A SIMULATION FRAMEWORK FOR THE ASSESSMENT OF THE IMPACT OF ADVANCED TRAVELER INFORMATION SYSTEMS ON USERS' CHOICE AND BEHAVIOR

NATHANAIL, Eftihia, Assistant Professor, University of Thessaly, Department of Civil Engineering, Pedion Areos, 38334, Volos, Greece, Telephone: +30 2421074164, Fax: +302421074131, E-mail: enath@uth.gr

ADAMOS, Giannis, Researcher, University of Thessaly, Department of Civil Engineering, Pedion Areos, 38334, Volos, Greece

PETAMIDES, Charalambos, Researcher, University of Thessaly, Department of Civil Engineering, Pedion Areos, 38334, Volos, Greece

ABSTRACT

The large mobility demand and the rare supply of the appropriate road infrastructure - both in urban networks and freeways, cause congestion problems, which affect the smooth travelling of road users who face mainly travel delays in their daily trips. Recently, much attention has been paid in developing Advanced Traveler Information Systems (ATIS) as an effective way to inform drivers to make route choices and avoid traffic congestion. It is obvious that both the way traffic affects road users behavior or reaction, as concerns mode, or route change and ATIS influences driver behavior and the way drivers adopt the information provided by ATIS, are important issues in attempting to understand and predict driver behavior. Such understanding is usually based on the development of models that capture and analyze user behavior in the presence of information, varying in type, mode, and content.

The purpose of this paper is to investigate and analyse the effect ATIS may have on travellers, by evaluating, at the same time, the impact of ATIS in drivers' decisions. Towards this direction, a platform is developed to collect and process data which lead to the development of driver behavior models. More particularly, the present paper is the first of two papers designated to modelling drivers' behavior and assessing the impacts of alternative information systems. Furthermore, the structure of the models as it is affected by the parameters used, and the population groups, is presented and discussed. Also, following a literature review, the framework of the research is established and the experimentation and some preliminary results are expressed. In the second upcoming paper, which will be the result of our further research, the models, as well as the testing and assessment of alternative information strategies will be presented.

Keywords:, Advanced Traveler Information Systems, route choice, modal choice, driver behavioural models.

INTRODUCTION

According to the latest statistics, 80% of European Union residents live in urban areas, and 40% live in large urban areas of over 200.000 inhabitants. All these civilians accommodate their travel needs in the same infrastructure, which also facilitates the transportation of all types of transport modes (public, cars, lorries, cyclists, pedestrians). On average, a European resident makes 1000 trips per year and half of these are less than 5 km long. Urban mobility accounts for 40% of all CO_2 emissions of road transport and up to 70% of other pollutants from transport (www. proudcities.gr).

As a result of all the above, as well as the combination of large mobility demand and rare supply of the appropriate road infrastructure, most metropolitan areas face congestion problems both in urban networks and freeways, affecting the smooth traveling of road users and causing daily travel delays, especially in the morning and evening peak-hours. Congestion is distinguished in literature into recurrent, when congestion takes place regularly and non-recurrent. Non-recurrent congestion is caused when random incidents happen on the roads, like traffic accidents or adverse weather conditions (heavy rain, snow, etc.).

Recently, there has been much interest and much attention has been paid in developing Advanced Traveler Information Systems (ATIS) as an effective way to infrom drivers to make route choices and avoid traffic congestion. It is obvious that both the way roads users behave or react to traffic, transit or route change and ATIS affect driver behavior in adopting the information provided, are important issues in attempting to understand and model driver behavior under the impact of ATIS. Such understanding is usually based on the development of models that capture and analyze user behavior in the presence of information, either by providing the information or by suggesting, for example, the best route to be chosen.

