one [41]. As Denscombe claims, using a consistency style throughout the questionnaire, on one hand may cause the participant to fall into a pattern of answers for example by putting 5 down as the answer for all questions, and on the other hand it allows the participant to get familiar with type of questions so that they can answer more quickly and without confusion [17].

Consequently, the adopted method required neither interaction with the systems nor previous experience. All that was required was to include a brief and non-technical but informative description of each considered system's functionality in the questionnaire to make sure that all the respondents have the same understanding of what each system is and what it can do to improve the safety of the drivers in general. According to Denscombe's recommendation, in order to collect, record, analyze, quantify, and compare the results of the questionnaire from a large number of respondents more quickly, self-completion questionnaire was designed for collecting data in this phase [17]. The questionnaire comprised a number of close-ended questions plus one open question. The first part of the questionnaire was dealing with the background information of the participants pertaining to both driving (e.g. frequency of driving, driving experience) and socio-demographic (e.g. age, gender, country) characteristics. In the second section, the participants were questioned to specify the systems in the questionnaire which they were familiar with. In the third part, following a brief description of every system's functionality, alternatives were presented and the respondents were asked to evaluate the usefulness of each system and choose between its different states (i.e. informative, automatic) independently. The evaluation of usefulness was based on a symmetric six-point useful-useless rating scale. This was followed by a question asking for participants' most preferred function among proposed systems that they most like to have in their current or future cars. The questionnaire was closed with an open-ended question where participants were asked to state their concerns and expectations that have to be met in order for ITS technologies to be acceptable to them.

The questionnaire can be seen in Appendix C.

4.2.2. SELECTION OF PARTICIPANTS

Certain primary assumptions were made to select the participants. First, although commercial vehicle drivers and motorcyclists are over-involved in some types of crashes, they were not considered for participating in the questionnaire. This was because motorcycles and commercial vehicles in comparison to passenger cars make up a small proportion (i.e. approximately 25%) of total motor vehicle's annual production around the world [44]. Second, although the probability of unlicensed drivers under the age of 18 years to be involved in different crashes is very high, they were excluded from consideration in this study. The reason for this was that the actual number of young drivers aged below 18 years who involved in traffic accidents is very small. Furthermore, this age group's impressions on the acceptability of ITS products cannot be assumed very meaningful because of their limited experience in driving.

Accordingly, to be eligible for participating in the questionnaire, the individuals had to:

- Be aged 18 years or older.
- Not drive a motorcycle or commercial vehicle.
- Hold a valid driving license.
- Currently drive an automobile.

Randomly approached people at various public places were asked if they would be interested in participating in a questionnaire on intelligent systems designed to decrease the road accidents. It was required first to establish the eligibility of individuals who expressed interest for participating in the questionnaire.

4.2.3. SUB-GROUPS DIVISION

As mentioned before, the emphasis of the execution of the questionnaire was to capture significant differences between different categories of drivers' sub-groups defined by age, gender, country, driving experience, and frequency of driving. The categorization criteria for each of these independent variables are presented below.

Age: Considering the age, drivers were categorized into three groups of: 30 years and under, 30 to 50 years, and 50 years or over. As Dulisse claims drivers fatality rates concerning their age form a U-shape curve which shows that both younger drivers and older drivers are remarkably overinvolved in traffic accidents. The drivers in the middle group age are at the bottom of this curve. The drivers over 50 may begin to experience difficulties at the wheel due to decreased response time, vision changes, or side effects from prescription drugs [19]. The high probability of the younger drivers to be killed in car accidents might be attributed to their emotional immaturity as well as the lack of experience.

Country: With the purpose of studying the probable variances between drivers' sub-groups with respect to their country of origin, it was decided to compare perceptions of drivers from Iran as a representation of countries with highest rate of traffic deaths and Sweden as an example of countries with lowest rate of road fatalities. According to World Health Organization report the estimated road fatality rates per 100,000 population in 2010 in Iran was 34 while in Sweden it was 3 [70]. This significant difference in death rates between these two countries implies the likely disparities among their drivers acceptance of ITS devices.

Frequency of Driving: In order to examine the influence of driving frequency on the acceptability of ITS to the respondents, the subjects were divided into two random groups based on the median value of the annual number of kilometers traveled by the participants.

Driving Experience: With the intention of exploring the likely association between driving experience and the level of acceptance, respondents who indicate higher respectively lower driving experience than average of the data set have been considered.

4.3. ANALYSIS OF QUESTIONNAIRE RESULTS

In this section the results of the executed questionnaire, aiming to explore the likely acceptability of candidate ITS products to various groups of drivers are presented and discussed.

4.3.1. PROFILE OF THE RESPONDENTS

The data collection was based on a similar questionnaire administered among car drivers in Gothenburg and Tehran. As most of the statistical measurements tests are sensitive to unequal sample sizes, it was tried to achieve an equal distribution of respondents in categories of each considered group. In total, 150 eligible

drivers' responses were considered for data analysis. The mean age of the sample was 41.5 years (SD 14.1 years). Approximately each category of the age group encompassed one third of the sample. With regards to gender, half of the respondents were male and half were female. Participants were equally divided in two categories pertaining to their country of origin. In terms of driving characteristics, on average individuals had been driving a car for 20 years (SD 13.5 years) and traveling annually 14,000 kilometers (SD 9866 kilometers). Table 2 represents participants' composition concerning their background characteristics.

Table 2. Background characteristics of respondents

Characteristics	All Drivers (n=150)
Age:	
mean	41.49
standard deviation	14.11
<=30	33.3%
30< <50	33.3%
>=50	33.3%
Gender:	
Male	50%
Female	50%
Country:	
Iran	50%
Sweden	50%
Driving experience:	
mean	20.04
standard deviation	13.54
Annual number of kilometers:	
mean	14216
standard deviation	9866.7

4.3.2. FAMILIARITY WITH THE SYSTEMS

Approximately half (54 %) of the respondents were familiar with the ITS concept. Vehicle Monitoring System (36%), Adaptive Cruise Control (30%), followed by Intelligent Speed Adaptation (22%), Drowsy Driver Warning (21%), and Adaptive Front Lighting (20%) were quite well known among the drivers. The less known features were sequentially Intersection Assistant (1%), Curve Speed Warning (2.5%), Forward Collision Mitigation (4.5%), Alcohol Detector and Interlocks (5%), Electronic License Key (7.3%), and Lane Change Support (8%). This may be because that well known systems have been on the automobile market for some years while others are either not commercially available or just being introduced to the market. Table 3 depicts the respondents' familiarity with the concept of ITS in view of their background characteristics.

Table 3. Familiarity with the systems considering background characteristics of the respondents

Characteristics	Familiarity with proposed systems
Age:	
<=30	35.1%
30< <50	40.7%
>=50	24.2%
Gender:	
Male	68.8%
Female	31.1%
Country:	

Iran	38.1%
Sweden	60.9%
Driving experience:	
<=20	55.5%
>20	45.5%
Annual number of kilometers:	
<=14,000	49.3%
>14,000	51.7%

In terms of gender male drivers appeared to be more familiar (69%) than female drivers with the concept of ITS. It may be because of the fact that females are less interested in using information technology based systems than males are. Generally mid aged drivers were more familiar (41%) with the systems than the other age groups. This higher acquaintance compared to younger drivers may be attributed to the greater driving experience the mid aged drivers have. Besides, generally older people do not view technology as the necessity of life as younger people do [69]. In particular, Swedish drivers appeared to be more aware of various ITS technologies (61%) than the Iranian drivers. This can be interpreted as world's development of advanced safety products is driven predominantly by research and development efforts in USA, Europe, and Japan [11], while Iran lags behind the rest of the world with regard to the development and implementation of intelligent transportation systems. Subsequently many vehicles produced in Europe (e.g. VOLVO Cars) are currently equipped with some types of ITS functions such as ACC and AFL but domestically produced automobiles in Iran (e.g. IRAN KHODRO & SAIPA) may be fitted only with some rudimentary types of static speed alerting and parking assistant system. The pattern of participants' familiarity with ITS concept across driving characteristics was approximately consistent.

4.3.3. COMPARING ACCEPTABILITY AMONG GROUPS

Age, gender, country, driving experience, and frequency of driving were cross-tabulated against participants' ratings for the usefulness of proposed ITS technologies. The differences in acceptability of ITS devices to the various groups of interest, which were revealed by inspecting the collected data, are presented in this section. It has to be noted that neither non-significant differentials nor slight-significant differentials which were considered to be inadequate for drawing conclusions are presented in this paper.

4.3.3.1. MATHEMATICAL PROCEDURE

Typically close-ended questionnaires result in quantitative data. Considering the kinds of collected data and the objective of the research, three types of mathematical statistics procedures were performed for task accomplishment. In order to determine how the level of overall responses was affected by various categories of an interested group, two-way ANOVA test with replication was executed [36]. Wherever the result of the two-factor ANOVA demonstrated a main effect of categories (e.g. male and female) of an independent variable (e.g. gender) on the overall responses, and/or a significant interaction difference between independent factors of two-way ANOVA (e.g. gender and entire systems) was found, since this difference could be between any or all of the systems and the categories of the interested group, at the second level, various two-sample Z-tests (e.g. gender and each system) were performed to identify where significance/s exactly exists. Z-test was applied rather than T-test, as the sample' size was greater than 30. Concerning age since the age categories were three, one-way ANOVA were used instead of Z-test [36].

4.3.3.2. EFFECTS OF INDEPENDENT VARIABLES

Correlation of Usefulness with Age

Regarding to the age of the respondents, the result of the two-factor ANOVA indicated a significant difference among various age groups' preferences, $F(2,114)= 8.15, P=0.0003$. Comparing the mean values, it can be concluded that averagely older drivers prefer the systems more than the other age groups do. However, regarding Intersection Assistant system, a great support was appeared from younger drivers. Table 4 demonstrates the significant differentials which were found based on the results of the performed one-way ANOVA tests among age groups in relation to each suggested system.

Table 4. Main effect of age on the acceptability of candidate ITS devices to the drivers

	Mean value age≤30 (n=50)	Mean value 30<age<50 (n=50)	Mean value age≥50 (n=50)	P value
DDW	3.5	4.1	4.3	0.003
NV	3.3	4	4.6	1.8E-8
FCM	4.2	3.8	4.6	0.0002
IA	4.3	3.8	3.2	0.002

Difficulties encountered by the older drivers due to natural aging process may cause this group of drivers to consider the systems, on average, more useful than the other age groups do. The high appeal from younger drivers can also be attributed to their limited driving experience.

While old drivers are over-represented in intersection accidents [51], it was found that the drivers of this group are significantly reluctant to accept Intersection Assistant system. If the intended safety benefits of this system are to be met, it is imperative to determine appropriate strategies for increasing acceptability of this product to older drivers.

Correlation of Usefulness with Gender

In view of the gender the result of two-factor ANOVA showed a main effect of gender on overall responses, $F(1,126) = 41.8, P=1.28E-10$, indicating that on average females prefer the systems more than males. Although regarding the Night Vision system, a significant stronger support among males than females was observed. Table 5 represents the significant differentials of conducted Z-tests between men and women in conjunction with each proposed system to determine where the significant differences between these two categories actually appeared.

Table 5. Main effect of gender on the acceptability of candidate ITS devices to the drivers

	Mean value Male (n=75)	Mean value Female (n=75)	P value
N V	4.25	3.70	0.003
LCS	3.38	4.05	0.0001
VMS	3.70	4.12	0.023
I A	2.98	3.65	0.001
ACC	3.33	3.97	0.001
FCM	3.50	3.98	0.008

The demand among male drivers with regard to the Night Vision system has a medical explanation indicating that men have poor night vision in comparison to women.

The high appeal from female drivers regarding Forward Collision Mitigation appeared to be promising, as drivers of this group are over-represented in rear-end collisions which are capable of being addressed by this technology [51].

Correlation of Usefulness with Drivers' Country of Origin

Concerning the respondents' country of origin, huge differences between Iranian and Swedish drivers' views were found, $F(1,126) = 25, P = 5.2E-07$, pointing out that the Iranian drivers consider the ITS systems more useful than the Swedish drivers do. Although based on the results of the executed Z-tests, it was appeared that ISA and LCA systems are supported considerably more by the Swedish drivers rather than Iranians. Table 6 represents the significant differences between these two categories of the interested group in conjunction with the proposed alternative systems.

Table 6. Main effect of country of origin on the acceptability of candidate ITS devices to the drivers

	Mean value IRAN (n=75)	Mean value SWEDEN (n=75)	P value
DDW	4.2	3.77	0.01
AFL	4.2	3.8	0.01
FCM	4.4	4	0.01
CSW	4.2	3.6	0.0006
ELK	4.2	3.6	0.001
ACC	3.8	3.4	0.03
VMS	3.9	3.5	0.02
ISA	3.2	3.7	0.02
LCA	3.5	3.9	0.01

Drivers from Iran feel the need for safety features more than the Swedish drivers do. This could be attributed to differences between these two countries regarding traffic situation, roads' condition, drivers' behaviors, and local driving norms [40]. For instance, curve speed warning is strongly preferred by the Iranian drivers, since Iran has lots of roads crossing over mountainous regions with many sharp curves which contribute to hazardous road conditions. As a pertinent example of differences in patterns of behavior between drivers of different cultures, in Iran speeding and frequent lane changing are quite common among drivers. The reason that these two systems rated comparatively low could then be mainly subject to this group of drivers' beliefs that they would be continuously given cautionary messages and warnings which would either distract or annoy them. This creates conditions where the ITS technologies most required and beneficial to them, will also be the ones that are rejected or least accepted because of unsafe ingrained driving norms [40]. At the same time, selection of FCM as the most favored function by the Iranian respondents indicates an appreciation of an actual solution to one other culturally specific issue that is the chaotic and complex driving environment.

