A STUDY ON PERCEIVED USEFULNESS OF ECO DRIVING ASSISTANT SYSTEMS IN EUROPE

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ABSTRACT

Assessing the usefulness of eco driving assistant systems is of high interest for system developers and researchers. This applies especially to systems which try to influence the driver's behaviour in everyday situations. This paper presents results of a survey simultaneously conducted in eleven European countries with more than 5000 respondents aiming at collecting needs and requirements for future eco driving assistant systems. Such systems have the potential of changing driving behaviour in the long run for supporting a more fuel efficient driving and reducing emissions caused by motorized traffic. Three different driver assistant systems are considered covering inefficiencies in pre-trip, on-trip and post-trip situations. Each system is assessed according to the factors of perceived usefulness, the expected environmental impact and the user's willingness to pay for it.
The study will show that in general car drivers welcome the deployment of eco driving assistant systems and rate them as useful. It likewise demonstrates that the acceptance of additional costs for the user is very low.

Topic: *From smart concepts to successful implementation*; Subtopic: *User and societal acceptance*

INTRODUCTION

The so called Green Intelligent Transport System (Green ITS) has become a generic term when discussing the reduction of the impact of road traffic on environment. High expectations are placed on drivers, vehicle manufacturers and traffic systems to contribute to this objective.

A strategic objective for emission reduction is the optimization of vehicle usage [1]. This can be achieved by reducing overall vehicle travel (e.g. by restrictive measures), influencing driving behaviour (e.g. by a more economic driving) or optimizing the traffic network (e.g. by introducing advanced traffic management measures). Several car manufacturers have solutions in place delivering trip information post driving, aiming to improve driving behaviour. FIAT for example could demonstrate that fuel savings of up to 16% could be realized in the short term [2]. But as showed in [3] these saving reduce significantly after one year since old driving habits re-emerge. Innovative driver assistant systems need to improve driving behaviour sustainably. For the development of such systems the user's perception of the technology is highly relevant. Technology has to conform with the user's ability to actually use it, the perceived usefulness and system advantages.

Many studies have been conducted to assess the user acceptance of driver assistant systems. Davis et. al. [4] described the different dimensions of technological acceptance which was used by Meschtscherjakov et. al [5] to investigate the acceptance of different driver assistant concepts towards a more economic driving. However none of these approaches included the assessment of user acceptance of cooperative technology aiming at influencing three factors mentioned earlier: reducing unnecessary vehicle travel, influencing driving behaviour and optimizing the traffic network in order to reduce fuel consumption and emissions.
Man et. al. [6] concluded from a driver survey on Green ITS that information on monetary savings, fuel consumption and environmental impact are highly relevant for drivers. However, up to now, no large-scale user study on the perception of car users regarding assistant systems aiming at fuel or emission reduction is known to the authors of this paper.

The objective of this paper is to:

1. Investigate the perceived usefulness of Green ITS by drivers in Europe
2. Describe regional differences in terms of perceived usefulness, their potential contribution to environmental protection and the willingness to pay for these future applications in Europe.

The main objective of Green ITS applications discussed in this paper is the reduction of fuel consumption. The term "*eco driving assistant system*" was found suitable to explain this main motive. The study considers drivers of motorized vehicles including cars, motorcycles and trucks. Cyclists or pedestrians are not a focus of this study.

METHOD

To collect user needs and requirements for future eco driving assistant systems a standardized questionnaire study was found to be the most suitable method. This approach helps to get a better idea of desired functionalities as well as motivating factors and barriers for vehicle drivers to use such systems before product design. Moreover the inclusion of a large amount of respondents enables the possibility to analyze regional differences within Europe.

SURVEY DESIGN

The questionnaire consists of three parts: (1) Driver information, (2) Vehicle information and (3) Rating of different eco driving assistant systems.

Questions for the first and second part were taken from relevant existing vehicle driver surveys such as questionnaires in [7] and the German national travel survey (MiD 2008) [8]. Gathered information comprised for example the respondent's age, gender, profession, type of vehicles used and vehicle features. Furthermore vehicle drivers were asked about their driving experience, annual mileage, and main driving purposes as well as the general frequency of use and functionalities of navigation devices used.