The a priori evaluation of the effectiveness of such systems requires the simulation of the drivers' behavior, through the development of prediction models for the individual driver behavior, as well as for the impact of such behavior on traffic. The present research aims at developing a framework which is used to develop drivers' prediction models, modelling mainly the decision of the drivers in route choice. Within the above context, the objectives of the research may be phrased as follows:

- to develop a platform for collecting and processing data that affect the drivers' behavior in route choice
- to assess the parameters that may be used in driver behavioral models
- to formulate and develop models to be used for the estimation of the probability of the effect ATIS may have on the travellers
- to examine and evaluate the degree of accuracy the above models may provide in the prediction
- to estimate and evaluate the impact of alternative ATIS strategies may have on drivers' behavior and traffic

The purpose of this paper is to investigate and analyse the effect ATIS may have on travellers, by evaluating, at the same time, the impact of ATIS in drivers' decisions. Towards this direction, a platform is developed to collect and process data which lead to the development of driver behavior models. More particularly, the present paper is the first of two papers designated to modelling drivers' behavior and assessing the impacts of alternative information systems. Furthermore, the structure of the models as it is affected by the parameters used, and the population groups, is presented and discussed. Also, following a literature review, the framework of the research is established and the experimentation and some preliminary results are expressed. In the second upcoming paper, which will be the result of our further research, the models, as well as the testing and assessment of alternative information strategies will be presented.

STATE OF THE ART

ATIS and Driver Behavioural models

ATIS (Advanced Traveler Information Systems) belong to the intelligent transportation systems (ITS), which are being intensively developed in a large number of research centers all over the world. Their basic task is to provide certain information to travelers so as to be better informed when they make their travel choices. This information is usually "real-time" concerning, for example, the traffic conditions and anticipated delays, accident occurrences or route guidance from origin to destination. The principal aim of these systems is to influence drivers' *behaviour* on route choice and departure time decisions in order to improve mobility and reduce traffic congestion.

Technological infrastructure is used to collect, process and disseminate network data so as to provide the appropriate information to users focusing mainly on route guidance, lane changing, etc. The procedure that is followed is based on two main parts: the data collection of the network and the provision of the information. The data collection is achieved through cameras placed on specific locations of the network. Then, these data are transmitted to an information management center, in order to be further exploited. The next stage includes the dissemination of these data to road uses, usually through radio, variable message signs (VMS), or advanced in-vehicle navigation systems. The most widely used types of information provided, are related to route guidance or travel times, but also weather, special incidents (e.g. accidents) or lane changing information or advice.

In general, the common practice in actual traffic studies in route choice modeling involves the search of the shortest path, as the route choice model enables the universal implementation of traffic assignment and simulation procedures to every network configuration (Bekhor, S. & Prato, G.G, 2009). The challenges in route choice modeling seem to be distinguished into two main categories, the *individuation of alternative routes*, especially in urban networks where the combinatorial nature of the problem cause the task not to be trivial, and the definition of the *correlation structure among the alternatives generated*, either in the deterministic or in the stochastic part of the utility function of a discrete choice model formulation (Bekhor, S. & Prato, G.G, 2009).

In the first of the above categories, a number of researches (Hunt & Kornhauser, 1997; Van der Zijpp & Fiorenzo-Catalano, 2005) approached the task of the individuation of the alternative routes by generating variations or adaptations of the shortest path search. Ben-Akiva (1984), by developing the labeling – approach, generated different optimum paths by minimizing different objective functions that represent heterogeneity in travelers' preferences. The link elimination (Azevedo et al., 1993) and the link penalty approaches (De la Barra et al., 1993; Park & Rilett, 1997) produce sequences of minimum cost paths by formulating heuristic rules that remove or penalize shortest path links before searching for the next optimum path (Bekhor, S. & Prato, G.G, 2009). Finally, Prato & Bekhor (2006) developed a branch and bound algorithm which constructs a connection tree between origin and destination of every trip by processing sequences of links according to a branching rule that takes into account logical constraints formulated to increase route likelihood and heterogeneity.

For the needs of the second category, a number of models have been developed, which suggest several solutions or approaches to the overlapping problem. The family of Logit

