Stated Preferences of European Drivers regarding Advanced Driver Assistance Systems (ADAS)

Vincent Marchau[*], Marion Wiethoff[**], Merja Penttinen[***] and Eric Molin[*]
[*] Faculty of Technology, Policy and Management
Delft University of Technology
Delft
The Netherlands
E-mail: vincentm@tbm.tudelft.nl

[**] Institute for Road Safety
Delft University of Technology
Delft
The Netherlands

[***] VTT Technical Research Centre of Finland
Finland

EJTIR, **1**, no. 3 (2001), pp. 291 - 308

Received: June 2001
Accepted: November 2001

The introduction of electronic Advanced Driver Assistance Systems (ADAS) in road vehicles is expected to improve traffic efficiency and safety significantly. As such, public policy makers are increasingly interested in the implementation possibilities of these systems. Successful implementation in the near future of these systems will largely depend on the willingness of people to buy and use these systems. The current knowledge regarding this willingness is limited. Therefore, in this paper the acceptance of potential users is explored regarding the first ADAS currently deployed. These systems involve proper distance keeping, speed limit adaptation and navigational support. The preferences for ADA systems have been measured using conjoint analysis techniques. Drivers of cars and trucks throughout Europe have been questioned about the overall attractiveness regarding several alternative ADAS. Alternative systems were presented based on their functional features, different levels of system price and varying types of roads on which ADAS could be used. On average, drivers consider it neither attractive nor unattractive to have support systems in their vehicle(s). However, the study shows that this finding needs to be qualified, as preferences depend on the specific system characteristics and the background characteristics of drivers.

1. Introduction

Modern societies are increasingly confronted with the externalities of road traffic, i.e. congestion, unsafety, consumption of scarce space, use of energy and emissions. For instance, about 42,500 people are killed and 3,500,000 injured every year due to road traffic crashes in the European Union (ETSC, 1999). In addition, increasing traffic congestion and related environmental stress of vehicle use for the coming decades is expected (e.g. OECD, 2000). To a large extent, these problems can be attributed to improper or suboptimal driving behaviour. For instance, Smiley and Brookhuis (1987) conclude that some 90% of all traffic accidents can be attributed to human failure in general. Congestion is not only the result of accidents; drivers' trip-making decisions and minute-by-minute driving behaviour are least similarly important (Lindsey & Verhoef, 2000). In order to improve driving behaviour, various technological systems are developed and (gradually) implemented which support drivers in controlling their vehicle in a better way. These systems are known as Advanced Driver Assistance Systems (ADAS), systems that automate, to a certain degree, the driver's throttling, braking, and steering tasks.

The range of possible ADAS applications investigated and developed these days is wide, varying from systems that support the driver in one specific driving task (e.g. distance keeping, lane keeping, speed control, route choice) up to highly advanced systems where the driver’s steering, throttling and braking tasks are entirely taken over (e.g. the autopilot). The technological feasibility of most ADAS is not the main issue anymore. This has been demonstrated within several experiments and pilots. In these (and other) studies, ADAS further proved to have potential for improving road traffic efficiency and safety significantly. It has, for instance, been estimated that large-scale implementation of collision avoidance systems, supporting the driver in case of imminent crash danger with oncoming vehicles or obstacles, could reduce road fatalities up to 45% (e.g. Hiramatsu et al., 1997, Sala et al., 1997). The large-scale implementation of systems which support the driver in keeping a proper distance to the nearest vehicle ahead (adaptive cruise control) could increase road capacity up to 25%, depending on system parameter settings (e.g. Morello et al., 1994; Minderhoud, 1999). A latter example involves Intelligent Speed Adaptation (ISA). These systems take into account the local speed restrictions and warn the driver in case of speeding or even automatically adjust the maximum driving speed to the posted maximum speed (Brookhuis & De Waard, 1999). The estimated safety effects of the use of speed control devices involve up to a 40% reduction of injury accidents (Varhelyi & Makinen, 2001) and up to a 59% reduction of fatal accidents (Carsten et al., 2000).

Next to demonstrating the technological feasibility and potential of several ADAS, the first generation of ADAS applications have recently become available on the market on a small scale (Bishop, 2000). Well-known examples involve systems that support the driver in vehicle following (adaptive cruise control), collision avoidance, and navigational choices. Consequently, the focus in this field is now gradually changing from technology development towards the possibility of ADAS implementation on a large scale (Van der Heijden & Wiethoff, 1999).

In particular, transport policymakers in various countries are increasingly interested in large-scale implementation of ADAS. However, current policy development regarding ADAS is highly complicated by large uncertainty regarding the contribution of ADAS implementation to general transport policy goals (Marchau & Van der Heijden, 1998). The likely contribution of these systems to traffic safety and efficiency is considered uncertain as, among others, high impacts will require large-scale implementation (Shladover, 1999). This will largely be determined by the willingness of users to adopt these systems. As to this willingness, not much is known yet (Brackstone & McDonald, 2000). Currently, ADAS applications are rapidly becoming available both for car drivers and for heavy vehicle drivers. Hence, insight into the willingness of future users to adopt these systems, is needed. Such insight is given by exploring the preferences of these users regarding system characteristics. Knowledge on user preferences enables implementation of systems in such a way that these groups will adopt these systems. The problem is how to study user preferences.

Different studies have been performed on user preferences regarding ADAS. Within these studies respondents have, in general, evaluated different attributes of ADAS applications of interest separately (e.g. Becker, 1994; Sayer et al., 1995; Kemp et al., 1998; Hoedemaeker 1999). Attributes are presented and respondents are asked to evaluate each attribute separately. This measurement method is relatively easy to construct and fairly simple for respondents to complete. However, this approach has shown serious limitations in terms of predicting overall preference behaviour (e.g. Oppewal, 1995). Individuals are likely to overestimate the importance of unimportant attributes as well as underestimate the importance of important attributes, as related to actual preference behaviour. This might be explained by the fact that usually more than one attribute plays a role in an individual's decision-making process and as such individuals make trade-offs among the different attributes of an alternative. These trade-offs are not taken into account by traditional measurement approaches.