The third part formed the main part of the survey. The respondents were confronted with illustrations and a short description of main functionalities of seven different eco driving applications. Examples for eco driving assistant systems were derived from literature and current innovations in the field of Green ITS. Three of these applications, which can help the driver actively to save fuel, are considered in this paper. They are differentiated by the conditions of use: *Pre-trip, On-trip and Post-trip*.

The following section gives an overview of the eco driving assistant applications from the survey which are analyzed in this paper:

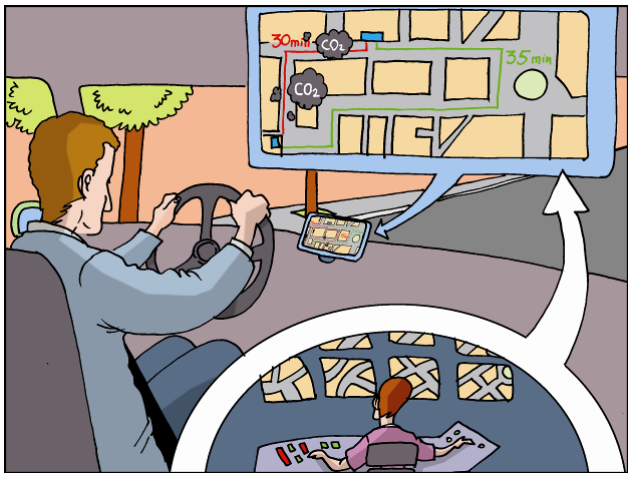

Figure 1. Pre-trip application

Pre-trip: The objective of this application is to support the driver choosing the most appropriate route to reach her/his destination. Calculated travel time information is based on real time data and provided by a central traffic management centre. Besides travel time information the driver also receives information on local emissions for different routes. In this example the traffic management centre suggests to use the route with a slightly longer travel time to contribute relieving heavily polluted areas e.g. caused by dense traffic.

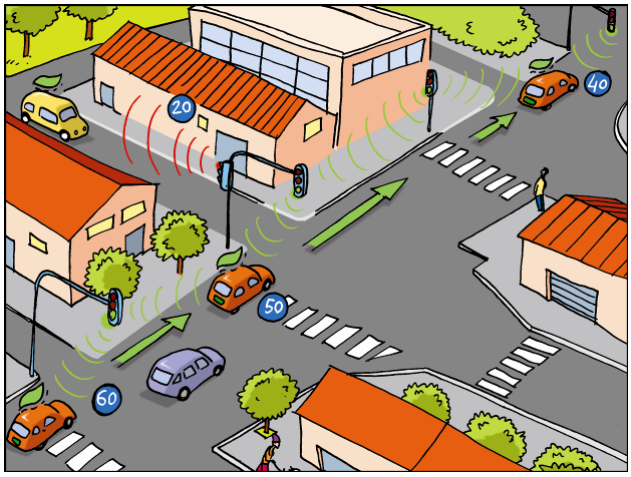

Figure 2. On-trip application

On-trip: The second application notifies the driver about the most suitable speed which allows her or him to drive through the intersections without stopping at traffic lights. The illustration demonstrates that recommended speeds differ from section to section and that cars and traffic lights communicate.