route models is widely used for these purposes and has in general a closed form and can be efficiently calibrated from desegregated data (Cascetta et al., 2002). In the applications, these models are usually combined with the "selective" approach of choice-set generation,
using both implicit (Dial, 1971) or explicit path enumeration techniques (Ben-Akiva et al., 1984; Antonisee et al., 1985). Route choice for a given choice model set is modeled using classical random utility models, usually with Logit and Probit specifications (Cascetta, 2001). Recently, modifications of the multinomial logit model (MNL) were proposed to overcome path-overlapping problems connected to independence of irrelevant alternative (IIA) property (Cascetta et al., 2002). For example, the C-Logit model shares the computational and calibration efficiency of the closed Logit model while eliminating the counter-intuitive results relative to generally overlapping paths. The basic idea is to deal with similarities among overlapping paths through an additional "cost" attribute, called the commonality factor in the utility function of a Logit model rather than through covariance of the random residuals of perceived path (dis)utilities assumed by Probit models (Cascetta, 1996). The idea of the Path Size Logit model (Ben-Akiva & Bierlaire, 1999) is similar to the C-Logit model. A correction of the utility for overlapping paths is obtained by adding an attribute to the deterministic part of the utility. The Cross Nested Logit and Generalized Nested Logit models relate the inclusion and nesting coefficients of the model structure to the network topology (Prashker & Bekhor, 1998). The Multinomial Probit and Logit Kernel models assume that the covariance of path utilities is proportional to the overlap lengths (Bekhor et al., 2002; Frejinger & Bierlaire, 2007; Yai et al., 1997).
Apart from the two categories of model behaviour approaches presented above, which belong to the probabilistic discrete choice models, some other approaches have also been suggested to address route choice behaviour under information provision. In particular, fuzzy rule-based systems, based on possibilistic concepts, provide a convenient modeling approach to treat linguistically expressed traffic information and the subjective knowledge of drivers (Peeta & Yu, 2004). Several fuzzy logic based models have been proposed for driver route choice under information. For example, Lotan & Koutsopoulos (1999) developed rule-based fuzzy models to analyze the interactions between a driver's existing perception and the real-time traffic information. Lotan (1997; 1998) incorporated a mechanism for perception update and the effect of driver familiarity under real-time information provision. Finally, Pang et al. (1999) used a rule-based fuzzy system to model driver route choice behaviour and calibrate the associated membership function using a neural network. Artificial neural networks is a new approach in the field of behavioural choice modeling which seems to be a valid alternative for the traditional choice models and are presented analytically in the following section.
The two basic approaches in the data collection that are widely used when modeling drivers' behaviour and choices, under the scope of ATIS, are *revealed preference* (RP) and *stated preference* (SP) data collection methods. Revealed preferences indicate how travelers behave in real-life situations, for example, observation of travelers' actual diversion in response to information. Stated preference data, on the other hand, indicate how travelers behave in hypothetical scenarios. Stated preference data can be extracted by SP surveys or by designed experiments with the use of simulators (Koutsopoulos et all., 1994). The advantage of SP data is that they can be collected in a controlled environment, relatively inexpensively. However, because these data indicate how travelers behave in hypothetical scenarios, the validity of the responses is a critical concern. For example, subjects may not be able to perceive differences in alternate trip scenarios (such as recreational versus work trips).On the other hand, revealed preference data, although much expensive and difficult to collect, does not suffer from such drawbacks (Koutsopoulos et all., 1994).

Neural networks in the modelling of drivers' behaviour

The neural network approach was firstly developed in the 1960s (Black, 1995). It was applied in developing computer-based artificial intelligence system based on neural network activity of the brain. Several studies (Davalo & Naim, 1991; Yang et al., 1998, Zhou & Nelson, 2000, etc.) have used neural network models to approach, for example, drivers' behaviour under ATIS, to explain route choices, to estimate time-varying origin-destination flows or to predict traffic congestion.

Literature has shown that Artificial Neural Networks (ANN) are better in handling complex problems than the traditional models because the former can easily deal with noisy data. This kind of data can complicate the calibration of the traditional models (Sayed & Razavi, 2000).

Nijkamp et all. (2004) compared the descriptive and predictive power of two classes of statistical models for multimodal network flows, the family of discrete choice models (i.e., logit and probit) and the neural network model (NN). The application concerned a large database of interregional European freight flows for two commodity categories (food and chemicals). Both the logit and the NN models were employed to predict the freight flows for each shipment from region i to region j. The results of the sensibility analysis showed that NN models are able to extract more information than conventional discrete choice models in the case of different policy scenarios. In, the other hand, the results also indicated that the logit modeling approach was slightly more sensitive to changes in cost attribute, while the NN modeling approach appeared to be fairly robust.

Critical assessment of the driver behaviour models

The impacts of ATIS technologies depend, to a large extent, on how travelers will respond to such systems, and that's why it is important to understand what factors influence travel decisions. The existing behavioural choice models usually assume perfect information, that is, individuals have knowledge of all alternatives. Clearly such an assumption is not defensible when the purpose is to evaluate the effect of information. At the same time, many networks performance models do not explicitly account for the effect of information, and use unrealistic behavioural rules (Al-Deek H. et al., 1998).