The trade-offs among attributes are explicitly considered by another measurement approach, the so called decompositional stated preference approach, also known as conjoint analysis (Louvière, 1988). By this approach individuals have to indicate their overall preferences for hypothetical profiles, described in terms of a set of levels of pre-specified attributes. Here, individuals are explicitly forced to make trade-offs among attributes. As profiles are constructed according to the principles of statistical designs, the overall preference can be decomposed into the weights these individuals attach to separate attribute-levels (i.e. the so-called part-worth utilities) in creating their overall evaluation of alternatives. As such it is possible to study the relationship between attribute-levels and overall preference behaviour in a more valid way as compared with a measurement approach where attributes are evaluated separately. Therefore, in this study, a conjoint analysis approach was chosen to explore the relationship regarding ADAS applications. In this study only ADAS applications were of interest which are likely to be (further) implemented in the near future as well as expected to improve traffic safety and/or efficiency significantly. Based on the results of a pre-study towards the availability of ADA systems and their potential in improving traffic performance the selected ADA systems involved: adaptive cruise control, intelligent speed adaptation and navigation (Wiethoff et al., 2001).

This paper is organised as follows. In section 2 the set-up of the specific conjoint experiment for this study is discussed. The response and characteristics of the sample are presented in section 3. In section 4 the overall estimated preference model is presented and discussed. The differences in preferences among different drivers and fleet-operators of cars, buses, and trucks are examined in section 5. Finally, conclusions are drawn in section 6.

2. The construction of the conjoint experiment

The underlying theory on individual preference and choice behaviour within the context of conjoint analysis assumes that this behaviour is the result of an individual's cognitive decision-making process (Timmermans, 1982; Louvière, 1988). This behaviour is based on the subjective perception and evaluation of choice alternatives in terms of their physical, functional and socio-economic (e.g. purchase price of an alternative) attributes. This then results in an individual preference structure for the various alternatives that determines the ultimate choice for an alternative. These assumptions are usually operationalised within the context of conjoint experiments, using the following procedure (Vriens, 1995; Molin, 1999):

1. a selection of salient attributes;
2. the determination of relevant attribute-levels;
3. the selection of an appropriate method for combining attribute-levels into profiles;
4. the choice of a measurement task;
5. the choice of a method for estimating preference or utility functions.

For each step, different strategies are possible, which are related to different assumptions, criteria and specific needs of the researcher (e.g. Timmermans, 1984; Louvière, 1988). An extensive discussion on the strategies possible and criteria for choice within the context of ADAS is presented in Marchau (2000). Specific choices made within this study are discussed in Mankkinen et al. (2001). In this paper, the above-mentioned steps will only be dealt with briefly.

The selection of salient attributes is usually accomplished by procedures in which potential users elicit the most dominant factors underlying their preference behaviour. These procedures require users to have a clear understanding of the alternatives of interest. Regarding ADAS, this is very unlikely, due to the futuristic character of these technologies. Therefore, in this study, the results of previous research being done in the same area have been used to arrive at an initial list of theoretical system characteristics (see Marchau (2000) for an overview). This resulted in an initial list of theoretical system characteristics, which was next operationalised to clear and measurable attributes and which discriminate alternative systems sufficiently from a user's point of view. The following attributes were the result: distance keeping, speed adaptation, navigation, usability (on different road types), and price (purchase costs). Of course, characteristics related to the impacts of ADAS on driving performance (e.g. travel time, safety, comfort, fuel consumption) might be considered as well. However, it is difficult to operationalise these characteristics into clear and meaningful attributes which are perceived unambiguously by respondents. Furthermore, these impacts refer more to perceptions of systems operating characteristics. These perceived contributions of the systems to the respondents' driving performance are, however, of interest. Hence, although not considered in this paper, perceptions in this respect have been asked explicitly and the results will be reported in the near future.

The next step is to select the relevant attribute-levels. The relevant levels in this context refer to levels that are assumed to represent plausible, future alternatives. These levels have been derived straightforward from the results of other studies (Apogee Research Inc., 1997; Marchau & Van der Heijden, 2000; Wiethoff et al, 2001). Those levels of attributes that were rather likely expected to become available in the near future, were assumed to be plausible levels. Regarding the attribute distance keeping the levels 'distance warning' (warning in case of too close following), ‘vehicle following’ (automatic following of preceding vehicles by automatic throttle and brake control) and ‘stop & go assistance’ (full longitudinal car control, including emergency braking) have been selected. For the attribute speed adaptation the levels selected involved no speeding support, speeding warning and speed limiting (the speed of the vehicle is restricted to the locally posted maximum speed) were selected. Regarding the attribute navigation the following levels were selected: no navigation support, static route information (information based on a conventional digital map), and actual route information (static route information extended with information on real-time traffic conditions). An overview of the selected attributes and their levels is presented in Table 1.