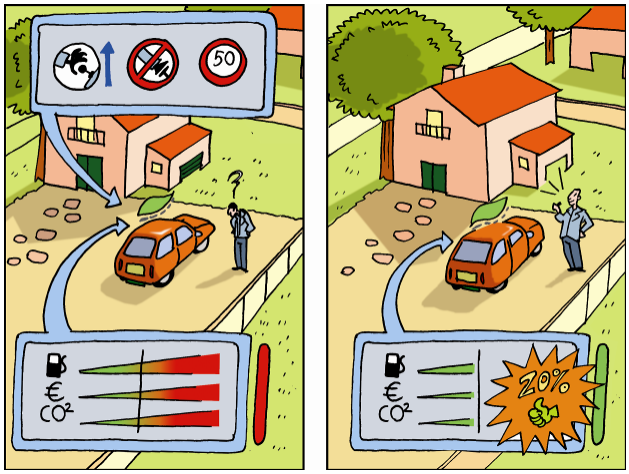

Figure 3. Post-trip application

Post-trip: After a journey the driver receives a report which indicates positive or negative driving behaviour of the last trip. The system is able to record such factors as inefficient gear change, erratic braking or speeding. The given parameters are used to calculate fuel consumption, the monetary value of fuel and the amount of CO_2 emitted. An improved driving style will result in a message showing the rate for improvement. Negative driving style results in a message showing potential improvement (e.g. gear change timing, acceleration/deceleration or speeding).

For each application the survey used the same questioning technique. The respondent was asked to rate up to 12 different items (dependent on the application) on a bi-polar Likert scale (*strongly agree (1), agree (2), neither agree nor disagree (3), disagree (4), strongly disagree (5)).*

This paper focuses on the analysis of the response of five selected items. It covers different characteristics of the perceived usefulness of the applications:

- *This service helps me to save fuel.*
- *This service should be turned off if I want.*
- *This service helps me actively contribute to environmental protection.*
- *This service would be useful for me.*
- *This service is worth paying for.*

The chosen items are partly based on Davis' approach to assess technological acceptance in [4] and [7] covering the perceived ease of use and usefulness of the applications. This selection was extended with items covering the contribution to environmental protection, willingness to pay for such applications and the impact on fuel consumption adapting Davis' approach to our focus of research.

SURVEY DISSEMINATION

An online questionnaire was found most suitable due to low costs, fast dissemination and easy monitoring of response data. The questionnaire was monitored and disseminated through the online survey tool Zoomerang (www.zoomerang.com). Each translation was placed on homepages of automobile clubs in 11 European countries: Norway (NO), Finland (FI), Germany (DE), France (FR), Belgium (BE), Austria (AU), Switzerland (CH), Slovenia (SL), Croatia (CR), Spain (ES) and Portugal (PO). The visibility of the survey was raised by implementing a banner on the page with the survey link. Aborted fill-outs were filtered and not considered in the data analysis. The time required for answering the questionnaire was around 10 minutes for a native speaker. The quality of the questionnaire was improved in several steps through pre-tests with native speakers. The survey was online between August 2010 and October 2010.

DATA ANALYSIS

Low response rates in particular countries made it necessary to aggregate the data to six geographical regions for data analysis: Northern Europe (NO, FI), Germany (DE), Alp Region (CH, AU), Western Europe (FR, BE), Eastern Europe (CR, SL) and Southern Europe (ES, PO). Due to the high number of responses in Germany compared to others this country was considered as an own region in the analysis. The total number of respondents from the comparatively small countries Croatia and Slovenia is of course not representative for Eastern Europe but it gives good indications for other countries within Eastern Europe which are also characterized by an increasing rate of motorization.

To calculate sound results for issues relating to overall Europe a weighting factor for each country was used which incorporated the countries population and car ownership.

The following description of results is performed first on a European level ensued by a regional analysis investigating varieties in the perceived usefulness of eco driving assistant systems in different European regions.

RESULTS

DESCRIPTIVE INFORMATION OF RESPONDENTS

In total 5807 responses were collected of which 97.4% were vehicle drivers and 2.6% said they do not drive a vehicle currently. The responses were collected from the different regions as following:

Region	Share of responses
Northern Europe	3.8%
Western Europe	28.2%
Germany	38.3%
Alp Region	6.5%
Southern Europe	20.6%
Eastern Europe	2.6%
	n = 5807

Table 1. Regional share of responses

The majority of participants (78.2%) were male and on average between 35 and 49 years old (median category). Four out of five respondents use their vehicle often to very often for purposes like shopping, visiting friends and family or vacation. The average age of cars driven was between 4 and 6 years. However a rather high share of respondents (15.0%) reports to drive a car which is older than 10 years. The majority (43.9%) drives a medium sized car or small car (17.4%). The annual driving performance of the respondents is almost equally distributed to three groups: below 12,000 km (35.6%), 12,000-20,000 km (32.3%) and above 20,000 km (32.1%).

