INTRODUCING SAFETY ON ADVANCED TRAVELLER INFORMATION SYSTEMS AND CONSEQUENT IMPACT ON DRIVERS' ROUTE CHOICES

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ABSTRACT. Advanced traveller information systems providing information on route choice, and drivers receiving such information modify their route characteristics accordingly. So far the information transmitted to drivers is mainly related to traffic conditions such as travel time, delay, queue or incident characteristics. A proposed development that could also improve road safety is to enhance on-board advanced traveller information systems with information on the safety level of the alternative routes. It might be the case, that drivers may change their route to follow a safer one. To assess the significance of such an introduction, its impact on driver choices needs to be explored. Hence, the present research investigates driver route choice in relation to three attributes: route distance, travel time and safety level. In order to capture driver choices a questionnaire-based stated preference survey was carried out and discrete choice analysis was performed on the survey results. Analysis results indicated that providing information on route safety influences driver route choice and supporting the development of such a system as a means to improve road safety.

INTRODUCTION

Drivers choose their route depending on several attributes including distance, travel time, traffic conditions (congestion, free-flow etc), route familiarity, road environment, route scenery etc. (Abdel-Aty *et al.*, 1997; Eby and Molnar, 2002; Hawas, 2004). However, within several applications of driver route choice into technologies, computer programs etc. only a few of these attributes are taken into account. According to such implementations driver route choice is mainly affected by travel time, traffic conditions, weather conditions and distance. Two such implementations which are used widely for the design of transport schemes and traffic strategies and on-line traffic management are Advanced Traveller Information Systems (ATIS) and traffic assignment models.

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Advanced traveller information systems are technologies which aim at providing information on route characteristics so as to assist drivers on choosing their routes (Ng *et al.*, 1995; Adler and Blue, 1998; Chatterjee, 1999; Levinson, 2003). They have been introduced into the market through a variety of products and services including navigation devices, variable message signs and mobile texts, demonstrating high acceptability amongst the users. The information can be provided either before the start of the trip (pre-trip) or during the trip (on-trip) and it mainly involves the traffic conditions of specific road segments or routes and also other types of adverse road environment conditions such as fog, winds, rain, adverse pavements conditions etc. The driver uses this information to choose his/her route taking also into account other attributes that he is aware of in respect to the alternative routes such as route length and route familiarity.

Traffic assignment models are macroscopic models that simulate traffic by assigning it to different alternative routes (being given an O-D matrix as input) according to several attributes the most important of which being travel time and distance. There is a great variety of such models, involving different dynamics, factors and elements involved with several new and more advanced models being constantly developed. Traffic assignment models are necessary to design and evaluate management strategies and within this framework they are also employed to predict traffic patterns (under different possible scenarios) to allow for the efficient implementation of advanced traveller information systems (Jayakrishnan et al., 1995).

What seems to be missing from the approaches implemented within ATIS and assignment models and has not investigated in great detail is whether the safety level of a route might be a prevalent factor for driver route choice. Abdel Aty *et al.* (1995) analysed commuters' route choice and found that influencing factors included travel time, travel time reliability, safety level and roadway characteristics. Route choice and safety level has also been investigated through the framework of willingness to pay for road safety. Rizzi and Ortuzar (2003) employed linear and non-linear utility models to estimate drivers' route choice for a specific interurban route as a function of travel time, toll charge and level of risk. Other contributing variables were found to be driver gender and age, presence of passengers, location of origin (in relation to the location of the route) and driving during the night. Yannis et al. (2005) investigated the contributing factors towards choosing a safer route (both interurban and urban) in exchange with a more expensive and/or less quick route. Driver gender, marital status, driving experience and household income were found to also influence driver choice. Still, the significance of road safety on choosing a route – not in relation with charging a certain cost for it – has not been thoroughly addressed.