Table 1. Selected attributes and their levels

Attributes	**Attribute-levels**		
distance keeping	distance warning	vehicle following	stop & go
speed adaptation	none	speeding warning	speeding limiting
navigation	none	static route info	dynamic route info
usability	motorways	Motorways & rural roads	all roads
price	EUR 500	EUR 1500	EUR 2500

The next step involves the selection of an appropriate method for combining attribute-levels into profiles that can be evaluated by the respondents. In order to create profiles, statistical design theory is used. Of course, all possible combinations of attribute-levels could be considered. This would result in a so-called full-factorial design, $3^5 = 243$. It may be clear that this number of profiles is too high to be adequately evaluated by the respondents. The number of profiles can, however, be reduced by making assumptions on how decision-makers combine part-worth utilities into overall utilities. In this study, no interaction effects between the attributes were assumed, which resulted in a main-effect model. Hence, the overall utility is assumed equal to the sum of the separate part-worth utilities. This model is often used in practice as it minimises the number of profiles and it has proven to predict reasonably well (Louvière, 1988).

Several so-called ‘main-effect’ designs are possible. In general an important characteristic of such designs is that they are orthogonal, i.e. a design in which the presence of each attribute-level is not correlated with the presence of any other attribute-level across all profiles. Such designs assure that an estimate of the main effect of one attribute-level is unaffected by the estimate of the main effects of other attribute-levels and provide the lowest number of profiles to be evaluated by respondents (Huber, 1987). As the choice of a so-called orthogonal ‘main-effect’ design is rather complicated, basic plans have been developed for which various orthogonal main-effect designs can be constructed (Adelman, 1962; Steenkamp, 1985). From these designs we chose the smallest orthogonal fraction by means of which all main effects can be estimated involving 27 profiles.

As the profiles have been constructed, a measurement task has to be formulated by which respondents are invited to indicate their preferences regarding the various profiles. In this study, a rating task has been favoured over a ranking or a choice task. A rating task is preferred to a choice task, because it provides more information per response: a rating indicates the strength of the preference for an alternative and a choice only indicates that an alternative is preferred to another alternative. A rating task is preferred to a ranking task as

the rating scale is often assumed to be of interval measurement level, while a ranking task is of ordinal level. This allows us to apply regression analysis to estimate the preference function, with the advantage of a well-developed error theory, allowing one to test the significance of parameters (Oppewal & Timmermans, 1992). Furthermore, it is easier to include rating tasks than ranking tasks in written questionnaires. The rating scale on which the respondents have to express their preferences involved an 11-point scale from '0' (extremely unattractive to have this system in their vehicle) to '10' (extremely attractive to have this system in their vehicle). This was based on previous experiences in this field (e.g. Marchau & Molin, 2001; Molin et al. 1999).
In order to test whether the scale, number, and transparency of the profiles were appropriate, a test-questionnaire was performed. The test respondents indicated that they understood the profiles and scale rather well, but considered the number of 27 profiles far too high to evaluate adequately. It was therefore decided to distribute three different questionnaires containing profiles in which the usability attribute was assumed to be fixed; one third of the respondents received a questionnaire containing nine profiles which were presented to be only of use on motorways, one third of the respondents received a questionnaire containing nine profiles which were presented to be only of use on motorways and rural roads, and one third of the respondents received a questionnaire containing nine profiles which were presented to be of use on all roads. Although this procedure has the disadvantage that individual preference models across different road types cannot be derived anymore, this was not considered to be a problem as we were mainly interested in exploring and comparing preference structures at the group. An example of the measurement task as presented in the questionnaire is presented in Figure 2.

system profile
vehicle following
speeding warning
static route info
€ 1500

How attractive would you find it to have this system in your vehicle?

extremely unattractive *0 1 2 3 4 5 6 7 8 9 10* *extremely attractive*

Figure 1. An example of a profile as presented in the questionnaire

Finally, a method for estimating preference functions has to be chosen. In this study, Ordinary Least Square (OLS) regression is used to estimate the parameters of the preference models, assuming the ratings to be of interval level. In order to estimate the effects of the categorical attributes and to standardise the levels across the attributes, the attributes have to be coded. Therefore, effect coding was applied. This involves that n levels of an attribute are coded by n-1 indicator variables. The first n-1 levels are coded 1 on the corresponding indicator variable, and coded 0 on all other indicator variables. The n-th level is coded –1 on all indicator variables (see Table 2) for the case of three attribute-levels). The estimated parameters for these indicator variables can then be applied to derive the part-worth utilities of the attribute-levels by multiplying the parameters with the coded values and summing across the indicator variables. In particular in this study the following main-effect preference model is estimated, using effect coding:

$$V_j = \beta_0 + \Sigma_k \Sigma_l \beta_{kl} x_{jkl} + e_j \qquad (1)$$

where

V_j = the overall attractiveness as indicated on an 11-point scale by the respondent of a profile j
β_0 = the regression intercept, indicating the average profile rating
β_{kl} = the regression coefficients, indicating the weight of the (coded) l^{th} level of the k^{th} attribute
x_{jkl} = the effect coded attribute-level l of attribute k of profile j
e_j = the error term

Hence, by applying regression analysis with effect coded attributes, the regression intercept is equal to the mean observed profile ratings, while the attribute-level part-worth utilities are expressed in terms of deviation from this mean. Note that the sum of an attribute's part-worth utilities is, by definition, equal to zero.

Table 2. Effect coding for three-level attributes

Attribute-level	First indicator variable	Second indicator variable	Derived part-worth utility
0	1	0	β_1
1	0	1	β_2
2	-1	-1	$-(\beta_1+\beta_2)$
Estimated parameters:	β_1	β_2	

3. Response rate and profile of respondents

During the first months of 2001, drivers of cars and heavy vehicles throughout Europe were questioned about their preferences regarding several alternative ADAS profiles. The data collection was conducted based on a similar questionnaire, distributed among vehicle and truck drivers, within six European countries: the Czech Republic, Finland, Germany, Greece, Italy, and the Netherlands. Except for Italy, car and van drivers were randomly approached at different public places within the different countries (e.g. service stations, airports, exhibitions, centres of automobile associations). Heavy vehicle drivers were approached by visiting different transport companies in the different countries. Italian car and van drivers were selected randomly among employees within companies of the Fiat group. As such, the Italian respondents might form a rather specific group of drivers. Whether this influenced their preference behaviour will be discussed below.