Vehicle drivers were also asked about the ownership and use of navigation devices. Drivers owning a navigation device (68.8%) stated that they use it on every trip (8.7%), frequently (32.9%), occasionally (43.9%), infrequently (10.8%) or hardly ever (3.7%). As expected, respondents use their navigation device mostly for finding an address (89.0%). Other functionalities such as finding Points-of-Interest (40.0%) and Traffic Message Channel (39.7%) are of rather secondary interest.

ACCEPTANCE OF ECO DRIVING ASSISTANT SYSTEMS IN EUROPE

Based on the first objective we focused on the European wide assessment of eco driving assistant systems. The aim was to find out how drivers perceive the different systems and to investigate if correlations between driver and vehicle characteristics and the acceptance of eco driving assistant systems are existent. Figure 4 shows how the driver assistant systems were rated according to five items introduced above.

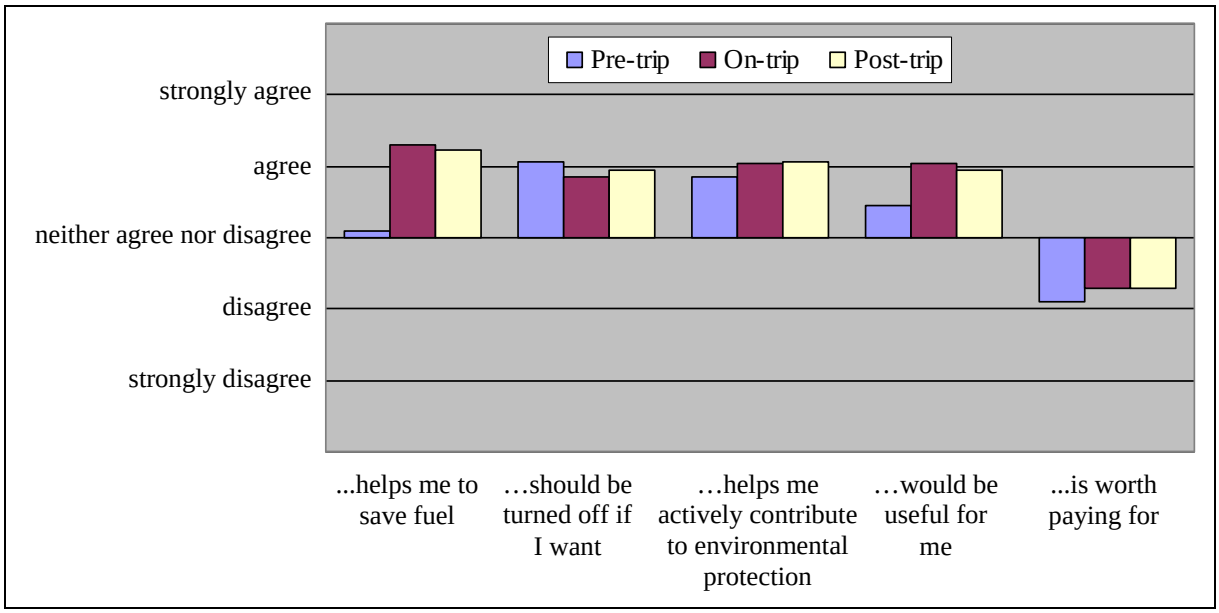

Figure 4. Rating of proposed of eco driving assistant systems in Europe

The analysis demonstrates that the assessment of the proposed eco driving assistant systems is good and the respondents rate the applications as valuable. Only marginal differences in the rating of the items *fuel saving*, *contribution to environmental protection* and *usefulness* can be observed between the three applications. The greatest benefit on a European scale is seen in the fuel reduction potential of the applications. Differences in the rating are described below.