The extreme variance between countries implies that culture has a critical effect on driving behavior and consequently plays an important role on drivers' acceptance patterns. Assuming this true, taking into account these differences is vital when designing ITS devices for a global market [40]. However, one can argue if all cross-cultural variances were regarded in developing ITS technologies, hazardous behaviors of drivers of a specific culture would become even worse [18].

Correlation of Usefulness with Driving Experience

In case of driving experience, two-factor analysis of variances showed no significant main effect of driving experience factor on raters' perceptions of ITS concept in general, $F(1,100) = 0.54, P = 0.45$, but the interaction between categories of driving experience and systems was significant, $F(1,100) = 3.07, P = 0.0004$. This demonstrates that more experienced drivers and less experienced drivers as the variables by themselves has no real effect on the respondents' general view of ITS concept, nevertheless there is a significant difference between these two categories of drivers in conjunction with at least one of the systems. Further analysis in the form of Z-tests revealed that more experienced drivers perceived Night Vision significantly more useful than less experienced drivers. Less experienced drivers, on the other hand, gave higher usefulness ratings for

Adaptive Cruise Control than more experienced raters. The significant variances between driving experience categories can be seen in Table 7.

Table 7. Main effect of driving experience on the acceptability of candidate ITS devices to the drivers

	Mean value Experience<20 years (n=62)	Mean Value Experience>=20 years (n=62)	P value
NV	3.5	4.4	7.04E-7

The pattern of perceived usefulness was approximately consistent across questionnaire respondents considering their driving experience. However, with reference to NV a high appeal from more experienced drivers occurred as they have probably driven in the dark on more occasions.

Correlation of Usefulness with Frequency of Driving

Considering the effect of the annual number of kilometers on ITS acceptability, the two-factor ANOVA did not show any significant influence of this factor on overall responses, $F(1,100) = 1.40, P = 0.23$, but an interaction between frequency of driving and systems was found, $F(1,100) = 3.43, P = 9.9E-5$. This indicates that although the frequent drivers' acceptance are not considerably differ from less-frequent in general but with regard to each system these two categories significantly affect the level of ratings for one or more systems. Thus, Z-tests were used so as to determine where the significant differences actually existed. It appeared that frequent drivers consider Night Vision and Drowsy Driver Warning systems more useful than less frequent drivers. Besides, less frequent drivers view Forward Collision Mitigation and Lane Change Support systems significantly more beneficial than frequent drivers. Table 8 depicts the results of the performed Z-tests where the significant differentials between mentioned categories of drivers were found.

Table 8. Main effect of driving frequency on the acceptability of candidate ITS devices to the drivers

	Mean value Annual km<14000 (n=62)	Mean value Annual km>=14000 (n=62)	P value
DDW	3.5	4.2	0.003
NV	3.7	4.2	0.02
FCM	4.4	3.9	0.002
LCS	4	3.3	0.0006

The difference between drivers which were categorized based on the annual number of vehicle's kilometers reflects that frequent drivers might trust in their capabilities in controlling the vehicle without aiding systems more than less-frequent drivers do. Although regarding to the Drowsy Driver Warning and Night Vision a stronger support from frequent drivers was appeared, indicating that frequent driver have more experience with driving over long distances or during night time.

4.3.4. STATED PREFERENCES

Preferences regarding States of the Systems

The respondents were also asked to choose between different states (i.e. informative and automatic) proposed by some of the systems. Informative systems are aimed at supplying drivers only with relevant messages that would help them to perform their task with a greater safety (e.g. collision warning system) while automatic systems are aimed at taking over drivers regulatory functions in circumstances under which they are overwhelmed (e.g. collision avoidance system) [35]. The preferences of drivers regarding the systems' level of automation was explored by carrying out a series of Chi-square tests. Comparing the obtained and expected values, it can be concluded that in general drivers accept ITS systems, on condition that the system allows them to keep certain amount of control over the vehicle, in other words the road users are more likely to accept the

informative systems rather than automatic. In view of age, it was appeared that, unlike older drivers, the intervening state of the systems are strongly disfavored by drivers between 30 and 50 years, $\chi^2(2,750), P=0.003$, the notable difference appeared in Forward Collision Mitigation; [$\chi^2(2, 150), P=0.004$], and Intelligent Speed Adaptation; [$\chi^2(2, 150), P=0.001$]. Besides, the overall results showed that considerably males prefer informative systems while females prefer automatic systems, $\chi^2(1, 900), P=0.006$, the significant differences appeared in relation to the Intersection Assistant; [$\chi^2(1, 150), P=0.01$], and Forward Collision Mitigation; [$\chi^2(1, 150), P=0.01$] systems. With regard to the country of origin, it has been demonstrated that there is no significant difference between Iranian and Swedish drivers' preferences in conjunction with different states of the systems. Also, no significant influence of driving experience on respondents' preferences towards the systems' level of automation was observed. Finally, concerning the annual number of vehicle's kilometer, it appears that the less-frequent drivers support the intervening states of the systems more than the frequent drivers do, $\chi^2(1, 620), P=0.002$, the significant difference was appeared in Curve Speed Warning; [$\chi^2(1, 124), P=0.02$], and Forward Collision Mitigation; [$\chi^2(1, 124), P=0.02$].

Overall Preferences

The results of the question that was being asked to conclude which of the proposed systems the participants would most like to use in their own vehicles are summarized in Table 9. Forward Collision Mitigation was selected by more participants than any other system. This system also attracted the highest proportion of “very useful” ratings. It is therefore likely to find an immediate acceptance by driving public. Considering the significant safety potential proposed by this system, manufacturers and system suppliers should give the highest priority for development and deployment of this system. By a narrow margin, the Adaptive Front Lighting was the second system that was most chosen by the questionnaire respondents. Both Night Vision and Drowsy Driver Warning were generally welcome among drivers. The remaining systems attracted much lower percentage of preferences, insofar as none of the respondents desired to have Alco-lock system in their own cars. However, considering this system attracted relatively high proportion of “very useful” rating, it seems that most of the respondents saw no actual need for the Alco-Lock system but recognized its value for increment safety on roads.

Table 9. Stated preferences of the different systems

System	Ratio	Proportion of “very useful” rating
Forward Collision Mitigation	23%	55%
Adaptive Front Lighting	19%	45%
Drowsy Driver Warning	15%	50%
Night Vision	14%	44%
Curve Speed Warning	6%	39%
Lane Departure Warning	6%	28%
Adaptive Cruise Control	4%	32%
Intelligent Speed Adaptation	3%	24%
Vehicle Monitoring System	2%	24%
Intersection Assistant	2%	17%
Electronic License Key	1%	28%
Alco-lock	0%	39%

4.3.5. CONCERNS ABOUT ITS ACCEPTANCE

As mentioned before, at the end of questionnaire, a final question was asked with a view to eliciting drivers' concerns and expectations that have to be met in order for ITS technologies to be acceptable to them. The

results of this question were qualitatively analyzed. Followings are the major concerns that could be expected to prevent ITS technologies from being accepted by the driving public.

Reliability

According to the respondents, system reliability is a critical factor in acceptability of an ITS device. A system that is not highly reliable could not find acceptance among the drivers.

If the technology were taking over the control of the car in emergency time, it would have to be totally reliable.

I would not accept a system unless I make sure that is 100 percent accurate and would work under any circumstances.

Some participants believed that the technologies would never be intelligent enough to handle a range of crash scenarios and road conditions, and as a result reliability of ITS equipment will always be called into question. There was a dominant belief among the participants that such technologies can only be deemed as backup tools and the drivers must ultimately trust on their own driving skills and abilities.

I don't think that any system could be 100% reliable. These systems might be used as a useful tool assisting you in some driving situations, but you as the driver are the ultimate responsible and have to rely on you own judgment.

False alarm rate

There were concerns that false alarms could affect drivers' perceptions of ITS devices negatively. Unwarranted alarms might result in drivers losing faith in the technologies and therefore even when an actual warning is raised, drivers would be less likely to react properly.

I think unwarranted alerts would be unavoidable in any computer system, but they have to be kept down to an absolute minimum. More repetitive false warnings might result in drivers to get desensitized to the systems and ignore the warnings even when they are really accurate.

Another participant raised concern about dangerous situations that false alarms could create threatening drivers' safety.

The warnings of the system must be valid. Panic of being warned about the situations that are not actually imposing a danger might give rise to hazardous conditions with negative impacts on safety.

Overriding option

A number of participants considered that, in some situations, using some systems would be annoying and, at worst, might be dangerous unless it has an override option which the vehicle's operator could activate it as needed.

I think that these systems are really useful, but there have to be an option to disable the system as required. I often drive in rush hour traffic. There are situations that you have to drive bumper-to-bumper or keep up very close to the leading vehicle in the traffic flow. In such situations, repetitive warnings from a forward collision system would be very annoying and could make the driver to be reluctant to the system.

Systems that automatically take over the control of the car are dangerous. For example, in order to safely overtake a car travelling in front of you, normally you have to go over the speed limit a little bit. If you overtake and meanwhile the speed limiter does not let you accelerate because you are about to exceed the speed limit, the system could cause a more dangerous situation that it could potentially eliminate. There have to be a button to turn the system off in such emergency situations.

System effectiveness

There appeared to be an overriding feeling stated by many of the participants that they would have to be convinced the equipment has been proved for its effectiveness before they would purchase it. For example:

Only once I assure research have confirmed that a device is practically able to cut down 90% or so of the relative accidents that is designed for, I would buy it.

Systems need to be validated through comprehensive testing procedures to convince drivers that they are absolutely effective in reduction of crash numbers and operational under all conditions.

Affordability

It was found that the price of the technology is a key element affecting drivers' willingness to purchase and use the equipment. For instance:

All the questioned systems sound to be very intelligent and appealing. But if they are too expensive, I rather prefer to do without them.

If you have to spend extortionate amount of money to buy a system, then I think most of the people would decide to cut it out. The technology must be affordable to the people with average income not just a luxury feature in expensive cars.

Distracting systems

There was also a concern expressed by some participants that the emerging technologies have the potential to distract the drivers to some degree from the driving task which could affect the acceptance of the system adversely.

Systems have to be carefully designed as the warnings require drivers' attention which would distract them from what they really need to be focusing on.

Cautions could be a distraction. When you are looking after an issued warning, you may fail to react quickly to dangers in front of you.

Ergonomically designed interfaces

Participants had concerns about the likely difficulties new technologies may give rise at the human-machine interface level.

The fact that such complicated systems may have too many buttons or features would concern me. I'm not sure about being able to interact with them.

Compulsory fitting system

There were opinions among the respondents that the reliable systems have to be made compulsory in all vehicles to be more effective and appealing. Enforcement was considered to be very important as long as the respondents did not want an unsafe driver on the road who threaten others' lives because he/she might be drunk, unlicensed, drowsy, etc.

If it has been proven that a technology will actually save lives, it should eventually be fitted as a standard feature like ABS and airbags. Such reliable features would make the vehicle more demanding.

While I would try to improve the safety of my own car by installing such systems, I could not control other drivers' behavior that might do stupid things. So I would feel protected with the technology, only if I know that every other driver has had it.

Invasion of privacy

It was mentioned by the participants that they were worried about the probability of the information from the systems to be monitored by the government, as it could invade their privacy and make them to feel big brother is watching them.

It would be rather inconvenience if you feel that the insurance company or the government is watching your activities. I would more concern about speeding because the system might pick it up. I need to know that I would not lose my driving license for occasional reckless driving.

Circumventable system

There were also issues raised by some participants about the potential of systems to be cheated or circumvented by outlaw drivers. In this case, the intended objective of the technology would be defeated.

If someone does not want to use the system, even if it were compulsory, he will try to circumvent it by cutting off relevant wires or simply ignoring the warnings. So what is the purpose of having such system out there?

I think the point of the technology is to change the behavior of unsafe drivers, but finally it is up to the driver to decide whether to respond to the alerts or not. I'm not sure that such equipment is going to help those stubborn drivers. If they are going to break the rules, they will still do that. For example if you have not held a valid license, you would use someone else's card.

5. GENERAL DISCUSSION AND COCLUSION

This paper describes the findings of the study conducted to gauge the acceptability of various ITS applications with high estimated safety potential to different sub-groups of drivers. The study was carried out in two key phases. The first phase encompassed preliminary activities required to be undertaken with the aim of identifying a small number of promising in-vehicle ITS devices that would be assessed for their acceptability. To this end, first it was necessary to identify drivers' needs in actual accident context. This was achieved by case-by-case analysis of the potential sources of accidents elicited by interviewing traffic experts based on their in-depth analysis of crash data. Promising ITS functions were conditioned based on their capability to satisfy drivers' needs. This analysis resulted in the selection of 12 systems for inclusion in the study; Alcohol Detection and Interlocks, Drowsy Driver Warning, Adaptive Front lighting, Night Vision, Intelligent Speed Adaptation, Curve Speed Warning, Adaptive Cruise Control, Forward Collision Mitigation, Intersection Assistant, Lane Change Support, Vehicle Monitoring System, and Electronic License Key. These systems, among several ITS technologies, were assessed to confer the greatest safety benefit to the road community.