In total 911 questionnaires were completed. The background characteristics of the respondents are presented in Table 3. Reliable statistics regarding these characteristics, describing the road user populations within the different countries, are difficult to find (Dahlstedt, 1999). Hence, the representativeness of the sample according to these characteristics could not be tested. As such conclusions should be handled with care. If the reported background characteristics significantly deviate from expected values and correlate with expressed preferences, conclusions on 'average drivers' and 'average preferences' cannot be generalised directly to the general road user population of interest. If no such correlations appear, a possible limited representativeness of the respondents has no effect on the conclusions.

However, it is unlikely that the distribution of gender and age of heavy vehicle drivers will differ between the sample and the general road user population. As for car and van drivers, this is more likely as a relatively high part of the respondents were interviewed along motorways (Finland and The Netherlands) or within institutes related to vehicle transport (Greece, Italy and Germany).

Often vehicle usage among these road users involves commuting and business motives. The fact that almost half of the car/van driving respondents indicated to be business drivers likely influenced the profile of the car/van driving respondents towards the profile of a business driver. For instance, the average Dutch business driver is a man, about 40 years old and drives many kilometres (Korver et al., 1998). For the other countries similar characteristics for business drivers are likely.

Table 3. Background characteristics of respondents

Characteristic / Group	All drivers (n=911)	Car/van drivers (n=705)	Truck/bus drivers (n=206)
Gender:			
male	82.0%	79.6%	90.3%
female	18.0%	20.4%	9.7%
Age:			
mean	38.3	38.0	39.3
(std)	(12.4)	(12.9)	(10.3)
Country:			
Greece	19.6%	15.4%	35.4%
Czech Republic	21.4%	26.6%	3.0%
Italy	9.9%	12.1%	1.5%
Germany	15.9%	20.4%	-
Netherlands	13.2%	12.3%	15.7%
Finland	20.0%	13.2%	44.4%
Type of driver:			
private (<50% business trips)	-	58.9%	-
business (>50% business trips)	-	41.1%	-
Type of vehicle:			
car	-	74.3%	-
van	-	4.2%	-
bus	-	-	1.7%
truck	-	-	19.9%
Annual number of kilometres:			
mean	41129	25874	97672
(std)	(47326)	(22670)	(67699)
Distribution of annual number of kilometres over different road types:			
motorways	38.3%	36.1%	46.2%
rural roads	30.3%	31.4%	25.8%
urban roads	31.9%	33.1%	27.7%
Familiar with:			
distance keeping	35.2%	36.2%	30.5%
speed adaptation	51.7%	45.6%	72.0%
navigation	53.1%	56.2%	40.6%

Car and van drivers from each country were well represented in the sample. For heavy vehicle drivers this was not the case, heavy vehicle drivers from Czech Republic, Italy and Germany were hardly or not represented. The mean annual number of vehicle kilometres of the drivers was about twenty-six thousand kilometres for the car and van drivers, and about ninety-eight thousand for the heavy vehicle drivers. These figures are high when compared to the average amount of kilometres driven at national levels. For Germany, Italy, Netherlands and the Finland national statistics in this context report between 13000 to 18000 km for car/van drivers in 1996 while for heavy vehicle drivers national statistics range from roughly 50000 to 100000 km in 1996 (CBS, 1997; USDOT, 1999; Finnra, 2000). The driving was done about equally on motorways, rural roads and urban roads, although heavy vehicle drivers drove over 46% of their annual number of kilometres on motorways. Finally, the respondents were asked to what degree they were familiar with the systems in the questionnaire. A majority of the respondents indicated that they were familiar with speed adaptation and navigation. In particular, truck/bus drivers appeared to be more familiar with speed adaptation than car/van drivers did. These results could be expected as trucks in Europe are currently equipped with static speed adapters. Furthermore, navigation devices have been on the vehicle market for some years too. Distance keeping support systems, on the other hand, are just entering the market.

Summarising, it seems plausible that the responding groups belong to the ‘road user’ population. Furthermore, it is clear that each group of interest in this study is represented by a reasonable number of respondents.

4. Overall preferences

The overall estimated preference model for all respondents is presented in Table 4. The estimated part-worth utilities, i.e. the utility that respondents derive from a certain attribute-level, are shown in the first column. These can be interpreted as deviations from the average profile rating (intercept). The second column shows the t-values, which are used to test whether the estimated part-worth utilities contribute significantly to the overall preferences. As only n-1 indicator variables are estimated for n attribute-levels, only n-1 t-values are presented for each attribute. Except for the attribute-levels vehicle following, no speed adaptation support and EUR 1500, all levels influence the overall profile attractiveness at a 0.05 significance level.

The third column indicates the relative importance of the attribute in relation to the overall utility. The relative importance is derived by calculating first the range of each attribute, i.e. the absolute difference between the highest and lowest part-worth of the levels of an attribute. Next, the range of an attribute is divided by the sum of ranges and the result is expressed in percentages.

An indicator for the performance of the model is given by the R-squares, which express the extent to which the estimated model fits the observed data. If the model is estimated from the average profile ratings, the R-square is 0.98, indicating an almost perfect fit. This is not surprising as all individual differences are already sorted out by aggregating the data before model estimation. On the other hand, the R-square of the model based on the individual data is rather low, indicating that individual ratings vary considerably. Hence, the predictive power of the models for individual preferences is low. Aggregate models in general yield poor results in terms of predicting individual preferences. In case of more homogeneous preference behaviour with respect to the evaluation of profiles, the R-square would increase. As, in this study, the first interest involves exploring the behaviour at aggregate level, the low R-square at the individual level is not considered to be a serious problem.