The On-trip and Post-trip systems received a very good rating (mean= 1.70 and 1.76 resp.) on the impact of lowering the fuel consumption. In contrast the Pre-trip system was rated significantly lower (2.91). Nevertheless all systems received a high agreement on the necessity of having an off option.

The potential to have a positive environmental impact was stated to be high for all systems (mean lower than 2.15). The average usefulness was rated again lowest for the Pre-trip system (2.54) and highest for the On-trip system (1.96). The disagreement on the worthiness to pay for the systems was in general very strong. The lowest payment acceptance was calculated for the Pre-trip system (3.90).

A further interest of the analysis was if specific driver characteristics or for example the use of navigation devices has an impact on the rating of the applications. Therefore a correlation analysis was carried out. The Spearman-Rho correlation coefficient which is suitable for ordinal categorized variables was used for this calculation. However the results of the analysis showed no statistical correlation of the ratings of eco driving assistant systems and driver characteristics. Values for the coefficient are below (+/-) 0.300 and therefore statistically not significant. The assessment of the proposed applications is independent from driver characteristics and the usage of navigation devices. Results for selected driver characteristics are presented below:

Driver characteristics	**Pre-trip**	**On-trip**	**Post-trip**
Country of origin	-,147	-,103	-,035
Age	,121	,092	-,102
Driving experience	,105	,078	-,097
Annual driving performance	,026	-,026	,046
Navigation device usage	,038	,050	,120
			significance level: p=0.05

Table 2. Analysis of correlations between applications and driver characteristics (Spearman Rho correlation coefficient)

REGIONAL DIFFERENCES IN THE PERCEIVED USEFULNESS

This section presents the assessment of regional differences in perception of the applications. The analysis focuses on three selected items: *usefulness, contribution to environmental protection* and *the willingness to pay*. Therefore Figure 5, 6 and 7 show the rating of these items within each region differentiated by application.

For the item *usefulness* the results suggest that respondents from Southern Europe rate the all applications comparatively high. Especially the Post-trip application is found to be very useful. Eastern European respondents rate the On-trip application the highest whereas the acceptance is the lowest in Western Europe the lowest. As already found in the Europe wide analysis the Pre-trip application is generally rated less useful than the On-trip and Post-trip options. This is especially true for Germany and the Alp Region. Southern Europe has the highest rating of the Pre-trip application.