The second phase was dedicated to understand the effect of independent variables pertaining to drivers' background characteristics on their perceived acceptability of various in-vehicle ITS products. A further focus was on identification of the significant impediments which would prevent ITS technologies to be accepted by the drivers from their own perspective. This was achieved by executing questionnaire involving a total of 150 car drivers from Iran and Sweden varying in age, gender, and driving characteristics.

This final chapter provides a general discussion of the work presented in this dissertation. It starts with a discussion of the main findings and other relevant issues. Following this, methodological concerns are discussed. The report concludes with suggestions for future work.

5.1. RESULTS DISCUSSION

Drivers' needs and ITS technologies

The first phase of the study provides key insights into the drivers' needs in aids through illustrations of the major safety issues drivers encountered according to experts' analysis of accident cases. The followings are the general finding emerged from this part of the research:

- Driving can be deemed as a difficult and stressful task which requires continues adaptation to a changing traffic environment. Accidents are the most apparent symptoms of the difficulties met by the drivers at the wheel [35].
- The first step toward the enhancement of safety on roads is identifying the actual needs of the drivers that call for assistance. This could be diagnosed through in-depth analysis of crash data [35].
- Currently studies are suffering from providing comprehensive information on the crash scenarios which are capable of being addressed by certain types of ITS technologies. Such data would be advantageous not only because of assessing the capability of ITS equipment in fulfilling particular needs of the drivers but also it can provide a practical safety analysis to enable impact estimation and in that way recognize priorities for action.
- The identified risk factors indicate strong need that drivers have of support in their driving while attempting to deal with the complexity of the driving task. Problems related to impaired driving, speeding, mechanical malfunctions, tailgating, lane changing, and restricted visibility were considered to be the major factors initiating accidents. These results are consistent with the findings reporting that unsafe driving behavior is the only or the contributing factor in over 90% of accidents around the world [52]. Speeding and unsafe lane changings are obvious issues in Western world as well. In

Sweden also 37-85% of drivers exceed the posted speed limits regulated based on the road and weather conditions [40].

- A driver's safety need can be considered as the negative point indicating a driver's inability in compensation for driving system deficiencies which generally result in an accident's production. Contradictory, from an optimistic view, it indicates what would have prevented the incident if its relative need had been satisfied [35]. In fact, ITS applications have to be designed in order to compensate for the actual difficulties drivers encounter behind the wheel so as to be efficient.

Acceptability of ITS technologies to various groups of drivers

The second phase of the study was set out to explore how various groups of drivers are likely to accept ITS technologies. In the paragraphs follow, the key findings have emerged by analysis of questionnaire results is discussed.

- In general drivers are reluctant to use devices that automatically take over the control of the vehicle. However, there is evidence based on the research outcomes that older drivers are more amenable to speed limiting systems and collision mitigation applications with active braking.
- Forward Collision Mitigation system appeared to have the highest perceived level of acceptability within the present research. Given the significant safety benefit that could be derived from this device, manufacturers should give a high priority for designing and marketing this system. For example, at the current stage in the development of the new generation of collision avoidance system, the technical community is coping with challenges pertaining to the reliable identification of generic obstacles including vehicles and pedestrians due to the unstructured environment as well as varying appearance of the people. This suggests that responsibility for the design improvement of this system should lie preliminary with system developers [23].
- Perceived acceptability of Alcohol Interlocks and Electronic License Key was remarkably low among the participants in this research. However, based on the results of other studies, these systems are predicted to yield the highest reduction in road trauma and costs [51]. The implication of this finding is that without putting appropriate strategies in place to enhance the acceptability of these systems to the drivers, the great potential of these systems in saving lives and cost will never be obtained.
- Notable, is that drivers who were familiar with ITS technologies, in general, perceived the systems more useful than the ones who were not aware of ITS concept. This indicates that experience affect perceived acceptability. It is therefore important to interpret the findings of studies on ITS acceptability in the light of degree and type of experience respondents have with the technology under examination [51].
- The outcomes of the study show that although traffic rules are the same in Sweden and Iran, drivers' perceived acceptability is culturally mediated. This indicates that an ITS that is of a great value for drivers in one country may not be perceived to be useful for drivers in another country due to particular local issues [40].
- Adjustable and easy human-machine interfaces should be offered with a view to encouraging users to explore emerging systems. For instance, concerning the high appeal from female drivers, it would be appropriate to provide female friendly interfaces and it that way attract more drivers of this group to actual system usage. Similarly, with regards to cultural differences, it is important that the systems interfaces can be adapted to a proper mode of data presentation (e.g. language, time and date) which would help to prevent drivers' distraction and mental overload while interacting with the systems [30].
- At the current point in development of ITS technologies there is remarkably little interest shown in segmentation of the market to capture different needs and perceptions of drivers in different groups

of age, gender, country, and so on [40, 51]. However, the results of this research indicate that drivers in diverse groups have different requirements and expectations that have to be met, if ITS technologies are to be acceptable to them. It is imperative for system designers and implementers to be aware of these differences and take them into consideration when designing and marketing ITS products [51].

Barriers preventing ITS acceptance

It was mentioned at the beginning of this report that every ITS device, even dedicated for enhancing the road users' safety, should develop a global acceptance from the consumers for whom they are designed for [35]. The further ITS development without establishing an understanding of how prospective users are likely to accept different technologies, the greater the risk of developing products that would never be purchased or used by the consumers [11]. If the desired benefits of these functions are to be realized to the full, it is imperative to identify impediments that could be expected to prevent the drivers from using ITS technologies in the intended direction [72]. The following paragraphs outline the main barriers that have emerged on the basis of the information derived from the questionnaire. Recommendations for enhancing ITS acceptance have also been made.

- It is necessary to provide the users with scientific evidence pertaining to the actual effectiveness of the ITS devices in reduction of the road crashes and severity of accidents. This information needs to be published broadly in the community [51].
- It is important that system developers and vehicle manufacturers consider an option which enables drivers to turn the system off as required. A case in point is the mandatory speed limiter system. Drivers must be able to turn the system off while over taking or dealing with emergencies.
- Generally users are not in favor of a system that is not reliable. As every technology has its own limits where the system cannot operate with total reliability and, therefore, might threaten driver safety, it is essential these limitations be recognized and acknowledged in operating manuals. Furthermore, relevant authorities need to provide required infrastructure which enables reliable functioning of the systems. For instance, for systems such as Intelligent Speed Adaptation, which requires real-time transmission of speed data, up-to-date digital maps must be arranged [72].
- Users are not likely to accept a device with high false alarm rate. As a pertinent example, the first generation of forward collision warning systems was rejected by the users due to the high rate of false alarms in congested traffic streams [5]. Hence, system suppliers must optimize the systems to minimize false alarms and then underline the situations under which false alarms could be raised in the user manuals. Such information would attract users' trust and increase the acceptability of the system to the users [51].
- Consumers will simply accept a system if it is perceived to be useful for them [11]. Although, the results from this research indicate that users often under-estimate the likely usefulness of ITS devices due to a basic lack of understanding of the accident types that are capable of being offset by those devices. Thus, it is critical to make aware consumers of the crash scenarios in which the technologies would actually yield the greatest benefit [51].
- There is evidence from present and previous research (e.g.Gray, 2001; Sixsmith, 1990) that drivers would not be keen to accept a system which they believe it may distract them. As a matter of fact, providing the driver with additional information from ITS electronic devices, even if the information matches to the safety needs of the driver, could conflict with the operator's driving task. As the final objective of an ITS function is to support the driver to compensate for a difficulty, it would be counterproductive to develop technologies which generate additional difficulties. It is important, therefore, to consider the limitations of the drivers' load acceptance, when planning to add a new component into an already complex system [35].

- Generally consumers are not in favor of interfaces which are poorly designed. Hence, it is necessary that developers and manufacturers provide system interfaces in a way that facilitates users' interaction with ITS products [56].
- Affordability is a major concern for consumers. Individuals generally are not willing to buy an expensive product even if the system is regarded to be very useful.
- Drivers are not likely to accept a system which they believe it can invade their privacy by monitoring their driving activities. This has also been demonstrated in a study conducted previously by Marwah et al, it was found that drivers are reluctant to an advanced Electronic License Key which incorporates a speed control system as it could be presumed like an automatic speeding ticket machine [42]. This suggests that system suppliers need to clarify the conditions governing the use of the technology [51].
- An ITS device is unlikely to be acceptable if the consumers believe it is vulnerable to circumvention. A case in point is Electronic License Key. Therefore, it is critical that system designers and implementers recognize ways in which their product can be tampered or cheated and develop measures to minimize the risk of such circumventions [51].
- Drivers will have no choice in deciding to accept an ITS application that is a standard feature in all vehicles. Therefore, one aggressive strategy to get high impacts with large scale utilization is that road authorities mandate vehicle manufacturer to adhere to standards on compulsory installation of the systems which their effectiveness and reliability are proven repeatedly through scientific experiments and successful long-term on-road operations. For instance, regarding significant expected benefit of using Anti-lock Braking System (ABS), it has become mandatory on new heavy goods vehicles since 1989 in United Kingdom [27].

The research outcomes in the context

It would not be appropriate to compare the results of the current study with prior researches on ITS acceptability reviewed at the beginning of this paper considering the differences in participants' volume, adopted methodologies, systems under investigation, and ambiguity regarding the description of acceptability that was adopted in the previous studies. On the other hand, bearing in mind that ITS technologies continue to mature rapidly, it is probable the functionalities of the systems investigated in the previous researches are now enhanced and different from what they were before. Thus, even for technologies that are in common, it cannot be known for sure whether the respondents in the previous research in fact have commented on the same system features as those considered in the present research. Nevertheless, with regards to Intelligent Speed Adaptation, a meaningful comparison could be made indicating that, alike previous researches, speed alerting system has been favored over speed limiting by majority of the participants of the present study.

5.2. METHODOLOGICAL CONCERNS

During the work presented in this dissertation different methodologies have been adopted to explore what needs drivers have of support in their driving, how ITS technologies fulfill these needs, and how different groups of drivers are likely to accept in-vehicle ITS products. A discussion on the advantages and drawbacks of the method used in each phase of the research is presented below.

Selection of ITS technologies

- The determination of drivers' needs for support depends on an extremely detailed analysis of crash cases with in-depth interviews of individuals implicated and cinematic reformation of the incidents [35]. Use of experts' opinions as the valuable input allowed putting the main drivers' needs forward as they could be directly deduced from critical situations that threatens the safety of road users' community.

- The advantage of determining needs using experts' analysis of accident data is that these are definitely pertaining to safety, and the needs deduced from them are actual drivers' needs in safety [35].
- Analysis of the safety problems through interviewing with experts has been favored over interviewing with a number of regular drivers since drivers typically tend to stress on task complications or blame other road users rather than define safety needs.
- Using expert opinion based on their in-depth analysis of accident cases has been preferred to use of existing accident databases, since in the objective of determining whether an electronic safety device can avoid a certain type of accident, detailed characteristics of the situation in which the accident occurred, must be considered. On one hand, it would be challenging to find such data as most of the details due to time and monetary limitations are not included in the accessible data sources gained from police procedures. On the other hand, the volume of information can be overwhelming if every single aspect of a traffic crash is recorded [4].
- In the objective of determining the capability of the ITS equipment to fulfill drivers' needs, it was not known for certain to what extent ITS functions are capable of preventing particular types of accidents as they have never been implemented on large scale in real world transportation. Long-term on-road studies could reveal reliable safety indications in traffic considering reduction of crash numbers [53].
- Regarding the accuracy of the performed interview, it could be a stretch to claim that the defined risk factors from Iranian experts' standpoint can be generalized to the drivers as a whole. As Iran, according to World Health Organization (WHO) statistics, ranks fifth all around the world for road traffic accidents [70], Iranian road traffic reconstruction experts seem to have more expertise and experience in accident analysis. This makes it possible to infer situations which the drivers in a country with more developed driving culture are less likely to meet but may be subject to severe accidents if they arise. Therefore, the risk factors defined by these experts can be seen as global needs drivers have in aids. However one can argue that further experts judgments enables to evaluate risk factors from different perspectives and level of details in addition to identifying particular driving problems in countries. As a matter of fact, explanations on "why an accident occurred" may be responded in different ways by different experts. For instance, technicians consider physical dimensions (e.g. friction, speed, and etc.) as the contributing factors in accident production. Others explain the role of traffic participants' behaviors in an accident occurrence. Nevertheless others will provide explanations on why such behavior appeared. Taking into account all these factors from different research fields makes it possible to enrich the analysis of the capacity of safety systems to meet the drivers' needs in an actual driving context both in terms of human parameters and external constraints [4].