Table 4. Attractiveness preference model of all respondents

Attribute	Part-worth utility	t-value[1]	Relative attribute importance (in %)
Distance keeping			16.5%
distance warning	0.19	4.469	
vehicle following	-0.04	-.842	
stop & go	-0.15		
Speed adaptation			24.8%
none	-0.05	-1.129	
speeding warning	0.28	6.450	
speed limitation	-0.23		
Navigation			33.0%
none	-0.57	-13.087	
static route info	0.11	2.513	
dynamic route info	0.44		
Price			25.7%
500 EUR	0.29	6.638	
1500 EUR	-0.05	-1.041	
2500 EUR	-0.24		
Regression intercept	4.88	159.299	
R^2 group level	0.98		
R^2 individual level	0.04		
n	911		

[1] As only n-1 parameters are estimated for each of the n attribute-levels, only n-1 t-values are given.

The intercept of the estimated model is 4.88, which is rather close to the middle scale value of 5. Hence, on average, the profiles are considered neither attractive nor unattractive. This corresponds to findings in a recent study on ADA systems in general (Marchau & Molin, 2001). Below the derived part-worth utilities will be discussed in more detail, focussing on the contribution to the overall attractiveness of the systems of each attribute-level, and assuming that all other attribute-levels remain unchanged.

With respect to the attribute distance keeping, warning systems (.19) are clearly more preferred to intervening systems, either vehicle following (-.04) or stop & go (-.15). As for the attribute speed adaptation, a warning device is preferred to no support or intervention. Hence, it may be concluded that people, on average, like the idea of systems that warn them in case of speeding.

Furthermore, the part-worth utility for no support is (nearly) zero and for speed limiting is negative. This indicates that systems which adapt speeds by limiting are strongly disfavoured in comparison to with systems which do not. Regarding the attribute navigation, dynamic route info is strongly preferred to no navigational support or static route info. Furthermore, the part-worths for both types of navigation support are positive and the part-worth for no navigation is negative. Hence, there appears to be a need for systems which give navigation support. The part-worth utilities of the attribute price, show, as expected, a decreasing tendency: an increase in price decreases the overall utility contribution. The estimated part-worth utilities for the attribute price indicate a nearly perfect linear relationship, considering that the part-worth of the middle level (EUR 1500) is not significant.

Comparing the attribute importance of the variables, it turns out that navigation is the most important attribute, followed by price and speed adaptation, which are considered nearly equally important. Distance keeping is considered the least important attribute. However, this measure of attribute importance has to be interpreted carefully, because this could be related to the range of attribute-levels chosen. If, for instance, a large range of attribute-levels would have been chosen, say EUR 250, EUR 1500 and EUR 2750, the range of the part-worth utilities would likely become larger too, with higher importance as a result. Consequently, conclusions based on attribute importance can only be drawn within the range of attribute-levels specified in this study.

5. Comparing preferences among groups

In this section, preference differences among the various groups of interest are examined. In the first place, the differences between pre-specified groups based on driving characteristics are examined. Next, preference differences between categories of selected socio-demographic characteristics are studied.

In general, preference differences between groups can be analysed by testing whether the regression differentials between groups significantly differ from zero. Therefore the following procedure has been applied. The analysis design is extended by including indicator variables enabling the estimation of contrast parameters. These indicator variables are constructed by replicating the set of original indicator variables of attribute-levels, while multiplying the indicator variables for the first group of interest by +1, and multiplying the indicator variables for the second group of interest by –1. By applying a t-test, it can be tested whether an estimated contrast parameter differs significantly from zero. If a contrast parameter is significant, it may be concluded that the two groups differ with respect to the corresponding part-worth utility.

Table 5 shows the part-worth utilities for which the corresponding contrast parameters indicated significant differences between the selected groups being compared. The part-worth utilities for which the estimated differentials were found not to be significant are not presented as the overall model presented in Table 4 can be used for these selected groups. Some of the differences found to be statistically significant are very small and therefore considered to be not relevant for drawing conclusions. The most important significant differences will be discussed below.

Table 5. Preference differences between groups with different driving characteristics

	--- Part-worths ---										
	Driver/vehicle type			**Mean annual number veh./km**		**Road type**			**Familiarity with**		
Attributes ↓	**private car/van**	**business car/van**	**truck/ bus**	**<41000 km**	**>41000 km**	**motorway**	**motorw +rural**	**all roads**	**dist. keep.**	**speed adapt.**	**navigation**
Speed adapt.											
speed warning	-	0.26	0.22	0.27	0.31	0.25	0.25	-	0.19	-	-
Navigation											
none	-	-0.61	-0.39	-0.58	-0.53	-0.58	-0.53	-0.59	-0.53	-	-0.65
Price											
500 EUR	-	-	-0.08*	0.33	0.17						
Intercept	4.88	4.72	5.16	5.03	4.49	4.81	5.00	4.83	5.14	4.75	4.70
n	415	290	206	649	253	323	293	293	320	471	484

*non significant at 0.05 level

The higher regression intercept for truck/bus drivers indicates that truck drivers on average consider the systems to be more attractive than car/van drivers do. Furthermore, business drivers have a lower utility for no support on navigation than truck/bus drivers, which suggests that business drivers value support on navigation higher than truck/bus drivers do. This might be explained that business drivers likely take more on-trip route decisions as compared to drivers of trucks and busses. This latter group often follows fixed routes and/or routes are pre-specified by their companies. As such, a lack of navigation support might be considered relatively less important for truck and bus drivers. Furthermore, truck/bus drivers value low price levels less than car/van drivers. This is not surprising, because trucks and busses are generally more expensive than cars and vans and therefore the relative price of a system in terms of the percentage of the vehicle price is less for trucks/busses than for cars/vans. Moreover, in general, truck/bus drivers do not have to pay themselves for a system as car/van drivers usually will.