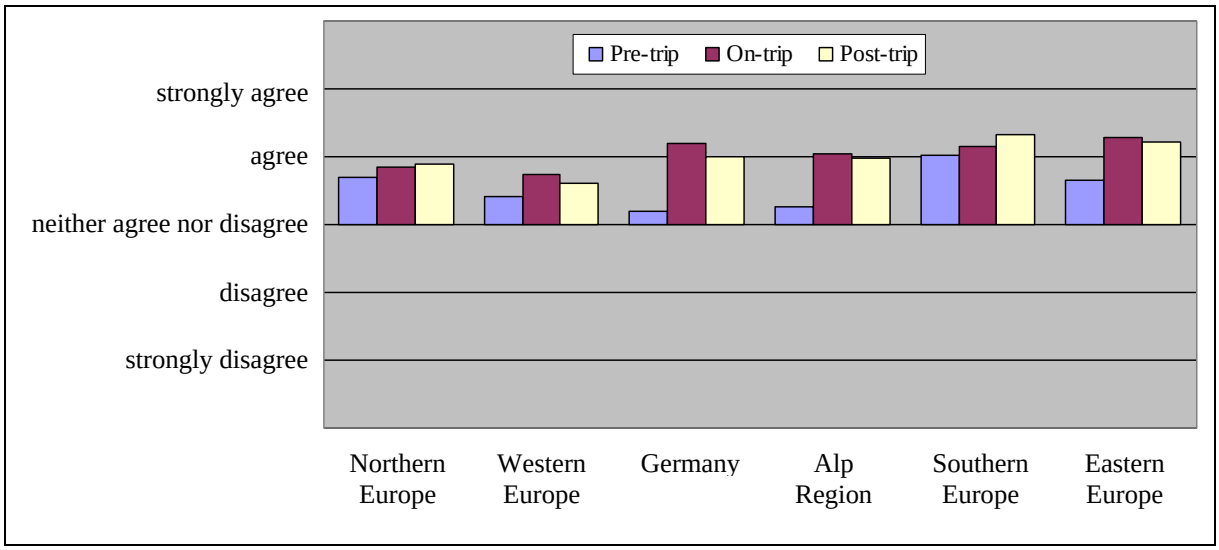

Figure 5. Regional analysis of the perception of usefulness of eco driving assistant systems

When analyzing the confidence of the respondents to *contribute to environmental protection* by using the proposed applications it can be shown that drivers from Germany and from the Alp Region are less convinced of the Pre-trip applications' potential than other European drivers. The application is rated best by Southern Europeans and Eastern Europeans. Regional differences for the On-trip and Post-trip applications are marginal.

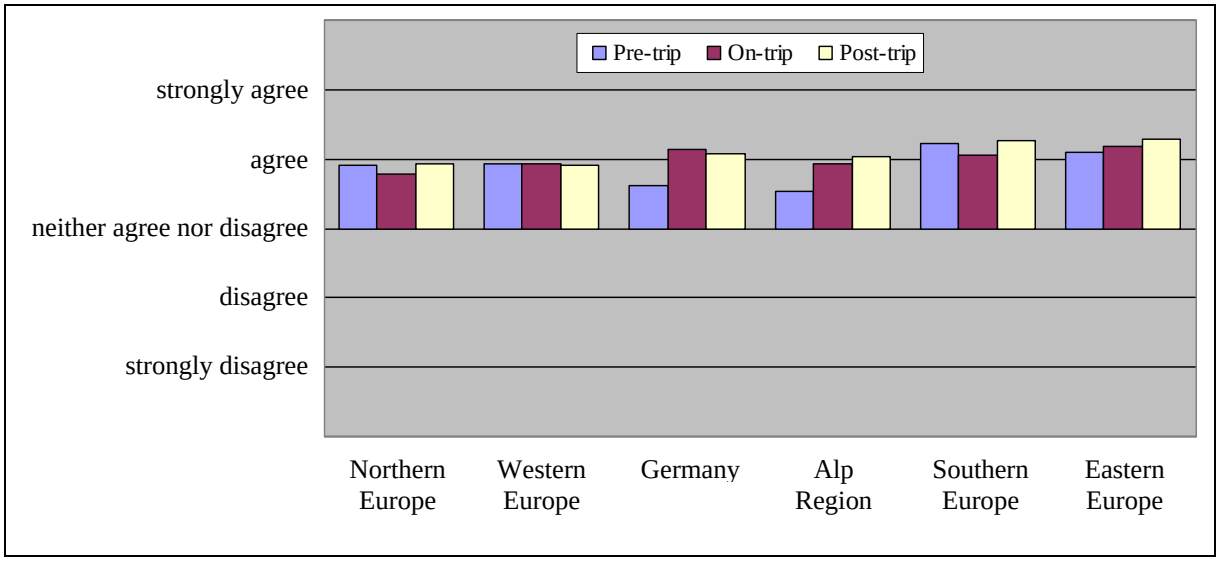

Figure 6. Regional analysis of the perception of the potential contribution to environmental protection of eco driving assistant systems

The question if an application is *worth to pay for* is by far the most controversial. As demonstrated in Figure 7 only a small share of respondents is in general willing to pay for such future eco driving assistant systems. This question is less dependent on the application but more on the origin of the respondent. While Eastern Europe and with a slightly less degree also Southern Europe are at least partly open to pay especially for the Post-trip and the On-trip application do the vast majority of German drivers refuse to pay for such applications.