If route safety level were a significant factor towards choosing a route, a proposed development which could result in the change of flow distribution between alternative routes and could also improve road safety, would be to enhance on-board ATIS with information on the safety level characterising available alternative routes (Benz *et al.*, 2006). In order to evaluate ex-ante the impact of adding such information to current ATIS, including its effectiveness on improving road safety, its impact on drivers' route choice behaviour needs to be explored. Within this framework, the present research reports an investigation of drivers' route choice behaviour employing a stated-preference (SP) questionnaire survey. Within this survey the importance of three attributes – namely, route travel time, distance, and safety level in respect to drivers' route choice and the possible factors that might determine drivers' preferences towards choosing the safest route were estimated. The paper discussion was extended to examining the benefits of the introduction of the route safety level into ATIS and traffic simulation software.

QUESTIONNAIRE SURVEY

Design of the Survey

A questionnaire survey was designed to assess the importance of the investigated attributes on drivers' route choice. As anticipated the results would not provide the most accurate description of driver behaviour as questionnaire surveys cannot elicit actual behaviour but only perceived, and these two might differ. Nevertheless, they are a sufficient means to determine trends and they also allow for the investigation of hypothetical scenarios. The main elements of the questionnaire survey involved the design of the questionnaire, the training of the team conducting the survey, and the participant sample.

The questionnaire consisted of four sections: the first section provided information on driver general and vehicle related characteristics including age, gender, category of vehicle driven, driving experience, annual mileage etc. The second section involved questions related to road safety. In particular, in our everyday driving we only experience and realise the importance of road safety when coming across or being involved in a road accident, or at near-miss accidents. Hence, the possibility of being involved in an accident is always perceived to be smaller than actually is. In addition, drivers are conscious of the importance of the travel time and length of a route as they experience these in all their trips. Hence, in this questionnaire section two questions aimed at raising driver consciousness in respect to road safety were included. Drivers were asked to estimate the number of fatalities in Greece during the past year, and were then informed of the correct number. They were then asked to rank in order of severity several injury conditions. In addition, drivers were also asked to rate the importance of the three examined attributes travel-time, length and road safety level when choosing an urban route. The third section was the stated preference experiment which is described in more detail in the next Section. The last section of the questionnaire involved information on driver demographic characteristics including marital status, household size, profession, education and income.

The team conducting the survey was trained appropriately and there was continuous communication between the team and the coordinator of the survey to allow for the specification of all possible issues that might have evolved.

Sample Characteristics

The survey involved urban trips and hence the survey was conducted to drivers driving inside the city of Athens. The sampling was random hence involved drivers of different age categories and characteristics and took place in various locations (offices, streets, car-washing facilities), in areas with different characteristics (economical, type of activities etc) and in different periods within a day (morning, afternoon and evening), both during weekdays and weekends allowing for a representative sample to be included in the survey. Tables 1 illustrates sample characteristics in respect to driver age, driving experience and annual mileage driven (expressed in kilometres).

Table 1. Participant age, driving experience and exposure

	Age	Driving experience	Annual mileage (km)
Average	35.19	14.44	16950.70
Minimum	19.00	1.00	1000.00
Maximum	72.00	51.00	300000.00
St. dev.	11.94	10.91	18952.58

Further analysis was performed to check for variable correlations and it was found that driver age and driver experience were highly correlated, as expected. The calculated correlation value was 0.935 and was significant at a 95% confidence level. Sample distribution in respect to other demographic sample characteristics, which will also be used in the analysis, are presented in Table 2.

Table 2. Participant demographic characteristics

Marital Status	No.	Number of children	No.	Household size	No.	Household income	No.	Education	No.
Single	212	0	224	1	46	0-10 000	62	Junior High School	21
Married	148	1	52	2	50	10 001-20 000	119	Senior High School	152
		2	62	3	104	20 001-30 000	88	University	187
		>2	22	4	98	30 001-50 000	56		
				>4	54	>50 001	22		

EXPERIMENTAL DESIGN

General

The theory behind setting up stated choice experiments can be found in Hensher *et al*. (2005). Discrete choice analysis in transport has emerged from consumer, psychology and marketing research (Luce and Suppes 1965; Green and Rao, 1971; Green and Srinivasan 1978), and it has first been applied in the transport domain for fulfilling the needs of forecasting travel demand and behaviour.