In order to study the influence of the annual number of vehicle kilometres on the respondents' preferences, drivers which indicate higher respectively lower annual number of kilometres than the average of the sample have been considered. It appeared that, on average, drivers with lower annual number of kilometres consider systems more attractive than drivers with higher annual number of kilometres. Frequent drivers might consider themselves more capable of performing driving tasks without assistance than less-frequent drivers do. Regarding the attribute price, the table further shows that a low price increases the overall utility contribution for less-frequent drivers more than for frequent drivers.

Considering different road types for which the systems might be applied, the largest significant differences found refer to the regression intercepts. It appears that systems which are applicable on motorways and rural roads are, on average, considered somewhat more attractive than systems which are applicable on motorways only or on all roads. This result indicates a slightly higher need for ADAS support on rural roads.

Finally, some significant differences have been found between the groups which were familiar with one of the presented functionalities of the systems. It appears that the group of respondents which were familiar with distance keeping consider, on average, the systems more attractive than those familiar with speed adaptation or navigation. This might be attributed to the fact that distance keeping is the most advanced and unknown ADAS functionality as compared to speed adaptation and navigation support. Hence, respondents familiar with distance keeping might be considered as early ADAS market.

Next, the preference differences between various socio-demographic groups are presented in Table 6. There appeared to be many significant differences between the different categories of gender, age and country of origin of the respondents. Again, most of these differences, although statistical significant, are very small and therefore considered to be of limited value for drawing conclusions. The larger significant differences will now be discussed in more detail.

The estimated regression intercepts on gender indicate that women prefer, on average, the systems more than men. Furthermore, regarding the attribute navigation, there is a stronger need for navigation support among men than among women.

Table 6. Preference differences between groups with different socio-demographic characteristics

	--- Part-worths ---									
Attributes ↓	**male**	**female**	**< 38 yr**	**>= 38 yr**	**Greece**	**Czech Republic**	**Italy**	**Germany**	**Nether-lands**	**Finland**
Distance keeping										
distance warning	0.20	0.19*	-	-	0.20	0.01*	0.25	0.24	0.16	-
Speed adapt.										
speed warning	0.28	0.28	-	-	0.20	-	-0.29	0.33	0.38	0.36
Navigation										
none	-0.61	-0.38	-0.66	-0.45	-0.17	-0.83	-0.58	-0.72	-0.81	-0.39
Price										
500 EUR	0.29	0.31	-	-	-0.08*	0.37	0.52	0.44	0.44	0.23
intercept	4.80	5.26	4.80	4.98	7.00	4.53	4.51	4.41	4.99	3.61
n	744	163	487	418	179	195	90	145	120	182

* not significant at 0.05 level

Considering the age of the respondents, it appears that older drivers (i.e. older than the average age of all respondents) prefer, on average, driving assistance more than younger drivers (i.e. younger than the average age of all respondents) do. Next, regarding the attribute navigation, there is a stronger need for navigation support among younger people than among older people.

Finally, when considering the country of origin of the respondents, large differences between the groups have been found. Drivers from Greece considered the systems on average attractive while drivers from Finland considered the systems on average unattractive. Drivers from other countries included in this study rated the systems, on average, in between Greek drivers and Finnish drivers. Dutch drivers considered the systems attractive nor unattractive, while drivers from Czech republic, Italy and Germany considered the systems, on average, slightly unattractive. This might be attributed to reported differences among EU countries regarding the concern about road safety/efficiency in relation to other issues such as perceptions of risks, attitudes, behaviour and opinions about vehicle driving , etc (Barjonet, et al., 1994). It appeared that distance warning is least preferred by Czech drivers. Speed warning positively contributes to the overall utility of Greek, German, Dutch and Finnish drivers. For Italian drivers the opposite was the case: speed warning decreases the overall utility of Italian respondents. This might be explained by the specific Italian respondents included in this study as discussed in section 3. The non-availability of navigation support appeared least preferred by Czech and Dutch drivers. Finally, Greek drivers appeared rather indifferent to low-priced systems as compared to the other driver-groups.

6. Conclusions

In this paper, the stated preferences of drivers for new electronic advanced driver assistance systems in road vehicles were examined by applying conjoint analysis. Utility functions were estimated, based on the respondents' ratings for hypothetical profiles, each varying in functional and cost related attributes. The estimated utility functions described the part-worth utility contribution of each attribute-level to the overall preferences of possible systems. The R-square for the model based on individual data appeared to be rather low, which suggests that there are great preference differences among individuals. This could not be further examined, however, as no individual models could be estimated because each of the respondents completed only one third of the number of profiles. However, all part-worth utilities were in anticipated directions and could be interpreted well, which provided face validity in the estimated preference models.

The estimated utilities indicate that the navigation attribute is most important, which indicates that the availability of navigation support within future ADAS applications can have a considerable effect on preferences for ADAS systems. As such, the implementation of navigational aids, preferably as part of an integrated system, should be stimulated. Price is the second important attribute. This implies that financial incentives can improve the preferences for ADAS. This would require, however, some additional research on how respondents expect that ADAS might be implemented. In this study no specifications were given if the ADAS were available for new vehicles only (like current distance keeping) or might be installed in existing vehicles also (like current speed adaptation devices and navigation systems). Purchase prices of vehicle equipment for new vehicles are perceived as relatively low as compared to the price of the new vehicle itself. These perceptions might have influenced the importance of the attribute price and will be subject of our future research.