Acceptability assessment

- Most of the participants in this study had no prior experience or physical interaction with the technologies of the research interest. Thus, it is not clear to what extent their acceptability of systems surveyed in this research may change once they interact with the systems.
- It needs to be mentioned that the outcomes of this report may not be generalizable as the participants surveyed in this research were not representative of the driving public in Iran and Sweden. Therefore, this research and the results emerged from it should be considered as exploratory. However, it would be useful that the related authorities who can affect designing and marketing ITS products to consider significant issues which were derived from the present study.
- Questionnaire was favored over the other research methodologies with a view to reaching larger group of respondents in a less time and with a lower cost. However, comparing to one-on-one interviews or focus groups, questionnaires are not as efficient in measuring the in-depth reaction of the prospective users to an emerging product. With questionnaires information on consumers' needs,

expectations, concerns, and ideas, which can be adapted by the suppliers to improve their product and make it more acceptable, cannot be obtained in sufficient level of details [17]. The respondents in this study had no opportunity to discuss the technologies under investigation or see them even through video segments.

- The determining factors used to evaluate the acceptability of the ITS devices were very limited and only one dimension of acceptance that is usefulness was regarded. There are several reasons for doing so. First, as mentioned before perceived usefulness has been proven repeatedly as the main entity which determines whether prospective users will actually adopt a system. Secondly, there are scientific evidences that some acceptability determinants including perceived ease of use and subjective norms became less important once experience with a system is attained [67]. Thirdly, it would not be much valuable to elicit and interpret users' perceptions of some factors such as usability and effectiveness of a system unless they have interaction with actual device. Finally, it was beyond the general scope of the present research to determine all of the possible constructs, the relationship among them, and their relevant contribution to the acceptability of ITS technologies [51].
- The geographical regions where respondents were surveyed restricted to the metropolitans, therefore, the sample did not consist of participants from rural regions. However, it is probable that many of the respondents drive outside urban areas, but it might not be much considerable. It is not known to what extent the type of road that the drivers mostly drive on is likely to affect the acceptability of an ITS device. Therefore, it is important to perform a study including drivers sampled from both urban and rural areas, and then examine the effect of distribution of annual number of kilometers over different road types (i.e. motorways, rural roads, and urban roads) as an independent variable on level of perceived acceptability.
- Within the sampled drivers there were probably differences in participants' driving style, type of job, socio-economic status, and degree of education. While these variables may have influenced the measurements, it is unknown how great such influence would have been.
- Each system in this study was presented as a stand-alone device in order to give respondents definite choices, and in that way achieve a clear understanding of their perceptions and priorities. But, in reality, it is probable that ITS technologies will be offered as integrated packages encompassing several optional features, as it would be much less expensive to add additional features to a base system rather than stand-alone functions [11].
- One source of weakness in this research was the approach that has been applied for measuring acceptability. In this investigation systems were presented and participants were asked to assess each system separately. While this measurement approach is rather easy to conceptualize and adequately simple for participants to complete, it has exposed serious shortages in predicting overall choice and preference behavior. As in reality prospective consumers make trade-offs among a number of alternatives as they consider buying which system/s can satisfy them to the greatest degree given their available purchasing power [41]. In view of the adopted measurement method, this research was failed to take into account these trade-offs.
- To reiterate, cost is an overriding factor in determining drivers' willingness to purchase and use a product. As the purchase price for all systems of the research interest was not readily available, it was not considered in acceptability assessment. Some research groups (e.g Brackstone and MacDonald, 2000; Cairney, 1995) have attempted to understand consumers' expectations about eventual cost of ITS products by asking the individuals to state "how much they would be willing to pay" for a given system. Nevertheless, as Cairney points out, the cost estimates suggested by the participants could not be assumed as a proper indicator of the price they are likely to pay in actual life. There are several reasons for this. First, as mentioned above, ITS technologies are likely to be introduced to the market as integrated packages rather stand-alone systems. Secondly, the estimates of price offered by the respondents can be seen, at least in part, as an indication of the degree to which they perceive the

systems to be useful for them, and in part as an indication of how complex they judge the systems are likely to be. Finally, regarding the novelty of intelligent transportation concept, most of the individuals in the community may have rather limited information on the possible costs for products of this type [11].

- Following the research topic, questions asked both in interview and the questionnaire were not on sensitive or controversial issues, it is believed that this research did not violate ethical principles. Besides, the respondents were asked whether or not they are willing to participate and asked for their consent beforehand [17].

5.3. FURTHER RESEARCH

The outcomes from the present research recommend that further research would be undertaken in the following areas:

- It is necessary to perform further research encompassing more representative sample of driving public (including rural drivers) with a view to identifying all possible issues that have a great importance to the drivers in evaluation of ITS products acceptance. An important focus of such investigation should be on systems that are appeared to be least preferred but expected to yield the greatest safety benefits (e.g. Alcohol Interlocks).
- It is recommended that further work be undertaken to determine the most efficient mechanisms for increasing drivers' acceptance of ITS technologies examined in this paper, especially those with high expected safety potential but low level of perceived acceptance. Some of such mechanisms have already been proposed in earlier parts of this discussion (e.g. compulsory installation of the technologies). The establishment of such strategies needs the cooperation of system developers, car manufacturers, road authorities, and other relevant interested parties.
- The motivation behind the development of ITS technologies, to some extent, is to enhance the safety on roads by improving the behavior of at-risk drivers. It can be assumed that the acceptance of these groups of drivers is far more important for the success of the intelligent transportation technologies. Consequently, it would be appropriate to bias acceptability assessment towards those groups of road users for whom the systems are likely to yield the greatest safety benefit [28]. Such an objective could be achieved by recruiting the participants among over-represented drivers in certain types of crashes according to analysis of crash data. For instance, as male drivers are over-involved in accidents pertaining to Drowsy Driver Warning [51], their acceptance of this system could help significantly to achieve this system's intended benefits.
- This dissertation has only focused on car drivers. Similar research should therefore be conducted to gauge the acceptability of ITS technologies to motorcyclists and commercial vehicle drivers as well.
- Further investigation on identification of cross-cultural differences is strongly recommended. Bearing in mind the huge differences between countries in their infrastructure, traffic situations, local driving norms, and driver behavior, an ITS designed for roads in one country may not be optimal or even operational in other markets. Hence, it is critical to identify these differences and take them into account when transferring an ITS product from one culture to another [40].
- It is recommended that further research be undertaken to examine the role of driving style, type of road drivers mostly drive on, socio-economic status, and occupation as an independent variable in affecting the acceptability of ITS technologies.
- Acceptability is not yet a well-described and understood concept in the sphere of ITS. Clearly, more work needs to be done to better understand acceptability determinants with a view to identifying acceptability constructs that are more important to the drivers in selecting specific ITS devices, and to determine the underlying factors that are more likely to change.

- This investigation has concentrated mostly on acceptability of in-vehicle ITS products. To the best knowledge of the writer of this paper, no study has been performed to measure road users' acceptance of the wide range of emerging infrastructure-based ITS systems. It seems that the development of such systems is predominantly based on a series of priorities decided by road authorities and designer of these technologies. Hence, to ensure the effectiveness and viability of the technologies of this type, it is essential to conduct further research to determine what drivers deem actually acceptable in these systems.

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APPENDIX A: DRIVERS' NEEDS CALLING FOR SUPPORT-RESULTS FROM THE INTERVIEW

Following is the list of driver needs for support as they have been established from the interview:

DRIVER'S STATUS

DRIVER'S DROWSINESS OR FATIGUE

Description:

Drowsiness or fatigue increases the probability of a late response from the driver to an unexpected event on the road scene. Driver's diminished alertness may be followed by inattention to the surrounding traffic situations, loss of control, and driving with inappropriate inter-vehicle gaps resulting in fatal or serious injury crashes. Fatigue at the wheel can be the consequence of travelling during the night or long distances, insufficient sleep, and so on.

A solution would be:

- To stop a sleepy or tired driver from driving by taking precautionary actions.

Respective safety need:

- The need for analyzing driver's alertness level.
- The need for support in emergency situations where the driver with diminished alertness does not respond appropriately.

DRIVER'S DISTRACTION

Description:

Drivers' distraction is assumed to be contributing factor in accidents production. Several activities such as talking to cellphones, searching for road signs, smoking, and so on can impact drivers' situational awareness negatively. An unfocused motorist may lose the directional stability of the automobile, and fail to recognize obstacles on the roadway or take proper decisions when something unpredicted happens.

A solution would be:

- To ensure that the system originated messages (i.e. from in-vehicle systems or cellphones) will not be a distraction.
- To draw the attention of unfocused driver to an imminent danger.
- To help the driver to concentrate on driving rather than other activities (e.g. looking for road signs).

Respective safety need:

- The need for determining the driver's level of distraction in relation to the complexity of surrounding traffic situation.
- The need for preventing an busy driver from being further distracted.

VEHICLE STATUS

MECHANICAL MALFUNCTION

Description:

While the ratio of road crashes, in which the mechanical malfunction is the major accident initiating factor, is considerably low, but they indubitably threaten road users' safety. For example, any problem in vehicle's brake or steering-wheel may contribute in a tragic collision.

A solution would be:

- To monitor different systems of the vehicle in order to alert the driver to potential malfunctions or problems.

Respective safety need:

- The need for determining whether different sub-systems of the vehicle are functioning properly.
- The need for alerting the driver to impending malfunctions or failures.

TIRE DEFECTS

Description:

Problems with the vehicle's tires are the contributing factors in several road accidents. Both under-inflated and over-inflated tires can threaten road users' safety and reduce the stability of the vehicle as well as its performance.

A solution would be:

- To inform the driver about the status of vehicle tires.

Respective safety need:

- The need for measuring the pressure in automobile's tires.
- The need for alerting the driver to under-inflation/s.

ROAD SCENE RELATED DIFFICULTIES

ADVERSE ROAD SURFACE CONDITION

Description:

Decreased friction of the road pavement such as icy surfaces increases the probability of spinning or slipping out of the roadway particularly in cases where the motorist is not attentive to the surface condition.

A solution would be:

- To inform the driver about the surface condition of their forward path in advance.

Respective safety need:

- The need for detecting anomalies over the road pavement.
- The need for alerting the driver to any detected abnormalities on the road surface.

ADVERSE VIEWING CONDITIONS

Description:

Generally, vulnerable road users such as pedestrians and bicyclists are at a higher risk than vehicle occupants. This crash-risk substantially increases in roads with low visibility than optimal conditions.

INAPPROPRIATE SET OF HEADLIGHTS

Description:

Safe driving in dark roads without clear visibility needs an appropriate set of lights. At fast speeds the driver needs a greater viewing distance whereas at lower speeds a clear outward visibility is preferred. In addition manual adjustment of the headlights may increase drivers' workload result in drivers' distraction and subsequently increase the crash risk since the driver needs to take eyes of the road to activate, deactivate, or dim the lights. Apart from this, when the vehicle turns into a curve the driver needs to have a better view of upcoming curve not the shoulder of the road. This can be considered as the major disadvantage of traditional front lights which leaves the intended direction dark when cornering. Besides, the high-beam glare from headlights of an oncoming or preceding vehicle can be considered as a major problem that leads to visibility contributing accidents.

A solution would be:

- To increase the driver's and other road users' view of the road environment ahead and on curves by setting the headlights' luminance appropriately without driver input.

Respective safety need:

- The need for adjusting headlamps luminance to benefit various speeds.
- The need for visibility enhancement of the road environment based on the level of ambient light without driver input.
- The need for optimizing the visibility of the vehicle's road path on curves.
- The need for dim the upper beam headlights in case of detecting an oncoming or approaching vehicle.

POOR VISIBILITY DUE TO DARKNESS OR BAD WEATHER CONDITIONS

Description:

While very few of the road trips occur during night, yet we see a substantial number of road crashes take place in the nightfall. Although drivers' fatigue and drunkenness can be assumed as the major factors initiating accidents after nighttime, darkness itself plays an important role in accidents occurrence as it can restrict motorists, visibility of the road environment. Several other aspects including bad weather, dusk, or aging can also affect drivers' view negatively.

A solution would be:

- To enhance the visibility of the roads with adverse viewing scenes.

Respective safety need:

- The need for providing the driver with a better view of the vehicle's path in poor visibility situations including dark or bad weather.

DISOBEDIENCE OF TRAFFIC RULES

UNLICENSED VEHICLE DRIVING

Description:

Drivers who are not qualified to drive and do not hold a valid driver's license are one of the most dangerous threats for the safety of the road users.

A solution would be:

- To prevent starting the car if the driver does not hold a valid driver's license.

Respective safety need:

- The need for determining if the individual is qualified to operate the vehicle.
- The need for stopping an unlicensed individual from operating a vehicle.

DRINKING AND DRIVING

Description:

The alcohol related impacts usually result in fatalities. Illegal drugs and alcohol can diminish drivers' alertness significantly. Intoxicated drivers normally tend to speeding and as a result may lose the control of the car or fail to recognize potential dangers on the roadway.

A solution would be:

- To immobilize the car, if the user were not assessed to be fitted for driving.

Respective safety need:

- The need for analyzing driver's level of drunkenness before and/or during operating the vehicle.
- The need for stopping a drunk driver from driving a car.