The traveler decision process is an intrinsic element in modeling traffic conditions with traveler information systems (Al-Deek H. et al., 1998). Consequently, several researchers have conducted simulation studies and/or proposed theoretical frameworks that incorporate behavioural characteristics into the traffic model process (Ben-Akiva et al., 1986; Mahmassani et al., 1990; Cascetta et al., 1991; Hamerslag and Van Berkum, 1991). Ben-Akiva et al. (1991) proposed the dynamic network modeling framework which presents a detailed description of the traveler decision process. Mahmassani et al. (1991) presented more specific simulation results based on a three-route network. All these studies address the impact of real-time information on travelers, supplied at the origin or en route, and exhibit route switching and departure time decision capabilities. However, the studies do not explore the actual benefits of information under different incident and network characteristics (Al-Deek H. et al., 1998).

METHODOLOGICAL APPROACH

The data collection process

The frame under which the experiment is set, as well as the measurement of the parameters to be used in the prediction modes are very crucial issues in the overall process. In order to develop driver behavior models, which may be used for the evaluation of alternative ATIS strategies, a data collection process has to be well defined. This process takes into account, initially, the number of days during which data will be collected, as well as the points of the network, where trip changes may occur due to information provision (figure 1). Furthermore, the ATIS scenarios are the main hypothesis of each run of the process, assuming certain traffic and environmental conditions, as depicted in figure 1. Two options are considered. Information provided pretrip, which may affect the travellers' decision on the time of departure, the transportation mode and the route to be taken, or en route, which may affect mainly the route choice. As far as the latter is concerned, information may be provided at different locations, and combination of them. Also, information provided at a location may affect route choice latter in the travellers'' trip (downstream the location of information), as traffic and other conditions contribute also in the travellers perception.
The following figure shows graphically the procedure that was followed for the collection of the data during the experiment. The procedure assumes a starting point on the first day, while the data are collected after each run of the whole process, depending on the traffic and environmental conditions according to the different scenarios and the type of the information provided to the users. The first node of the network assumes that the pre-route information may be provided, whereas en-route information is provided at every node before the final node, which composes the destination of the traveller.
Finally, an update of the accuracy of the information may be provided to the travellers, which may also affect their choices in their next trips.