With respect to distance keeping and speed adaptation, the warning level is more preferred than the other levels. These findings suggest that it has to be tried to implement systems that have a warning functionality. In addition, regarding speed adaptation, warning support is preferred to no support. Hence, there appears a need among drivers for speeding warnings. Regarding navigation, the dynamic route info level is more preferred than the other levels. As such, an effort should be undertaken to (further) implement systems which couple actual traffic information with in-vehicle navigation support.

In addition to the estimation of the overall utility model, utility functions for pre-specified groups have been estimated. Considering groups with different driving characteristics, the results show that, on average, heavy vehicle drivers consider the systems more attractive than car- and van drivers do. A low price level of systems is more preferred by car/van drivers than by truck drivers. Hence, heavy vehicle drivers can be considered an initial target group for implementation. Furthermore, frequent vehicle drivers consider the systems less attractive than less-frequent vehicle drivers do. So, this latter group might also be considered an interesting market for initial implementation.

As statistics on the driver population of interest were lacking, it was not possible to compare the characteristics of the respondents with the characteristics of the population. However, given the distribution of characteristics, it seems plausible that the responding groups belong to the driver population.

It was further examined whether there are preference differences between the various socio-demographic variables, like gender, age and country of origin. The largest difference involved the country of origin of respondents. Greek drivers considered the systems attractive. Czech, Italian, German and Dutch drivers considered these rather neutral while Finnish drivers considered them unattractive. Summarising, only a few preference differences appeared to be significant and most differences were rather small. Only the country of origin might explain preference differences between individuals. In addition, probably other characteristics to explain preference differences between individuals have to be measured, like, for example, risk behaviour, driving style, traffic accident history, vehicle operating cost, etc. Examination of these effects will be the subject of future research

In this study it is found that the ADAS functionalities examined are, on average, rated close to the middle scale value. Hence, drivers tend to judge having assistance systems in their vehicle(s) neither attractive nor unattractive. As such, there appears to be more basis for implementing these systems on a larger scale than is often thought. Hence, this result may inspire the minds of many policymakers who are uncertain regarding the user acceptance of driver support services. This study shows how the attractiveness of the systems changes by varying the specific system operating characteristics and background characteristics of drivers. This provides policymakers with some guidelines to stimulate the implementation of systems that maximise this attractiveness and discourage the implementation of systems that are considered unattractive.

Overall, it may be concluded that the conjoint approach is a useful tool to examine user preferences for innovative transport technologies. In future research the usefulness of this approach for such applications will be further explored.

Acknowledgement

This article is based on a study performed in ADVISORS (**A**ction for advanced **D**river assistance and **V**ehicle control systems **I**mplementation, **S**tandardisation, **O**ptimum use of the **R**oad network and **S**afety), a research project within the 5th Research Framework Programme of the European Union.

References

Adelman S. (1962) Orthogonal main-effect plans for asymmetrical factorial experiments. In: *Technometrics*, no 4, p. 21-46.

Apogee Research, Inc (1997) *ITS national investment and market analysis: final report*. ITS America, Washington DC.

Barjonet P.E., T. Benjamin, R.D. Huguenin & R.D. Wittink (1994) *SARTRE: Social Attitudes to Road Traffic Risk in Europe*. Research Report R-94-57, SWOV Institute for Road Safety, The Netherlands

Becker S. (1994) Summary of experience with autonomous intelligent cruise control (AICC), Part 2, Results and conclusions. In: *Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems*, Artech House, Boston, p. 1836-1843.

Bishop (2000) *A Survey of Intelligent Vehicle Applications Worldwide: Overview*, Richard Bishop Consulting, Granite, USA.

Brackstone M. & M McDonald (2000) Behavioral response : still a major concern for AVCSS? In: *ITS journal*. Vol. 5, no. 4, p. 363-382

Brookhuis K. & D. de Waard (1999) Limiting speed, towards an intelligent speed adapter (ISA). In: *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 2, Issue 2, , pp. 81-90.

Carsten O., M. Fowkes & F. Tate (2000) Implementing intelligent speed adaptation in the UK: Recommendations of the EVSC project. *Proceedings of the 7th World Congress on Intelligent Transport Systems*, 6-9 November, Turin, Italy.

CBS (1997) *Zakboek Verkeer en Vervoer 1997*. Centraal Bureau voor de Statistiek, Voorburg/Heerlen. (in Dutch)

Dahlstedt (1999) *SARTRE2-Tables - Another set of opinions about traffic and traffic safety of some European drivers*. VTI report No. 446/446A, VTI, Linkoping.

ETSC (1999) *Intelligent Transportation Systems and Road Safety*, European Transport Safety Council, Brussels.

Finnra (2000) *Statistical tables about roads and road traffic in Finland*. Finnish Road Administration, Helsinki.

Heijden R.E.C.M. van der & M. Wiethoff (1999). *Automation of Car Driving: Exploring societal impacts and conditions*. TRAIL Studies in Transportation Science No. S99/4, Delft University Press, Delft.

Hiramatsu K., K. Satoh & F. Matsukawa (1997) Estimation of the number of fatal accidents reduced by Advanced Safety Vehicle (ASV) Technologies. In: *Proceedings of the 4th World Congress on ITS*, ITS Congress Association, Brussels.

Hoedemaeker M. (1999) *Driving with Intelligent Vehicles. Driving behaviour with Adaptive Cruise Control and the acceptance by individual drivers*. TRAIL Thesis Series T99/6, The Netherlands TRAIL Research School, Delft University Press, Delft.

Huber J. (1987) Conjoint analysis: how we got here and where we are. In: *Sawtooth Software Conference Proceedings*, Sawtooth Software Inc., Washington.