ROAD SIGN VIOLATIONS

Traffic signs represent the important information which is necessary to have a safe road trip. Disobedience of road signs because of the motorists' failure in observing them may lead drivers to make incorrect decision such as slipping out of the legal speed limit or illegal overtaking.

A solution would be:

- To reflect the relevant information to the driver in advance, and alert him/her to disobedience of traffic signs.

Respective safety need:

- The need for informing the driver about the presence of traffic signs beforehand.
- The need for warning the driver about his/her violations.

FAILURE TO YIELD RIGHT OF WAY AT INTERSECTIONS

Accidents at intersections are one of the most common reasons for inter-city fatalities, and occur because of the driver's failure to yield right-of-way or observe other vehicles and predict their drivers' subsequent actions. This problem could be exacerbated at intersections without traffic lights or in junctions with obstructed view caused by other vehicles, buildings, or other obstacles.

A solution would be:

- To support the driver in the situation assessments by reflecting relative information and avoid collisions in critical intersecting conditions.

Respective safety need:

- The need for detecting other vehicles around an approaching intersection.
- The need for warning the driver where a conflict situation is detected.
- The need for preventing impending collision automatically, when the driver does not respond by him/herself.

TAILGATING

Driver's failure to keep a safe distance from the vehicle ahead sometimes may result in rear-end conflicts due to leading vehicle's sudden deceleration or stop.

A solution would be:

- To keep a safe distance from a leading vehicle.

Respective safety need:

- The need for recognizing unsuitable inter-vehicle distances.
- The need for assisting the driver to keep a safe headway with vehicle ahead.

VEHICLE'S DIRECTIONAL INSTABILITY

UNSAFE BRAKING SITUATIONS

While driving the motorist may be surprised by unpredictable events, and suddenly press the brake pads for being able to stop immediately. Rapid braking particularly while steering or bending, or on pavements with non-symmetric friction usually result in vehicle's skidding due to locked up wheels.

A solution would be:

- To avoid the wheels from locking and skidding.
- To stabilize automobile's directional movements.
- To minimize stopping distance.

Respective safety need:

- The need for helping the drivers to remain in control of the vehicle and reduce the stopping distance by stabilizing vehicle's longitudinal and latitudinal movements during rapid and heavy braking.

PANIC BRAKING

Generally, drivers are not prepared for panic stoppings (e.g. when a pedestrian unexpectedly run into the path of a moving vehicle) which relatively require a maximum braking pressure to be applied in order to stop the vehicle immediately. In such emergency situations most of the drivers fail to brake with sufficient force resulting in longer and unsafe stopping distance.

A solution would be:

- To minimize stopping distance during panic braking.

Respective safety need:

- The need for assisting the driver to apply full braking so as to execute an emergency stop.

EMERGENCY EVASIVE MANEUVERS

Quick lateral maneuvers to evade an unforeseen impediment, pavements with non-symmetric friction, and rapid bending usually leads the car to slip out of its trajectory. In such situation the driver will no longer be able to steer the vehicle in his/her intended direction.

A solution would be:

- To stabilize automobile's sideways movements.

Respective safety need:

- The need for enabling the driver to steer the vehicle in the intended direction during emergency evasive swerves by stabilizing automobile's latitudinal movements.

SPEEDING

EXCEEDING THE SPEED LIMIT

There is an obvious relationship between excessive speed and accident fatalities. Even professional drivers cannot slip out of the speed limit without increasing crash risk. A vehicle with a higher speed is a greater threat to its own occupants as well as other road users' safety. Excessive speed results in dangerous long distance of braking, vehicle's instability during cornering maneuvers, and makes the driver unable to control the vehicle in case of happening something unpredicted. For instance, if the vehicle ahead suddenly decelerates, or a pedestrian step onto the vehicle's path, the driver can avoid the collision only if the vehicle is moving at a low speed so he/she has enough space and time to take appropriate maneuver without striking the leading vehicle or pedestrian. It has to be noted that traveling slower than minimum speed limit is as hazardous as driving with an excessive speed.

A solution would be:

- To help the driver to keep the speed of the vehicle based on the predefined speed limit in a given area.

Respective safety need:

- The need for recognizing the local speed limit.
- The need for adapting speed of the vehicle according to the legal speed limits.

INAPPROPRIATE SPEED ON BENDS

The vast ranges of off-path accidents are because the motorist takes a curve with inappropriate speed. Bending too fast usually result in rollovers. The likelihood of incidence of crashes on bends is much more than straight paths.

A solution would be:

- To prevent the operator from taking a bend with an unsafe speed.

Respective safety need:

- The need for providing the driver with information on maximum safe speed to be taken for a coming curve.

- The need for warning the driver when the vehicle is approaching at a speed greater than recommended rate.
- The need for adapting speed of the vehicle according to the estimated speed threshold in emergency situations.

COLLISIONS WITH GENERIC OBSTACLES ON THE ROADWAY

COLLISIONS WITH OTHER VEHICLES/UNSEEN OBJECTS

The overwhelming majority of crashes, especially in urban areas, are due to the driver's failure to keep the safe distance from the vehicle ahead which may lead to a rear-end crash. This failure can be a result of driver's inattention, rapid acceleration of striking vehicle, or sudden deceleration of the leading vehicle. Besides, collisions with other unseen obstacles across the road path such as fallen tree can also be assumed similar to rear-end accidents except that in most cases result in fatal crash tragedies.

A solution would be:

- To alert the driver to the presence of dangerous obstacles on the roadway.

Respective safety need:

- The need for detecting approaching obstacles on the vehicle's trajectory.
- The need for alerting the driver in case of detecting a hazardous obstacle.
- The need for avoiding collisions or mitigating severity of object impacts.

PEDESTRIANS NOT CROSSING ROAD AT CROSSWALK

In urban environments, vulnerable road users compose the bulk number of road accidents victims rather than the vehicle's occupants. Vehicle accidents with unprotected road users typically result in death or irreparable injuries. Child-pedestrians are one-thirds of all pedestrian fatalities. Therefore there is a logical need for protecting at risk pedestrians who may cross the road without seeing approaching vehicle from imminent collisions.

A solution would be:

- To protect approaching pedestrians or cyclists of an imminent collision with the vehicle.

Respective safety need:

- The need for detecting approaching pedestrians on the roadway.
- The need for alerting the driver to the presence of pedestrian as an impending hazard.
- The need for avoiding or mitigating pedestrian impacts.

ANIMALS MOVING ON OR AROUND ROADWAY

Travelling on rural roads imposes the danger of animal impacts. Despite from the necessity of protection of animal's life, colliding with animals particularly at high speeds often leads to automobile's occupants mortalities.

A solution would be:

- To notify the driver about the animals on or around the roadway.

Respective safety need:

- The need for detecting animals crossing or near the vehicle's moving path.
- The need for alerting driver approaching animals of an impending hazard.

UNSAFE LATERAL MOVEMENTS

INADVERTENT LANE DEVIATION

Unintentional deviance of the car from its moving lane that could arise as a consequence of the motorist's inattention may lead to tragic accidents.

A solution would be:

- To help the driver to keep the vehicle in a correct position within its lane.

Respective safety need:

- The need for detecting lane markings and features.
- The need for preventing driver's unintentional drifting out of the lane.

OVERTAKING AND LANE CHANGING MANEUVERS

Overtaking can be considered as a hazardous driving activity. In order to make an overtaking maneuver safely, a driver must take many factors into the account. For instance, a poor estimation of the time required to overtake especially on two-lane roads with opposing traffic flow or on freeways with a fast approaching vehicle from the behind can result in fatalities. Furthermore, other automobiles in the blind spots of an overtaking vehicle are a serious threat that may subject to an accident.

A solution would be:

- To prevent unsafe lane changes by recognizing risks in adjacent lanes of traffic.

Respective safety need:

- The need for detecting surrounding vehicles which may pose threats while overtaking.
- The need for warning the driver to the impending hazard.
- The need for avoiding crashes during lane changing maneuvers.

DEPARTING THE ROAD EDGES

Departing the road edge occur when a vehicle traverses the edge line of the road and leave its traveling path either on curves or on straight paths. Departing the road edges is predominantly a hazardous situation since vehicles typically rollover or bump into stationary obstacles like trees, utility poles, or other fixed objects. There are many reasons that may result in a roadway departure crash like poor visibility, excessive speed, impaired driving, slippery road surface, or etc.

A solution would be:

- To maintain the vehicle in a correct position within its trajectory in conflict situations.

Respective safety need:

- The need for detecting road edges' markings and features.
- The need for detecting obstacles on the road shoulders.
- The need for warning the driver when the vehicle is about to leave the road edges.
- The need for preventing the vehicle to swerve off the road edges in critical situations.

SECONDARY RISKS

DRIVING IN MONOTONOUS AND TIRESOME ENVIRONMENTS

Travelling on monotonous roads may reduce drivers' alertness to his/her surrounding traffic situations. Therefore in case of arising something unpredicted the driver may not respond properly. Aside from this matter every motorist desires driving comfortably in tiresome traffic situations such as traffic jams or monotony highways with sparse traffic flow.

A solution would be:

- To release the driver from regulating functions to keep a safe distance in both sparse and congested traffic flows.

Respective safety need:

- The need for detecting a leading vehicle or tail of the approaching traffic jam.
- The need for following the vehicle ahead while keeping a safe headway.

CONGESTED TRAFFIC FLOWS

Every driver would appreciate to have information about the traffic conditions on alternative routes towards their intended destination so as to make the best possible decision to avoid congested traffic flows.

A solution would be:

- To support the driver make the best choice among alternative routes towards their destination congestion by providing him/her with relevant information.

Respective safety need:

- The need for providing the driver with information about local traffic condition of the road network.

CAR PARKS CRASHES

Car park crashes are not seen as serious traffic problems but they are happening on many occasions.

A solution would be:

- To help the driver to avoid bumping into something while parking the car.

Respective safety need:

- The need for helping the motorist to determine the distance between obstacles and automobile's edges in a parking maneuver.

DRIVER' STATUS MONITORING SYSTEMS

DROWSY DRIVER DETECTION AND COUNTERMEASURES

Also known as: Drowsiness Detection System, Driver Vigilance Monitoring, Fatigue Monitoring System, Alertness sensing [6].

Description: Drowsiness detection applications can alert the users whenever they assessed to be sleepy or impaired. The automatic systems can intervene into driving activities and bring the car to a standstill. These functions are able to notice operator's drowsiness or inattention by monitoring both user's (e.g. head and eye movements) and vehicle's (e.g. lateral movement and speed) behavior [6, 8]. In case of emergency where the driver is not responding, an ideal system would assist the driver by safely stopping and parking the vehicle on the road side through performing automatic maneuvers [54].

Need fulfillment: This system monitors driver alertness in order to:

- Warn the driver in case of driving with impaired alertness.
- Assist the driver by parking the vehicle in a safe location automatically.

Crash relevance: Crashes where driver's diminished alertness due to drowsiness or fatigue is the contributing factor.

Associated risk: Driver's drowsiness or fatigue at the wheel.

Effectiveness: Estimations on expected safety benefit with fatigue monitoring system with wide implementation implies up to 15% reduction of fatal and injury related crashes on motorways [53].

DRIVER WORKLOAD SUPPORT

Also known as: Driver State Estimation.

Description: The motivation behind the development of this system is to make sure that the vehicle's operator would receive important information from different applications only when he/she were capable of accepting it. That is to say that driver work load support ensures that system initiated messages and warnings will not cause drivers' mental overload and distraction. Considering driver's acceptance capacity with respect to the driving situation, relevant information would be prioritized and presented as it was necessary. For instance, a driver who is in the middle of a critical intersecting situation would not be able to receive an incoming call till he/she has crossed the intersection. Likewise, visual information may be presented as an auditory message to a busy driver [50].

Need fulfillment: This system measures driver's real-time workload in order to:

- Prevent an busy driver from being distracted or overloaded by system initiated information.

Crash relevance: Crashes where driver's distraction as a consequence of receiving application originated messages, is the contributing factor.

Associated risk: Driver's distraction due to system initiated information.

Effectiveness: No evidence of estimations on the effectiveness with driver workload support reported as yet.

VEHICLE STATUS MONITORING SYSTEMS

Also known as: Vehicle Diagnostic Systems.

Description: These systems are a number of independent services that constantly monitor the behavior of various components of the vehicle and alert the user to any abnormalities instantly. For example, problems related to vehicle's engine, tires, brakes, ABS, and so on can be diagnosed by VMS [26].

Need fulfillment: This system monitors physical condition of the vehicle in order to:

- Provide the driver with relevant information on the status of various sub-systems of the vehicle.
- Warn the driver if any potential malfunctions were detected.

Crash relevance: Accidents attributed to malfunctions or problems in vehicle system.

Associated risk: Vehicle system malfunctioning.

Effectiveness: The effectiveness of various vehicle diagnostic systems has been calculated separately.

TIRE PRESSURE MONITORING SYSTEM

Also known as: Real-time tire pressure monitoring system.

Description: TPMS is a specialized vehicle monitoring system designed to provide the driver with the relevant information on the condition of the vehicle's tires. The air pressure in each tire is measured either using relevant information from wheel speed recorders (i.e. indirect systems) or pressure sensors (i.e. direct systems) [2].