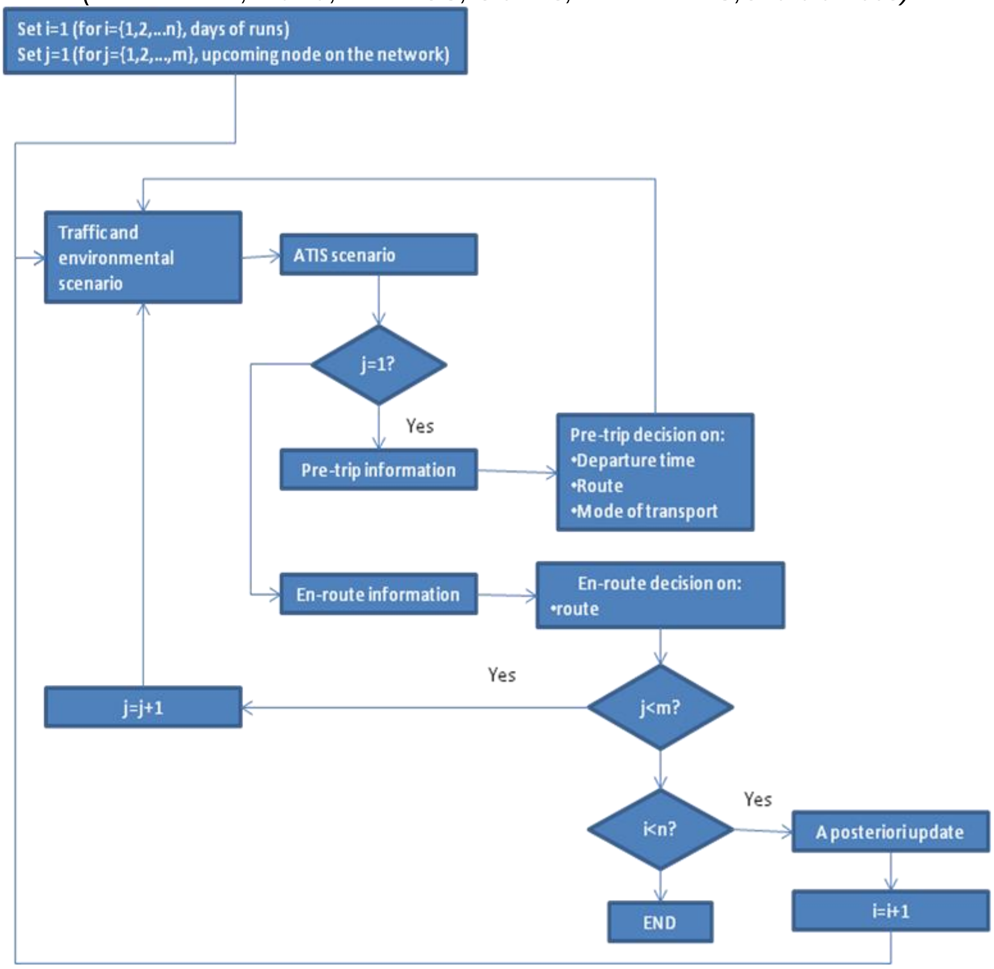

Figure 1 – The logical diagram for the data collection procedure

The ATIS scenario defines the information strategy. This is characterized by the following attributes:

1. Time of information: The time of information defines whether information is provided pre-trip or en route. Information may also be provided both pre trip and en route, in which case the overall impact on the driver decision is simulated further in the traffic simulation model.
2. Location of information: Information may be provided on one specific route (e.g. the freeway only), at specific nodes (upstream them, in order to allow for route change), or on all possible routes amongst which the driver may choose (including the city network).
3. Type (and content) of information: The content determines whether the information is qualitative (e.g. "expected delays") or quantitative (e.g. "expected travel time ½ hour"). Also, the message disseminated to the drivers may be informatory, informing about the conditions to be expected, or advisory, suggesting an alternative (e.g. "take next exit", "choose alternative route", etc.).
4. Feedback: Another factor which may alter the ATIS scenarios is the possibility of providing the driver with a feedback about the actual travel times, once his trip is completed. This factor may affect the driver's compliance to the information, next time he/she will be provided by it.

The driver behaviour model parameters

The parameters that affect travellers' choice, which are also used for the construction of the relevant prediction models are distinguished in four main categories:

1. User characteristics, which refer to the users for which the information is provided, and who are expected to be affected in terms of route choice. Mode and time of departure may also be affected, however, they are not modelled in the current work.
2. Trip characteristics, which describe the need for travelling, when, where, why, and imply the possibility of changes.
3. Route attributes, which relate to the one on more itineraries which can be taken to accomplish the trip.
4. ATIS attributes, as described in the previous paragraph.

The dependent variable that is affected by the above parameter categories reflects the travellers' behavior, in terms of route choice (mode and time of departure choice are not addressed in the current paper). Compliance with speed limits and other driving behavioral rules may also be addressed (also not addressed in the current paper). The variables (dependent and independent), their type and values are given in table I and are described below. Where numerical values are not feasible, and the variables are qualitative, bivariate or multivariate format is selected.

- **Gender:** In some studies, the gender (male vs female) appears to play an important role in the degree of acceptance of advice provided by information systems. According to Vaughn et al (1993), while males are more willing to accept advice they are also less likely to purchase an information system. Also, males are more willing to accept advice and make their decisions faster than females. However, other studies indicated that the gender does not seem to statistically affect the route choice.
- **Age:** According to Mahmassani et al (1999) the age of commuters may affect their departure time switching behaviour. Older commuters may tend to tolerate greater schedule delay than young ones. Also, younger males are more sensitive to level-of-service measures, since they are observed to switch more frequently to increase trip-time savings and avoid congestion on the best path (Srinivasan K.K. & Mahmassani H.S., 2003).
- **Level of education:** The level of education seems to be affecting acceptability of information. A discrimination of drivers based on their level of education is used in various studies, most frequently using the following categories (Dia, H., (2002): High school or less, vocational or technical school, undergraduate degree, post graduate degree.
- **Income level per capita:** Same applies for the income level, where it may be categorized in two or three categories, e.g. low, medium and high (Dia, H., (2002)).
- **Type of user:** The habit on the facility and even the route used seems to affect the willingness to change route. The modal captive users are not considered here, as the research focuses on the private car users.
- **Previous experience on delay on this route and this direction:** Experience affects advice acceptance, as the more experienced the drivers, the less willing they seem to accept advice, as compared to the less experienced drivers. Also, experience drivers make their decisions faster (Vaughn et al, 1993).
- **Trip purpose.** The trip purpose affects the route choice (Boger et al., 2004). As it is observed in urban areas, where a homogenous driver population exists, the time and