For the present study a route choice context was selected for this experiment, considering a typical daily home-work journey. A binary choice experiment asking participants to select route A *versus* route B at a time was designed based on a factorial design of 3 variables and three variation levels. The three variables were selected to be: route safety level, travel time and length. The selection of these variables (travel time and distance) was made under the basis that they are quite significant ones both in terms of participant comprehension, real driver behaviour and also in terms of them being applied in relevant transport-related domains (ATIS and simulation sofware). Travel time and distance are two route characteristics that drivers are usually aware of when choosing their route, and can be measured in contrast to e.g. route scenery. In addition, travel time is one of the most important attributes when making a trip, especially in the case of an urban trip that is being made on an everyday basis. Route distance is an attribute that is being used in traffic assignement techniques.

Another option which could be useful for valuing time and risk reductions is to use travel cost as a proxy variable in the SP design, and provide an alternative definition of level of safety based on alternative means of presentation already used in the literature (e.g. annual fatal accident rate in route *x*). The design could be improved by knowing boundaries values for these two attributes, and then derive the design levels accordingly. However, as it would be rather difficult for participants to be aware of the attribute of cost, and in particular of estimation of the actual cost of their trips (would it be only fuel, would it include travel-time and other phychological attributes, wearing of the vehicle etc) and how this might influence their choices in reality, this approach was not implemented.

Statistical design

A catalogue plan of fractional factorial designs was used for the statistical design (Kocur *et al.* 1982). This is a standard procedure used in transportation practice to facilitate setting experimental plans. The design allows for the orthogonal estimation of main effects and denoted interactions, meaning that all estimates of effects are uncorrelated. The plan 3^3 (3 variables of 3 levels each) would imply 27 choice options in a full factorial design. Presenting all 27 choices to an individual would originate fatigue effects during the experiment. Then, we have considered a fractional factorial dividing the original design in 3 different blocks of 9 choices. Levels of variables were coded as [1, 0,-1] and expressed as differences between two options, where level 0 can correspond to the same variable level in both options (e.g. no change in travel time between route A and B). The design used different base levels for describing respondents' current variable situation (e.g. most frequent travel time in route A). Dominant situations were avoided by swapping variable levels amongst two options. Using two coding variables [1 0, 0 1, -1 -1] we could account for more general patterns of interactions between variables, also if we fix to zero one of the two coding variables for each attribute to gain equi-distance in the contribution of the attribute levels. An example of choice situation presented to the respondent appears in Figure 1.

Route option A		Route option B	
Travel Time	60	Travel Time	30
Distance	10	Distance	15
Safety Level	20	Safety Level	5

Figure 1. Choice situation presented to the respondent

Selection of variables

One of the key issues in a stated preference design is the presentation of variables to respondents. A realistic means of presentation will avoid the known hypothetical question bias. Since safety related variables such as risk reduction are not easily understood by individuals, it is necessary to assure that respondents consider the same definition for this variable when asked to choose amongst alternative route options. The attributes characterising each route option shall thus be familiar to road users. The presentation of level of safety was described in advance to the choice context to avoid the information bias to be present in the experiment.

Three variables were selected to characterise each route option: travel time, distance and level of road safety. As the questionnaire survey would be conducted to drivers of the city of Athens, the levels of variables were defined considering typical travel times and distances during peak hours in Athens, and are presented in Table 3.

Table 3. Variable levels for the SP design

	-1	0	1
Travel time	30	40	60
Distance	10	15	20
Safety Level	5	10	20

Travel time was expressed in minutes, route length/distance in kilometers and route safety level in the probability of having a killed or seriously injured (KSI) accident as a driver per 100 000 drivers. The average road safety level was estimated to be around 20 for the city of Athens; this information was also provided to the participants in the second section of the questionnaire.

RESULTS

Route Choice Model

As described in the previous Section, participants were asked to choose between two alternative routes (route A and route B) that were determined by three attributes: travel time, length and road safety level. To estimate the importance of each of these three attributes data were analysed using discrete choice analysis. The utility function involves two main terms: one describing the observed variables V and one describing the unobserved variables and can be stated as (Ben-Akiva and Lerman, 1989):

$$U_{in} = V_{in} + \varepsilon_{in}$$

where:

U_{in}: the utility of alternative i for individual n;
V_{in}: the systematic (deterministic) component of utility of *i* for individual *n*;
ε_{in}: the random (disturbance or error) component of utility *i* for individual *n*.