Need fulfillment: This system continuously monitors condition of the vehicle tires in order to:

- Detect any under-inflation in vehicle tires.
- Alert the driver to malfunction of tires.

Crash relevance: Accidents where malfunctions of tires (e.g. worn out, deflated, or under-inflated tires) are contributing factors.

Associated risk: Defective tires.

Effectiveness: Consistent with eSafety Forum report, wide implementation of TPMS in Germany can reduce crashes related to tire malfunctions by up to 35% [22].

ROAD SURFACE CONDITION MONITORING SYSTEMS

Description: This system supports the driver by providing the driver with the information about the condition of the road surface he/she travelling on. The user will be warned by the system in case of detecting any anomalies on the road surface such as slippery pavements [6, 8]. Then the operator can take a proper action so as to avoid immediate dangers. Such information could be provided through either inter vehicle or roadside sensors communications. Such systems can be integrated with Adaptive Cruise Control or Forward Collision Mitigation in order to optimize the required safe following or warning distance between vehicles [8].

Need fulfillment: This system monitors the condition of the road surface in order to:

- Detect any anomalies on the road pavement.
- Alert the driver to any detected anomalies over the surface of the forward path.

Crash relevance: Accidents attributed to poor pavement condition.

Associated risk: Adverse road surface condition.

Effectiveness: According to Lind, et al. road surface monitoring systems have the potential to affect 40% of fatal accidents related to poor road surface condition in Sweden [39].

VISION ENHANCEMENT SYSTEMS

INTELLIGENT LIGHTING SYSTEMS

Also known as: Adaptive Front Lighting (AFL), Advanced Front-Lighting System, Automatic Headlights [6].

Description: Intelligent lighting systems incorporate one or a number of technologies that serve to optimize driver's and other road users' visibility of the road environment considering vehicle's speed (Speed Adaptive Headlights), the level of the environment's luminance (Automated Headlights), steering wheel angle (Cornering Controlled Headlights), and presence of an oncoming vehicle (Auto-dimming Headlights) by setting the headlights' luminance appropriately without driver's interference [6]. Speed adaptive headlights can regulate the pattern of luminance to benefit varying speeds. At low speeds the radiation pattern is adjusted outward and downward to allow an enhanced viewing of the road surroundings and road surface while the beam is projected narrower and longer for higher speeds in order to provide the driver with a greater visibility of farther distances [6, 8]. Moreover, automated headlights are aimed at reducing driver's workload allowing headlamps' auto-light setting. These systems continuously monitor the level of environment luminance and turn the front lights on in case of detecting a minimum threshold of luminance [6]. Further, old-style front lights only illuminate the road path right in front of the vehicle during cornering rather than the intended path. Cornering controlled front lights using the data from steering wheel angle or satellite maps adjust the direction of the auxiliary beams to provide an ideal view of roadway for the driver when he/she turns into a curve [6, 8]. Auto dimming headlights is also an additional feature of intelligent lighting systems that can be also beneficial for other road users since it has the ability of dimming the high-beam headlights in cases where an oncoming or approaching vehicle is detected in order to make sure that the headlights beam will not dazzle other road users [6].

Need fulfillment: This system automatically optimizes the luminance of the roadway in order to:

- Provide a better viewing of the road surroundings that suits various speeds by adjusting the pattern of luminance.
- Improve the visibility of the road environment by adapting the brightness of the front lights according to the level of ambient luminance.
- Increase the visibility of the vehicle's path on curves by directing the additional lighting to the right or left side of the car depending on the direction of the approaching bend.
- Enhance the visibility of the other road users by auto-dimming high beam headlamps when oncoming traffic flow is detected.

Crash relevance: Accidents where adverse viewing is the contributing factor.

Associated risk: Poor visibility of the road because of inappropriate set of headlights.

Effectiveness: Bayly, et al. reported that adaptive front lighting systems have the verified potential to affect 0.5 percent of all traffic fatalities while the full potential (i.e. in case of large-scale utilization) is 8 percent [6].

NIGHT VISION DEVICE

Also known as: Automotive Night Vision, Intelligent Night Vision, Night Vision Assistant [6].

Description: Night Vision Devices, using built-in infrared light sources (i.e. active systems) or thermal imaging cameras (i.e. passive systems), provide the user with an improved view of the roadway by projecting a more clear vision than the driver's current field of view. This enhanced visualization of the vehicle's path is further than the visual field that the vehicle's upper beam headlights can provide and has the advantage of not dazzling oncoming traffic flow. The improved image of the surroundings is presented to the driver through a Heads-Up Display (HUD) overlaid on the vehicle's front glass shield [6, 8].

Need fulfillment: This system projects an improved or higher clarity view of the road path in order to:

- Provide the driver with an enhanced view of the road in poor visibility situations including dark or bad weather conditions.

Crash relevance: Accidents where adverse visibility is the contributing factor.

Associated risk: Poor viewing conditions due to dark and bad weather.

Effectiveness: According to Lind, et al. estimations on expected safety benefit with both intelligent lighting and night vision systems implies 45% reduction of vulnerable road users including pedestrians and cyclists in Sweden [39].

AUTOMATED ENFORCEMENT SYSTEMS

ELECTRONIC LICENSE KEY

Also known as: Smart card systems.

Description: Electronic license key is designed to enhance road safety by stopping unlicensed drivers from operating a vehicle. Driver's license in the form of a smart card will be used to start the engine. A variety of information such as drivers' medical details can be stored on these electronic devices. Future electronic licenses may also be capable of monitoring and recording the activities of the drivers to see whether or not they violate traffic rules [6].

Need fulfillment: This system assesses whether an individual is eligible to operate a vehicle in order to:

- Prevent an individual without a valid driving license from operation of the vehicle.

Crash relevance: Accidents involving unlicensed drivers.

Associated risk: Unlicensed driving.

Effectiveness: According to Regan, et al electronic license key can decrease the number of accident which unlicensed drivers are involved down to 95 percent [51].

ALCOL-LOCK

Also known as: Alcohol Detection and Interlock (e.g. breath- based test interlocks, sniffer system, and skin contact system) [6].

Description: The motivation behind the development of Alco-lock systems is to eliminate the risk of intoxicated driving. The primary functions are units incorporated into the start key of the automobile. The operator needs to blow into a narrow plastic pipe connected to a built-in unit that is capable of analyzing the individual's Blood Alcohol Content (BAC). The car will stay immobilized, until the alcohol detector unit determines that the user is fit to drive [6]. Some other systems using biotechnology can also monitor the driver's BAC through his/hers skin in touch with the steering wheel while the car is being used, and if it was necessary, the application will warn the operator to stop. If the user neglects the advice, then the automobile's head-lights will start blinking. Covering the hands with gloves cannot cheat such system. Except alcohol, biological units are capable of detecting illegal drugs [33].

Need fulfillment: This system analyses driver's level of intoxication in order to:

- Warn the user if he/she is assessed to be drunk.
- Immobilize the vehicle to stop the intoxicated driver from using the car.

Crash relevance: Accidents where alcohol is the main factor initiating the accident.

Associated risk: Drinking and driving.

Effectiveness: Regan, et al. estimated the predisposition of the breath-based test interlocks to reduce the number of alcohol related crashes by 96% [51].

SIGN RECOGNITION SYSTEM

Also known as: Traffic Sign Detection and Recognition System.

Description: These applications have been developed to recognize and reflect the traffic signs to the driver. The goal is to reveal the driver from looking after road signs. The new generation of sign recognition systems may also be capable of taking over the control of the vehicle to comply with the detected traffic rules. Furthermore, such systems can be integrated with Adaptive Cruise Control in order to detect upcoming curves [16].

Need fulfillment: This system constantly monitors road traffic signs in order to:

- Reflect relevant information to the driver beforehand.
- Warn the driver when he/she violates legal traffic limitations.

Crash relevance: Crashes that disobedience of traffic rules is the contributing factor.

Associated risk: Road sign violations.

Effectiveness: de la Escalera and colleagues, based on the results of a simulation study, observed recognition rates over 80% under different road and lighting environments [16].

INTERSECTION ASSISTANT (IA)

Description: Intersection assistant systems serve to support the driver in situation assessments and avoid collisions in critical intersecting conditions. As the traffic crossing at most of the intersections are obscured by obstacles like other vehicles or buildings, vehicle's built-in conventional sensors singly are not effective enough for detecting threatening conditions at intersections. Thus, the ideal way for detecting other vehicles in the range of intersections is cooperative wireless communication technologies (i.e. V2V and RVC) combined with satellite positioning and digital map. Once vehicles approach a junction, they exchange relevant information such as their speed and location through communication. The system processes the input data and reacts correspondingly. Data is represented via on-board displays to inform driver about existence of other vehicles passing through the intersection. In conflict situations, IA warns the driver to stop for the hazardous stream of traffic or intervenes directly into the brake, if the driver neglects warning [7].

Need fulfillment: This system receives and processes relevant data from other intersecting vehicles through inter-vehicle communication technologies in order to:

- Provide the driver with information regarding presence of other vehicles in the approaching junction.
- Warn the driver if a conflict situation is recognized.
- Avoid collisions by intervening with driving tasks if the driver is not responding.

Crash relevance: Multi-vehicle conflicts at intersections and other intersection accidents where excessive speed, inattention, or obstructed view are contributing factors.

Associated risk: Failure to yield right of way at intersections.

Effectiveness: In a simulator evaluation of the effects of IA, Benmimoun and Chen reported about 20% reduction in all multi-vehicle accidents at intersections in case of system-wide deployment [7].

BRAKE ASSISTANCE SYSTEMS

ANTI-LOCK BRAKING SYSTEM (ABS)

Description: Today, ABS is a standard feature of almost every automobile. The idea is to support the users in remaining in charge of the car and lessen the braking distance by averting the wheels from being locked up locking in unexpected braking maneuvers. ABS guarantees the automobile's directional stability between its trajectory lanes, and avoids swerving on bends and slippery pavements in braking movements [10]. There are a number of reasons that may bring the wheels to be locked including braking and cornering, braking on wet pavements, and so on [71]. Such dangerous conditions can be recognized by observing the speed of each individual wheel of the vehicle [6].

Need fulfillment: This system constantly tracks and adjusts the braking pressure in wheels of the automobile in order to:

- Prevent the wheels from being locked up or skid in unsafe braking conditions [6].

Crash relevance: All accidents where the driver applies brake. Anti-lock braking system may be related to a variant of auto accidents including sideswipe crashes, frontal or side impact collisions, roadway departure crashes, and jackknife collisions in heavy vehicles [3].

Associated risk: Unsafe braking situations.

Effectiveness: Kahane reported that ABS has a significant potential in reduction of almost all type of accidents on different road surfaces. For instance, on wet roads, multi-vehicle crashes can be affected by up to 24% for fatal and another 14% for non-fatal accidents. The probability of fatal collisions incidence with pedestrians also can be reduced down to 27% with ABS [34].

EMERGENCY BRAKE ASSIST (EBA)

Also known as: Braking Assist System (BAS)

Description: Braking assist system is capable of recognizing emergency braking and making the best use of brakes so as to stop the automobile instantly with least possible braking distance. Moreover, EBA can be integrated with ABS to reduce the risk of wheels to be locked in heavy braking. This system distinguishes between panic and normal braking, based on the rapidity with which the driver press the brake pedal, and maximize the brake pressure if an emergency situation is detected. Braking assist system may also incorporate forward scanning radars to detect obstacles such as other vehicles or pedestrians on the vehicle's moving path. When the system deems an accident is imminent, and the operator's braking response is insufficient, EBA will be automatically activated [6].

Need fulfillment: This system recognizes panic braking in order to:

- Develop maximum brake force even if the driver applies the brake lightly so as to stop the vehicle immediately with the shortest possible braking distance [6].

Crash relevance: Any braking relevant crashes. Page and colleagues suggest that emergency brake assist systems will mostly be pertinent to multi-vehicle crashes (including frontal, rear, and side impact collisions), pedestrian-vehicle crashes, and non-rollover single vehicle crashes with a stationary obstacle on the vehicle's path ahead [47].

Associated risk: Panic Braking.

Effectiveness: Lawrence, et al. demonstrated that for a car braking while traveling at 100 km/h, this system can reduce stopping distance by up to 45% [38]. Page, et al. estimated that EBA has the potential to affect 6.5-9% of passenger vehicle occupant fatalities, 10-12% of pedestrian fatalities, and 11% of total injuries in France [47]. Lind and colleagues also estimated the expected safety benefit with emergency braking assist system in reduction of multi-vehicle fatalities by 40% and about 18% of roadway departure fatalities in Sweden [39].