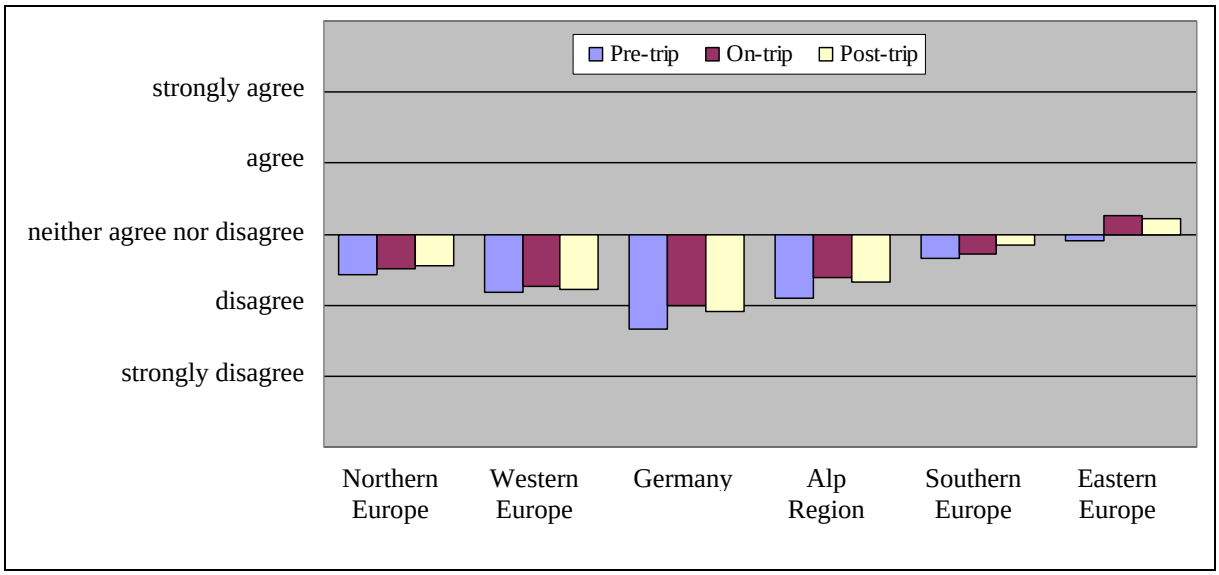

Figure 7. Regional analysis of the willingness to pay for eco driving assistant systems

DISCUSSION

The study presented in this paper demonstrates that all three applications introduced above are considered as useful enhancements by the respondents. There are only minor differences in the rating of the applications especially in the case of On-trip and Post-trip applications. Both show comprehensible direct benefits for the driver. Drivers seem to be highly motivated to use eco driving assistant systems because their fuel saving potential can be directly converted into money savings.

The somewhat lower acceptance of the Pre-trip application can be explained by a reduced willingness to obey to recommendations which have no direct benefit for the individual driver. The application suggests a route which takes into account not only the actual travel time but also the actual pollution load on all eligible routes. For example if a route is highly polluted with particulates based on heavy traffic the city has an interest to reroute drivers aiming to use that route. Here individual interests of drivers have to stand back community interest. The results show that contribution to environmental protection on a voluntary base work only partially.

The On-trip system demonstrates a functionality which is already in place in some European cities where Variable Message Signs (VMS) are used to inform drivers to adapt their speed to get onto a green wave. Integrating this functionality into the car is greatly welcomed by the majority of the respondents. However it needs to be verified if drivers will give up their individuality to strictly follow speed advices which are expected to be often somewhat lower than the actual speed limit. Driving a motorized vehicle is not at all exclusively rational.

The positive results of the Post-trip system show that drivers are highly interested in receiving information on their driving performance to track their improvement and also to receive detailed information on ways to improve their driving style. As shown in Man et. al. [4] cost-related information is the most important motivation to change the driving behaviour. Since already a majority of drivers has a fuel consumption indicator at their disposal extended functionalities such as displaying progress in fuel economy and monetization of these information are able to foster long term driving style improvements.