Kemp M.A., J.E. Lapping & M.R. Kiefer (1998) Consumer acceptance of automotive crash avoidance devices: the results of focus group research. In: *Proceedings of the 8th ITS America. Meeting*, ITS America, Washington D.C.

Korver W., M.J.W.A. Vanderschuren & A. Vieveen (1998) *Profile of the Dutch business car driver*. Report INRO-VVG 1998-13, TNO-Institute for Infrastructure, Transport & Regional Development, TNO, Delft. (in Dutch)

Lindsey R. & E. Verhoef (2000) Congestion Modelling. In: D.A. Hensher & K.J. Button (eds.) *Handbook of Transport Modelling*, Elsevier Science Ltd, Oxford, p. 353-373.

Louvière J.J. (1988) *Analyzing Decision Making: Metric Conjoint Analysis*. Sage University Paper Series on Quantitative Applications in Social Sciences, Series No. 07-067, Sage Publications, Beverly Hills.

Mankkinen E., V. Anttila, M. Penttinen, V. Marchau & A. Stevens (2001) *Actor interests, acceptance, responsibilities and users' awareness enhancement*. ADVISORS Deliverable D2.

Marchau V.A.W.J. & E.J.E. Molin (2001) User stated preferences regarding vehicle-driving automation. In: *The International Journal of Technology, Policy and Management*, (forthcoming)

Marchau V.A.W.J. & R.E.C.M. van der Heijden (1998) Policy aspects of driver support systems implementation: results of an international Delphi study. In: *Transport Policy*, vol. 5, no 4, Elsevier Science Ltd, p. 249-258.

Marchau V.A.W.J. (2000) *Technology Assessment of Automated Vehicle Guidance: Prospects for automated driving implementation*. TRAIL PhD Thesis Series T2000/1, Delft University Press, Delft.

Marchau, V.A.W.J. & R.E.C.M. van der Heijden (2000) Introducing advanced electronic driver support systems:**{**PRIVATE **}** An exploration of market and technological uncertainties. In: *Transport Reviews*, Vol. 20., No. 4 Taylor and Francis Ltd, London, p. 421-433.

Minderhoud M.M. (1999) *Supported Driving: Impacts on Motorway Traffic Flow*. TRAIL Thesis Series T99/4, The Netherlands TRAIL Research School, Delft University Press, Delft.

Molin E.J.E. (1999) *Conjoint modelling approaches for residential group preferences.* Dissertation, TU Eindhoven.

Molin E.J.E., V.A.W.J. Marchau, S. van Hoytema & D. de Waard (1999) Drivers' stated preferences for a driver state monitoring system. In: *Proceedings of the TRAIL 5th Annual Congress 1999*, Part 2, TRAIL Research School, Delft.

Morello E., Th. Benz & J. Ludmann (1994) AICC Assessment. In: *Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems*, Artech House, Boston, p. 1900-1907.

OECD Road Transport Research (2000) *Outlook 2000 -- Perspectives 2000*, OECD, Paris.

Oppewal H. & H.J.P. Timmermans (1992) Conjuncte Keuze Experimenten: Achtergronden, Theorie, Toepassingen en Ontwikkelingen. In: A.E. Bronner (ed.): *Jaarboek van de Nederlandse Vereniging van Marktonderzoekers*, 1992-1993, p. 33-58. (in Dutch)

Oppewal H. (1995) *Conjoint experiments and retail planning: modelling consumer choice of shopping centre and retailer reactive behaviour*. Dissertation, TU Eindhoven.

Sala G., N. Clarke, P. Carrea & L. Mussone (1997) Expected Impacts of Anti-Collision Assist Applications. In: *Proceedings of the 4th World Congress on ITS*, ITS Congress Association, Brussels.

Sayer J. R., M.L. Mefford & P. Fancher (1995) Consumer acceptance of adaptive cruise control following experience with a prototype system. In: *Proceedings of the Human Factors and Ergonomics Society 39th annual meeting*, Vol. 2. Human Factors and Ergonomics Society, p. 1092-1096.

Shladover S.E. (1999) Intellectual challenges to the deployability of AVCSS. In: *78th Meeting of the Transportation Research Board*, Transportation Research Board, Washington DC, 13p.

Smiley A. & K.A. Brookhuis (1987) Alcohol, drugs and traffic safety. In: J.A. Rothengatter & R.A. de Bruin (eds.) *Road users and traffic safety*. Van Gorcum, Assen, p. 83-105.

Steenkamp J.E.B.M. (1985) De constructie van profielsets voor het schatten van hoofdeffecten en interacties bij conjunct meten. In: *Jaarboek van de Nederlandse Vereniging van Marktonderzoekers,* p. 125-155. (in Dutch)

Timmermans H.J.P. (1984) Decompositional multiattribute preference models in spatial choice analysis: a review of some recent developments. In: *Progress in Human Geography*, No 8, p. 189-221.

Timmermans H.J.P.(1982) Consumer choice of Shopping Centre: An Information Integration Approach. In: *Regional Studies,* No. 16, p. 171-182.

USDOT (1999) *G7 Countries: Transportation Highlights*. U.S. Department of Transportation, Washington D.C.

Varhelyi A. & T. Makinen (2001) The effects of in-car speed limiters: field studies. *Transportation research. Part C, Emerging technologies.* Vol. 9C, no. 3, p. 191-211

Vriens M. (1995) *Conjoint analysis in marketing; developments in stimulus representation and segmentation methods.* Dissertation. RU Groningen.

Wiethoff M., T. Heijer & E. Bekiaris (2001) How could Intelligent Safety Transport Systems enhance safety? *The 5th International Congress on Technology,Policy and Innovation*, June 26-29, 2001, The Netherlands.