ELECTRONIC STABILITY CONTROL (ESC)

Also known as: Active Stability Control, Vehicle Stability Enhancement System, Active Skid and Traction Control [6]

Description: Electronic stability control serves to optimize the contact between vehicle tires and road in order to help the drivers to stay in control when the vehicle is about to swerve out of its trajectory. Driving on poor road surfaces, sudden over-steering in order to avoid a hazardous situation, rapid cornering, or emergency braking, in most cases, may cause loss of optimum traction between the vehicle and road surface leading to vehicle's lateral instability [6]. This diminished lateral grip substantially increases the risk of sliding, spinning, and rolling over. Comparing the current driving situations with standard driving conditions, the system decides whether the operator is near to fail in controlling the car. If an emergency condition is detected, the system distributes necessary amount of traction amongst wheels, and adjusts brake pressure for every single wheel of

the vehicle so as to stabilize the vehicle in emergency evasive maneuvers. ESC coordinates Anti-lock Braking System and Traction Control System (which maintains maximum traction of the tires when accelerating) to improve vehicle's handling when cornering and braking. This means that every vehicle fitted with ESC system necessarily has ABS and TCS, but the reverse is not always true [6]. Nowadays, ESC is a common feature in passenger vehicles that can avoid rollover impacts [8].

Need fulfillment: This system continuously compares the operator's intended direction considering driver's steering input to the vehicle's actual movement direction in order to:

- Detect an eventual loss of control in which the vehicle is not going where the driver intends.
- Adjust the brake pressure to ensure each wheel is receiving the required level of brake force to avoid swerving.

Crash relevance: Off-path on a curved or straight path crashes, rollover crashes, and accidents attributed to excessive speed and poor road surface.

Associated risk: Emergency evasive maneuvers.

Effectiveness: According to Lind, et al. estimations of the full potential expected with electronic stability control implies 20% reduction of all fatal accidents in Sweden [39].

SPEED ADAPTING SYSTEMS

INTELLIGENT SPEED ADAPTATION (ISA)

Also known as: Intelligent Speed Assistance, External Vehicle Speed Control, Speed Alerting System.

Description: In general ISA refers to any system which helps the drivers to keep the speed of their vehicle based on the government's predefined speed limit in a given area [8]. Three levels of intervention employed for implementing ISA systems: advisory, voluntary, and mandatory. Advisory systems can only warn the user if he/she exceeds the legal speed limit without taking any action in order to limit the speed of the vehicle. Voluntary systems can limit the speed of the vehicle to the prevailing speed limit when it is enable, but they can be disabled by the drivers at any time they want. The highest level of control over the vehicle is related to mandatory systems which ensure that the driver cannot slip out of legal speed limit [12]. The local speed limits can be communicated to the automobiles either via roadside transponders or through GPS technology [6]. A GPS based ISA system incorporates satellite positioning linked to a digital map database that contains information such as maximum driving speed for the road network [Bishop]. The predetermined speed limits can also be obtained using optical recognition technologies (i.e. traffic sign recognition system) [16]. The ideal ISA systems are variable and dynamic systems which are capable for adjusting the speed limit by recognizing certain locations (e.g. school zone, pedestrian crosswalk, and sharp bends on roads) or certain conditions (e.g. weather condition, traffic congestion) [6, 12].

Need fulfillment: This system continuously monitors the speed of the vehicle, current speed limit on a road, and variable speed limit zones in order to:

- Warn the driver when he/she slips out of the local speed limit.
- Adapt speed of the vehicle consistent with the legal speed limit in a certain area.

Crash relevance: Excessive speed related accidents.

Associated risk: Speeding.

Effectiveness: Carsten and Tate claim that a mandatory intelligent speed adaptation system expected to reduce 20% of related injury accidents, as well as another 37% of fatal accidents. A dynamic version of mandatory ISA system may result in the reduction of relevant injury accidents up to 36% and 59% of fatal accidents [12].

CURVE SPEED WARNING (CSW)

Description: This system can be assumed as a specialized type of speed adaptation systems which is precisely designed to prevent the operator from taking a bend with an unsafe speed. For this reason Curve Speed Warning integrates three services: the first service encompasses procedures for detecting oncoming bends on the roadway; the second function provides the driver with information on the safe speed to be pursued which is computed based on the degree of curvature of the coming curve; and the third function imposes automatic speed control of the vehicle so as to achieve a safe speed when the driver does not react by him/herself [24]. Information about the characteristic of the approaching curves can be drawn from preexistent satellite maps of the road. Future systems may take other parameters, including road pavement and climate condition, into consideration so as to optimize the computation of the safe speed [8].

Need fulfillment: This system constantly spots the current position of the vehicle compared with a digital map stored on an on-board computer in order to:

- Determine the coming curve's radius.
- Recommend a safe speed to be taken for the approaching curve.
- Warn the driver to a dangerous speed.
- Avoid an impending hazard by imposing speed control when the driver does not respond appropriately.

Crash relevance: Off-path, multi-vehicle, and rollover on curves crashes. Any speed related accidents on curves.

Associated risk: Inappropriate speed on sharp bends.

Effectiveness: Lind et, al. estimated the expected safety benefit with regional warning systems including curve speed warning and downhill speed warning in reduction of crash by 13% in case of large scale deployment [39].

OBSTACLE AND COLLISION WARNING AND PREVENTION SYSTEMS

FORWARD COLLISION MITIGATION (FCM)

Also known as: Rear End Crash Driver Warning Systems, Forward Collision Warning and Avoidance [6].

Description: Collision warning systems are capable of assisting the drivers to evade approaching threats by alerting them whenever an object is assessed to be a hazardous obstacle on the trajectory. The prevention systems provide a supplementary avoidance feature which intervenes with the driving task by automatic braking and deceleration in cases where the driver does not respond properly or the crash determined to be unavoidable. These systems considering the speed and directional movement of various objects on the road path determine the potential dangers. Collision avoidance systems can be seen as specific types of ACC with limited performance [58]. Some systems can also spontaneously tense seatbelts in a pre-collision situation [8]. Forward collision warning systems can also facilitate safe distance keeping from leading vehicles [51].

Need fulfillment: This system continuously tracks vehicle's trajectory in order to:

- Detect common obstacles such as pedestrians, cyclists, vehicles, or other stationary or moving objects on the road path ahead.
- Alert the driver to an impending collision.
- Intervene with the driving task if the driver was not responding.

Crash relevance: Rear-end, head-on, and object collisions. Accidents where driver's diminished vigilance level caused by fatigue, distraction, or inattention is contributing factor [6].

Associated risk: Collisions with generic obstacles on the roadway.

Effectiveness: Forward collision warning systems were expected to be effective at reducing all rear-end crashes by up to 57% [6].

PEDESTRIAN PROTECTION SYSTEMS (PPS)

Description: These systems are designed specifically for recognizing pedestrian, and generally are beneficial in inter-city environments where the pedestrians are walking surrounding traffic and might step onto the road path without seeing approaching vehicle [8]. The Pedestrian Protection Systems philosophy is to distinguish pedestrians or other unprotected road users like cyclists from other obstacles in order to warn the driver about their presence on the vehicle's moving path. These systems, employing visual sensing technologies, are able to recognize both motionless and moving pedestrians, track their moving direction and speed, and assess the impending danger. In cases where the accident cannot be avoided, PPS can intervene in braking actions, and trigger external airbags which may lessen the risk of fatality and moderate injury severity of the pedestrian struck by the vehicle. Currently, the technical community of PPS development encounter with challenges of robust identification of pedestrians without any fault, since people's appearances represent a high range of variation (e.g. different clothing, height, size, dynamic shape, and viewing angles) [23].

Need fulfillment: This system constantly tracks the road ahead in order to:

- Detect a pedestrian or cyclist on the vehicle's trajectory.
- Alert the driver to an eminent pedestrian crash.
- Intervene with the driving task if the driver was not responding.
- Expand exterior airbags to moderate the impact.

Crash relevance: Pedestrian crashes.

Associated risk: Pedestrians not crossing road at crosswalk.

Effectiveness: Holding and colleagues investigated the special effects of exterior airbags on a passenger vehicle in collision with adult-pedestrian crash test dummies. It was found that the airbags can significantly absorb the kinetic energy exerted on the pedestrians. The authors also claimed that such systems can reduce the risk of head injuries by 20% for a collision at 40 km/h [31].

ANIMAL DETECTION AND WARNING

Description: These systems have been specifically developed to recognize animals and general are beneficial in rural roads. The procedure for detecting animals system is alike to pedestrian recognition systems with certain alterations in the technical specification owing to the variances between their characteristic. One other

mechanism is to keep the animals away via ultrasonic sound diffusors [6]. Roadside to Vehicle Communication (RVC) technologies can also be useful in preventing vehicle-animal conflicts since they can alert the driver to the regions well-known for occurrence of animals nearby. Roadside beacons collect information from sensors, which can recognize animals walking over or near the roadway considering their body heat or movement, and then transmit this data to the vehicle once it is in the range of the transponders [8].

Need fulfillment: This system continuously monitors the road ahead in order to:

- Detect animals crossing or on the vehicle's trajectory.
- Alert the driver to an impending animal collision.

Crash relevance: Any accident involving animals, including both crashes with animals, and collisions that result from evasive maneuvers to avoid animals on the road.

Associated risk: Animals moving on or around roadway.

Effectiveness: No evidence of studies on the effectiveness with animal detection system has yet been conducted [6].

LATERAL MANEUVER SUPPORTING SYSTEMS

LANE DEPARTURE WARNING AND AVOIDANCE SYSTEM

Also known as: Lane Departure Warning and Control, Lane Keeping Assistance [6].

Description: LDW system constantly monitors the automobile's position between its trajectory lanes. The cautionary applications alert the user when he/she is about to leave the moving lane inadvertently (i.e. not when the driver uses turn signals or steers the wheel deliberately to perform a lateral maneuver) [6]. The prevention applications, apart from notifying the user, maintain the car within lane by adjusting steering-wheel angle. There are a number of mechanisms for detecting lanes from use of magnetic markers and digital maps to image processing techniques [8].

Need fulfillment: This system constantly tracks the position of the vehicle within the lines of a marked lane and compares it to driver's steering input and on/off condition of the relevant turn signal in order to:

- Warn the driver if the vehicle begins to drift out of its lane while the indicator light is not on in that direction.
- Perform corrective steering maneuvers so as to maintain the vehicle in a correct position within its lane.

Crash relevance: Off-path on a curved or straight path, side-swipe, head-on collisions. Accidents where driver's diminished vigilance level caused by fatigue, distraction, or inattention is contributing factor [6].

Associated risk: Inadvertent lane deviation.

Effectiveness: Lind, et al. estimated the positive effect of Lane Departure Warning and Avoidance System in reduction of off-path fatalities by up to 40% in Sweden [39].

LANE CHANGE COLLISION WARNING AND AVOIDANCE (LDW)

Also known as: Lateral Collision Avoidance, Lane Change Assistance, Overtaking Assistance, Blind Spot Monitoring, Side Object Detection and Warning System [6].

Description: Lane change support systems serve to assist the operator during lane changings on the road network by monitoring adjacent lanes of traffic and warning the driver to impending hazards. Various radars and sensors are engaged to monitor vehicle's lateral blind space, and alert the driver to identified dangers in the blind spots. Warnings are presented to the user through visual symbols or auditory messages [6]. More advanced systems, employing longer range radars, may also track the road ahead to detect fast approaching vehicles which may pose head-on collision threats in lane changes. Avoidance systems can prevent unsafe lane changings through automatic corrective counter steering [8].

Need fulfillment: This system continuously monitors the adjacent lanes of the traffic in order to:

- Spot surrounding vehicles that may present hazards when overtaking.
- Warn the driver to the impending risks.
- Prevent crashes in overtaking or lane changing maneuvers.

Crash relevance: Side-swipe, head-on conflicts [6].

Associated risk: Overtaking and lane changing maneuvers.

Effectiveness: According to Lind, et al. lateral collision avoidance systems have the potential to affect 20% of side-swipe fatalities in Sweden [39].

ROAD DEPARTURE WARNING AND AVOIDANCE (RDW)

Description: Road departure warning system has been developed to warn the drivers when they are likely to be at the risk of swerving off the road path and collide with an obstacle, plus when they are approaching to a curve with an excessive speed. To achieve this goal, RDW integrates two subsystems: lateral drifting warning, and a map-based curve speed warning. Lateral drift warning is the more advanced version of lane departure system which apart from detecting the lane that the vehicle is traveling within, using vision-based and radar-based sensors can assess the width of paved road shoulder as well as the existence of any obstacle on the road shoulder. Combining this information, the system can adjust the warning alerts according to the criticality of the circumstances. For example, when the vehicle is drifting onto an obstructed shoulder, the warning must be at its highest urgent level rather than in case of swerving into a width and unobstructed shoulder. Road departure avoidance systems can perform automatic steering and braking control to keep the vehicle within its lane as well, when the crash is not avoidable [8].

Need fulfillment: This system, featuring digital maps which notify the system of approaching curves, continuously monitors the position of the vehicle within its trajectory, its speed, as well as road's surroundings in order to:

- Warn the driver if the vehicle begins to swerve off the road edges.
- Prevent an imminent danger by imposing steering and braking controls to maintain the vehicle in a correct position within its trajectory.

Crash relevance: Off-path on a curved or straight path conflicts. Accidents where driver's diminished vigilance level caused by fatigue, distraction, or inattention is contributing factor [6].

Associated risk: Departing the road edges.

Effectiveness: According to Mckneever road departure warning system has the potential to affect 8.4% of road fatalities and 4% of injury crashes in US [43].

SECONDARY ASSISTING SYSTEMS

ADAPTIVE CRUISE CONTROL (ACC)

Also known as: Autonomous Intelligent Cruise Control, Intelligent Cruise Control [6].