The issues of payment and controllability deserve special attention. Besides the high interest of European drivers in Green ITS solutions the results of the study also demonstrate an equally high rated need to be able to have control over eco driving assistant systems being able to deactivate them anytime. But when considering the integration of such an option a conflict of the utility of such applications arises. Applications like the On-trip application need a high market penetration in the first place. If only used on a voluntary base the benefit of such applications is limited.

Another major challenge is to raise the willingness of drivers to pay for the use of eco driving assistant systems. The study shows very low acceptance if the applications are not free of charge. Thereby only minor variances can be demonstrated for the rating of the different applications it can be more interpreted as a basic attitude not to pay for traffic related information. This finding is of high interest since, as stated before, market penetration is a crucial factor for the efficiency of cooperative systems.

Unexpected was the result that none of the analyzed driver characteristics has an impact on the assessment of eco driving assistant systems. It was expected that e.g. the frequency of use of navigation systems would have an impact on the rating of Green ITS applications which could be disproved.

During the analysis of regional differences three important observations have been made:

1. Some countries tend to be more open towards eco driving assistant systems than others. Thus respondents from Southern and Eastern Europe have the highest ratings for the items examined whereas Western Europe rates *usefulness* and *impact on environmental protection* of all applications comparatively low.
2. All countries tend to rate the Pre-trip application less useful than the On-trip and Post-trip application. Interest in using this application is comparatively lower and has been discussed above.
3. A more positive assessment of eco driving applications is not necessarily connected with a higher *willingness to pay* for such services. This is especially true for Germany. German respondents rate the *usefulness* and *impact on environmental protection* of the On-trip and Post-trip application almost as high as Southern and Eastern Europeans but have the lowest *willingness to pay*. The difference of 1.3 points in average for the rating of the Post-trip application compared to Eastern Europe is significant.

The discussion of the results of the regional analysis is limited to a descriptive analysis of differences. To further elaborate it, data on the personal motivation to use such applications, the individual awareness of problems in the traffic system, the consideration of ITS solutions already in place and cross data analysis (e.g. a connection to national travel surveys) is necessary since the state of the road traffic network in European countries is very diverse. This diversity of factors influences the motivation to use eco driving assistant systems and is a determining factor for the perceived *usefulness* and therefore the acceptance of such systems. These issues need to be taken into account when designing eco driving assistant systems for specific countries and developing business models for introducing such systems.

CONCLUSION AND OUTLOOK

The objective of this study was to assess the perceived usefulness and benefits from eco driving assistant systems. These systems aim to support the driver in reducing the fuel consumption of her or his vehicle. Therefore a web survey has been conducted in which respondents had to rate a Pre-trip, an On-trip and a Post-trip application.

It could be shown that the usefulness of such systems is in general rated positive and most of the respondents expect reductions in fuel consumption and are highly motivated to use eco driving assistant systems. This confirms a high fuel saving potential if implemented. But the study also suggests that any application that does not respond to immediate personal cost-related benefits of the drivers has little chance to penetrate the market.

Potential fuel savings trough large scale implementation of cooperative systems is expected to be high but the implementation itself is costly and time-consuming and their effectiveness largely depended on penetration rates. This makes a contemporary large-scale dissemination such as the Pre-Trip and On-trip and application very unlikely. Therefore the highest potential for short term implementation can be stated for the Post-trip application. Taking into account the issue of controllability by the driver and the need for long-term motivation strategies as found in [3] significant fuel savings can be achieved.

Regional differences of the perceived usefulness of eco driving assistant systems are nominal for most of the analyzed determining factors. The willingness to pay for such future applications is the sole exception. Whereas in countries of Southern and Eastern Europe the benefits of such systems prevail and drivers are partly open to bear these expenses do the vast majority of German drivers refuse to share costs.

To guarantee successful integration of Green ITS solutions in the future, there is need for further investigation of the acceptance of different level of fees and payment models, reasons for the regional differences for the willingness to pay as well as on strategies to motivate drivers using eco driving assistant systems in the long-run to ensure sustainable fuel savings and therefore CO2 emissions.

ACKNOWLEDGEMENTS

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