In the designed model, the alternative i was choosing route B instead of A and the utility of this choice was estimated using the following dependant binary variable:

$$\text{Route choice} \begin{cases} 1 \text{ if the examined route (route B) was selected by the driver} \\ 0 \text{ if the examined route (route B) was not selected by the driver} \end{cases}$$

Binary logistic regression was employed to estimate the utility of a route and the resulting in the following expression:

$$U_B = \alpha_1 x_1 + \alpha_2 x_2 + ... + \alpha_n x_n$$

where:

U_B:	the utility of route B;
x_i:	observed parameters (explanatory variables);
α_i:	parameter coefficients (estimators).

Hence, the explanatory variables – following several trial-and-error cases – were selected to be the difference between the attributes of reference route (route B) and those of route A. Hence, the components of the utility in the investigated model were:

T-dif.:	travel time difference (minutes);
L-dif.:	length difference (kilometres);
RS-dif.:	road safety level difference (number of killed or seriously injured drivers per 10^5 drivers).

The results of the analysis are presented in Table 4.

Table 4 Variable coefficients for the route choice model

	Coefficient	t-stat	Significant at
Tdif	-0.078	26.000	100%
Ldif	0.024	1.714	90%
RSdif	-0.147	14.700	100%

The estimated model demonstrated a quite good fit ($R^2 = 0.577$) and a total prediction percentage of around 80%. Results indicate that road safety is the most important factor in choosing a route – at least in respect to the way that drivers expect themselves to behave. Hence, drivers would select the safest route and then the quickest one, while the length of the route did not seem to affect driver choice. This reinforces the need for the introduction of the road safety parameter into advanced traveller information systems, and also justifies the introduction of road safety into traffic assignment models.

Safest Route Choice Model

One other question that arises from the previous results is whether the preference on a safer route also depends on other driver characteristics. Hence, further analysis was conducted using logistic regression modelling (as this is described in the previous sub-section), and the dependant variable was set to be the utility of choosing the safest route between the two alternative ones:

$$\text{Safest route choice} \begin{Bmatrix} 1 \text{ if the examined route (safest route) was selected by the driver} \\ 0 \text{ if the examined route (safest route) was not selected by the driver} \end{Bmatrix}$$

First, the drivers' revealed preferences were tested against drivers' stated preferences (safest route choice). Drivers' revealed preferences were collected from their rating of route travel time, length and safety level in terms of their importance when deciding on a route ("1" being not important at all and "10" being very important). The results of the analysis are presented in Table 5.

Table 5 Variable coefficients for the safest route choice model

	Coefficient	t-stat	Significant at
Travel time	-0.125	0.020	100%
Length	0.027	0.020	ns
Road Safety level	0.180	0.017	100%

The resulting model produced an average fit (R^2 = 0.160) with about 65% correct prediction percentages. Results indicate that drivers who considered road safety to be quite important in choosing a route, did choose the safe route, whereas drivers who considered travel time to be the most important factor did not choose the safest route, but the quickest one. Hence, revealed and stated driver preferences seem to be in accordance.

Following this, an attempt was made to relate safe route choice with other driver characteristics including driver age, gender, driving experience, annual mileage, marital status, education. In addition, to that the length variable was removed from the model as it did not seem to affect drivers choice towards the safest route. The investigated parameters were elaborated in such a way as to provide meaningful results, including categorisation of variables in several levels and removal of outliers. Table 6 illustrates the factors the influence of which was found to be significant on selecting the safest route.