Description: ACC facilitates travelling on roads by releasing the driver from regulating functions to keep an appropriate headway distance in sparse traffic flows. ACC takes the preset speed till its detector radars notice a leading vehicle. The fitted automobile gradually changes the speed via active throttling and braking so as to adapt to the speed of the vehicle in front of it while maintaining the preset following distance. As soon as the trajectory determined to not be obscured, the device will spontaneously make the vehicle to reaccelerate and move at the preselected speed [8, 48]. Typical cruise controls function at speeds greater than 40 kilometers per hour and are not suitable for using in crowded traffic situations. The new generation of ACC which is also known as low speed ACC or stop-and-go has been specifically developed for driving in metropolitan areas and overcrowded traffic flows. Such systems are able to keep following the stream of the traffic immediately and decelerate the car until it comes to a standstill [8, 48].

Need fulfillment: As long as the system is activated, it continuously monitors the equipped vehicle's forward path in order to:

- Detect a slower vehicle ahead.
- Adjust to the speed of leading vehicle while keeping the preset headway distance.
- Reset to the predefined speed when the traffic clears.

Crash relevance: Rear-end conflicts [6].

Associated risk: Driving in monotonous and tiresome environments.

Effectiveness: As Abele and colleagues claim, the probability of rear-end collisions with ACC would be reduced by 25%. The authors also discuss that ACC and its functional enlargement (i.e. stop-and-go), apart from their safety benefit, have a significant potential to increase road capacity by reducing traffic congestion [1].

TRAFFIC CONGESTION ASSISTANT

Description: Traffic congestion assistants go one step further than stop-and-go systems by assisting the drivers both before approaching and during driving in congested traffic flows. To achieve this goal, three tasks have to be performed respectively by the system: warning and information (W&I), active pedal (AP), and stop-and-go (S&G). Warning and information functions are responsible for providing the driver with real-time information of approaching traffic situation using vehicle-to-vehicle and road-to-vehicle communication technologies, thus, the driver can either prepare for driving in the congestion or decide on an alternative path. Active pedal decelerates the vehicle gradually prior to a specific distance from the tail of the traffic jam. This can reduce the risk of unfavorable sudden braking when the tail of the congestion is seen unexpectedly. Apart from the danger of forceful braking close to the traffic congestion which may result in a series of head-to-tail accidents, it can also increase the inflow of traffic due to growing the jam at the tail [65]. Stop-and-go is employed at the final stage where the vehicle joins the traffic jam. As a typical stop-and-go system, it follows a leading vehicle swiftly keeping a short distance with no need for the driver's reaction. Although here the communication is not limited only to the leading vehicle, but also comprises other vehicles that are laid longitudinally on the road path. As

the road ahead become clear of congestion, the stop-and-go will be disengaged and switched to the manual driving mode [65].

Need fulfillment: This system incorporates wireless communication and distance keeping in order to:

- Detect the tail of the approaching traffic flow.
- Reduce the speed to join the traffic jam.
- Follow the leading vehicle immediately.

Crash relevance: Rear-end conflicts.

Associated risk: Congested traffic drive.

Effectiveness: According to the results of a simulator study conducted by van Eenennaam et, al., congestion assistant was found to be very effective and efficient in improving both traffic safety and efficiency as well as unpleasant driver behavior which is a part of the cause of traffic jam [65].

ROUTE PLANNING ASSISTANCE

Description: Rout planning systems support the drivers by providing them with information that can help them to select effectively among the available alternatives towards their intended destination. The required information (e.g. traffic flow situations, payment condition, etc.) is communicated to the vehicles using inter vehicle communication technologies. Various sensors and radars are engaged to collect real-time data about the surrounded traffic situation of the vehicle's current location. This information can be divided into two categories of critical (e.g. collisions, traffic flow situation) and non-critical (e.g. average velocity) data. Every equipped vehicle will broadcast the collected critical info to all other vehicles within its radio rang. Non-critical data would be accessible through inter-vehicle inquiries [20].

Need fulfillment: This system employs inter-vehicle communication technologies in order to:

- Assist the driver make an optimum route planning choice by providing him/her with local traffic condition of possible routes towards their destination.

Crash relevance: -

Associated risk: Congested traffic flows.

Effectiveness: These technologies have been assessed to have a promising effect in balancing the traffic flow [20].

PARKING ASSISTANCE SYSTEM

Also known as: Parking Aid systems.

Description: Nowadays an assortment of parking assistant applications are available varying from functions that are simply trigger a horn when the vehicle's edges is about to strike to something (i.e. optical parking assists) [49] up to highly advanced systems that are capable of parking the car automatically into a chosen parking space (i.e. intelligent parking assistants) [8].

Need fulfillment: This system employs radar or optical sensors in order to:

- Provide the driver with information about the location of the automobile's edges in a car park maneuver.
- Warn the driver if any obstacles are detected in the warning range of the sensors.

Crash relevance: Car park crashes.

Associated risk: Car park crashes.

Effectiveness: No evidence of estimations on the effectiveness with parking assistance systems reported as yet [6].

APPENDIX C: QUESTIONNAIRE

A Questionnaire on Intelligent Transportation Systems

The purpose of this survey is to examine how acceptable are various in-vehicle Intelligent Transportation Systems (ITS) to the driving public. You don't have to have any prior knowledge about the systems. All required information is represented in this survey. The questionnaire is voluntary and it does not require specific personal information. If you have driving experience and agree to take part in this survey please take your time and complete the questions.

In-vehicle Intelligent Transportation Systems are mounted electronic systems in vehicles which help the driver in different driving activities by providing warning or informing messages about potential dangers on the road ahead, or taking the control of the vehicle automatically. The main objective of ITS systems is to prevent or mitigate impending collisions. ABS, Cruise Control, navigation, and speed alerting systems are examples of ITS equipment.

1. Background information

Age: years old

Male Female

Driving Experience: years

Approximate annual number of kilometers: km.

Distribution of annual number of kilometers over different road types:% Urban Roads ,% Motorways, % Rural Roads

Type of vehicle you drive: Car/Van Bus/Truck

Driving purpose: Private (<50% business trips) Business (>50% business trips)

* Here business driving means that you drive with a vehicle which belongs to your workplace, and has no personal usage.

2. What type/s of the following ITS technologies are you familiar with?

- | | |
|---|--|
| <input type="checkbox"/> Drowsy Driver Warning | <input type="checkbox"/> Adaptive Cruise Control (ACC) |
| <input type="checkbox"/> Alcohol detection and interlocks (Alco-lock) | <input type="checkbox"/> Intelligent Speed Adaptation (ISA) |
| <input type="checkbox"/> Intersection Assistant | <input type="checkbox"/> Curve Speed Warning |
| <input type="checkbox"/> Lane Change Support | <input type="checkbox"/> Electronic license key |
| <input type="checkbox"/> Adaptive Front Lighting | <input type="checkbox"/> Obstacle and Collision Mitigation Systems |
| <input type="checkbox"/> Night Vision | <input type="checkbox"/> Vehicle Monitoring System |

3. In the following section, please rate each represented ITS application from zero (extremely un-useful) to five (extremely useful) based on your perceived usefulness of the system, and then circle your preferred number. Please select the attribute level of some systems which are available in two from of: Warning, and Automatically avoiding. You can find the definition of each system in associated section if you are not already familiar with that system.

* Please rate each system as it is, and without comparing to other systems which may have similar features.

3.1 Drowsy Driver Warning

Description: Drowsiness detection applications can alert the users whenever they assessed to be sleepy or impaired. These functions are able to notice operator's drowsiness or inattention by monitoring both user's (e.g. head and eye movements) and vehicle's (e.g. lateral movement and speed) behavior.

How would you rate for the usefulness of this system?

Extremely Un-useful

Extremely useful

0 1 2 3 4 5

3.2 Alcohol detector and interlocks

Description: The motivation behind the development of Alco-lock systems is to eliminate the risk of intoxicated driving. The car will stay immobilized, until the alcohol detector unit determines that the user is fit to drive.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

3.3 Electronic license key

Description: Electronic license key is designed to enhance road safety by stopping unlicensed drivers from operating a vehicle. Driver's license in the form of a smart card will be used to start the engine. A variety of information such as drivers' medical details can be stored on these electronic devices. Future electronic licenses may also be capable of monitoring and recording the activities of the drivers to see whether or not they violate traffic rules.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

3.4 Vehicle Monitoring Systems

Description: These systems are a number of independent services that constantly monitor the behavior of various components of the vehicle and alert the user to any abnormalities instantly. For example, problems related to vehicle's engine, tires, brakes, ABS, and so on can be diagnosed by these systems.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

3.5 Night Vision

Description: Night Vision Devices provide the user with an improved view of the roadway by projecting a more clear vision than the driver's current field of view. This enhanced visualization of the vehicle's path is further than the visual field that the vehicle's upper beam headlights can provide. The improved image of the surroundings is presented to the driver through a Heads-Up Display (HUD) overlaid on the vehicle's front glass shield.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

3.6 Adaptive Front Lighting

Description: Adaptive front lights optimize the visibility of the vehicle's road path ahead and on curves considering vehicle's speed, steering wheel angle, and the level of the environment's luminance without driver's interference. For instance, at higher speeds it illuminates farther distance while at lower speeds beam patterns will be adjusted down and outward. In addition while cornering the inner headlight illuminates the upcoming turn while the outer one maintains a straight beam pattern. It also has the ability of dimming the high-beam headlights in cases where an oncoming or a preceding vehicle is detected in order to make sure that the headlights beam will not dazzle other road users.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

3.7 Forward Collision Mitigation System

Description: Collision warning systems are capable of assisting the drivers to evade approaching threats by alerting them whenever an object is assessed to be a hazardous obstacle on the trajectory. The prevention systems provide a supplementary avoidance feature which intervenes with the driving task by automatic braking and deceleration in cases where the driver does not respond properly or the crash determined to be unavoidable.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

I would like to use the collision mitigation system which

- Only warns me about a potential collision
- Perform automatic functions if the crash is not avoidable.

3.8 Intelligent Speed Adaptation

Description: Any system which either warns the driver or automatically limits the speed of the vehicle when it exceeds the legal speed limit of a given area. More advanced variants are capable for adjusting the speed limit by recognizing certain locations (e.g. school zone, pedestrian crosswalk) or certain conditions (e.g. weather condition, traffic congestion).

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

I would like to use a speed adaptation system which

- Only warns me when I slip out of legal speed limit.
- Automatically limit my speed to the safe speed threshold.

3.9 Curve Speed Warning (CSW)

Description: This system can be assumed as a specialized type of speed adaptation systems which is precisely designed to prevent the operator from taking a bend with an unsafe speed.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

I would like to use a curve speed system which

- Only informs me about the required safe speed for an upcoming curve.
- Automatically adjusts the speed on curves.

3.10 Lane Change Support

Description: Lane change support systems serve to assist the operator during lane changings on the road network by monitoring adjacent lanes of traffic and warning the driver to impending hazards.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful
0 1 2 3 4 5

3.11 Intersection Assistant

Description: The intersection assistant can reduce risks at intersections, specially the crossings with no right-of-way and the intersections which the crossing traffic is obscured by buildings or other vehicles, by providing information about the presence of other vehicles via onboard displays and using floating information between vehicles or vehicles and roadside equipment. In conflict situations, IA warns the driver to stop for the hazardous stream of traffic or intervenes directly into the brake, if the driver neglects warning

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful

0 1 2 3 4 5

I would like to use intersection assistant system which

- Only warns me to the presence of other intersecting vehicles.
- Automatically apply brakes in conflict situations.

3.12 Adaptive Cruise Control

Description: ACC facilitates travelling on roads by releasing the driver from regulating functions to keep an appropriate headway distance in sparse traffic flows. ACC takes the preset speed till its detector radars notice a leading vehicle. The fitted automobile gradually changes the speed via active throttling and braking so as to adapt to the speed of the vehicle in front of it while maintaining the preset following distance. As soon as the trajectory determined to not be obscured, the device will spontaneously make the vehicle to reaccelerate and move at the preselected speed. The new generation of ACC are also able to keep following the stream of the traffic immediately and decelerate the car until it comes to a standstill.

How would you rate for the usefulness of this system?

Extremely Un-useful Extremely useful

0 1 2 3 4 5

4. Which of the following systems do you most like to have in your vehicle? (Please choose only one system)

- | | |
|---|--|
| <input type="checkbox"/> Drowsy Driver Warning | <input type="checkbox"/> Adoptive Cruise Control (ACC) |
| <input type="checkbox"/> Alcohol detection and interlocks (Alco-lock) | <input type="checkbox"/> Intelligent Speed Adaptation (ISA) |
| <input type="checkbox"/> Intersection Assistant | <input type="checkbox"/> Curve Speed Warning |
| <input type="checkbox"/> Lane Change Support | <input type="checkbox"/> Electronic license key |
| <input type="checkbox"/> Adaptive Front Lighting | <input type="checkbox"/> Obstacle and Collision Mitigation Systems |
| <input type="checkbox"/> Night Vision | <input type="checkbox"/> Vehicle Monitoring System |

5. What concerns about/expectations of ITS you have that needs to be met in order for these technologies to be acceptable to you?

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Thank You