Table 6 Variable coefficients for the safest route choice model

	Coefficient	t-stat	Significant at
Travel time	-0.083	-3.952	100%
Safety level	0.207	10.350	100%
Age	0.122	1.649	90%
Driving experience	-0.192	-2.157	95%
Annual mileage	0.085	1.932	90%
Education	-0.163	-2.763	95%

The resulting model produced an average fit (R^2 = 0.170) and the correct prediction percentages were about 66%. Still, several factors that contribute to drivers' route choice were revealed. In particular, driver age and drivers' preference on choosing the safest route are related. Driver age was classified under the following categories: drivers aged between 18 and 24 years old, who correspond to the category of young drivers, drivers aged between 24-34 years old who comprise an intermediate category between young and "mature" drivers, drivers aged between 35-64 years old who are considered to be "mature" drivers and drivers older than 65 years who correspond to the elderly drivers group. Results indicate that drivers tend to prefer safer routes with increasing age, which confirms the fact that younger people are considered to be a risk taking group. This has also been observed in their driving as they have, for example, been found to be rather prone to traffic rules violations (Reason et al. 1991; Aberg and Rimmo 1998).

Driver experience is another factor influencing drivers towards selecting a safe route (mainly to a quick one). Driving experience was classified under three categories: 0-1 years of driving experience (usually corresponds to young and inexperienced drivers), 2-5 years of experience and over 5 years of experience which corresponds to experienced drivers. Although driver age and driver experience were found to be highly correlated (Section on sample characteristics), the implemented categorisation of these variables cancelled this correlation. Results indicate that inexperienced drivers would select the safe route more than experienced ones. Experience in driving raises the feeling of security that one attributes to his/her driving. Applying the risk compensation rule in this case that assumes that its driver has a specific acceptable level of risk which determines his/her driving behaviour. Hence, the more secure one feels with his/her driving (which is a consequence of driving experience) the riskier behaviour he/she will adopt, and in the examined case the safety level of a route will be of a less significant attribute.

Another factor influencing drivers towards selecting the safest route is driver exposure. Annual mileage was divided into four categories: less than 5000 km's per year which corresponds to rather low exposure, between 5001 and 12500 km's, which can be considered as "average" exposure, between 12501 and 20000 km's per year (rather high exposure) and over 20000 km's per year, which corresponds to high exposure. Results reveal that drivers who drive greater distances select the safest route more than drivers who drive less. Driver exposure and behaviour could be related by several hypotheses as for example: drivers who drive more feel more secure about their driving and tend to drive in a less safe way, or drivers who drive more usually do driver longer distance trips (usually involving interurban or rural areas) and hence adopt a more cautious behaviour. Although the relationship between driver exposure and driver safely behaviour has not been established, in this case it seems that greater exposure results in safer route choice.

Education also seemed to play a role into route selection, as drivers having received higher education tend to prefer less safer routes. Results indicated that driver gender, marital status, number of children, household size, profession or income do not influence drivers on choosing a route.

CONCLUSIONS

This study investigated the influence of the safety level of a route on driver route choice, for urban areas. The tool employed for this investigation was a stated-preference questionnaire, including a stated choice experiment. Drivers had to select the route they would chose for an everyday urban trip, between two alternative routes that were defined through three attributes: travel time, length and safety level. Discrete choice analysis was performed to identify drivers' preferences.

Results revealed that the safety level of a route is not only a contributing factor to route choice, but also the prevalent one, amongst the investigated ones. In addition, drivers' revealed preferences on the significance of the attributing factors on when choosing a route came in accordance with their stated ones, as drivers who choose the safest route rated road safety as the most important parameter. Several demographic characteristics also contribute to drivers choosing the safest route. In particular, drivers tend to choose the safest route more with increasing age and decreasing driving experience. Annual mileage was another contributing factor, as drivers who demonstrated higher exposure would choose more the safe route. Driver education was also found to be a contributing factor, whereas other characteristics such as gender, marital status, household income and profession did not affect drivers' route choice.

The determined significance of road safety reinforces the need for the introduction of road safety into advanced traveller information systems, with the aim of improving road safety. It is expected that drivers being provided with information on the safety level of a route might change their route from less safe to safer ones, which may improve road safety. However, this can be a dynamic equilibrium as the safety level of a route is also dependent on traffic volume, and change in traffic volumes might modify the safety level of a route. To estimate the effects of drivers' route choice – once safety level is considered as a contributing factor – on road safety, traffic assignment algorithms that consider route safety level need be developed. The results of this study and the aforementioned implications emphasise the need for further research on the contribution of the attribute of road safety on route choice.

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