direction of travel may depict also the trip purpose. In order to be able to consider this parameter in all model formulations (with or without the user characteristics), the trip purpose is modeled through the time of the day travel. Specifically, through the survey, the assumption that the morning peak accommodates mainly trips going to work, whereas the evening peak reflects traffic returning home, is investigated.

- **Traffic conditions.** Traffic conditions affect the driver choice, as regards the route change, as well as the driving behavior (i.e. travel speed) (Dia, H., 2001).
- **Estimated - perceived proportion of remaining traveling on same route over total trip:** The remaining trip length may affect the driver in route changes. The longer less length this is, the lesser the probability of route switching**.**
- **Type of facility currently being used:** In order to observe the effect of the type of the facility on the alternative routes, two types of infrastructure are assumed, the freeway and the city network.
- **Easiness of route change:** It is a qualitative indicator, which relies on the perception of the driver on the easiness of changing networks (i.e. from the freeway to the city network and vice versa) in terms of the network interconnectivity and the conditions, which prevail (according to the driver) on the connectors.
- **Feasibility of changing route later:** The assurance of existence of downstreams nodes, where a route change may occur, may affect the drivers' non compliance with an advice, where the advice is provided.
- **Weather.** Two alternative cases are anticipated. The first assumes that the weather is dry, whereas the second refers to conditions which reduce the driving comfort, i.e. rain, fog, snow.
- **Light conditions:** Here, daytime versus night time are considered, and in addition to the above, night time with good illumination or poor and no illumination.
- **Time of information:** information may be provided before the trip (pre trip), or during the trip (en route), or both. In the last case, the choice is considered to be affected also by the pre trip information. However, the significance of the coexistence of these types has to be proved
- **Facility for which the information is provided.** The ATIS may provide information about the prevailing and anticipated conditions on the route he is on, or on both routes. The options are the freeway or the city network only, and both alternatives.
- **Content of information:** Two subcategories exist:
    - <u>Qualitative</u>: The ATIS may be just informing the driver about the prevailing and anticipated conditions on the route(s); or it may be advising about the route to be taken.
    - <u>Quantitative</u>: ATIS may provide quantified information to the drivers about the estimated travel time on the network used, or may even provide similar information for the alternative network.
- **The information feedback** determines whether or not the driver is provided with the actual travel times, once his trip is completed. This may be combined with the indicator below, i.e. information reliability.
- **Information reliability:** If information feedback is provided, the information reliability comprises a parameter that may affect future choice of the driver. This may be calculated as the % difference of the estimated versus the actual travel time on the selected itinerary, as well as the time difference of the two alternatives (time if he had continued on the facility, thus if he had not taken the advice, and actual time, having taken the advice). The function that estimated information reliability is:

((|Tinfo-Tactual|)*100/Tactual)*((|Tselected_route-Troute_before_advice|)*100/Troute_before_advice)

Table I – Models' variables and type of values

Variable	**Options**	**Type of data**	**Value**
Change of route	Yes	Bivariate	1
	No		0
Gender	Male	Bivariate	1
	Female		0
Age	18-25	Multivariate	1
	26-39		2
	40-59		3
	>60		4
Level of education	High school or less	Multivariate	1
	Vocational or technical school		2
	Undergraduate degree		3
	Post-graduate degree		4
Income level per capita	Low (<15000 euros)	Multivariate	1
	Medium (15000-40000 euros)		2
	High (>40000 euros)		3
Type of user	Freeway commuter	Bivariate	1
	City network commuter		0
Previous experience on delay on this route and this direction	Yes	Bivariate	1
	No		0
Trip purpose	"Go to work"-morning peak	Bivariate	1
	"Return home"-evening peak		0
Traffic conditions	Volume to capacity	Numerical	
Estimated – perceived proportion of remaining on same route over total trip	Proportion	Numerical	
Type of facility currently used	Freeway	Bivariate	1
	City network		0
Easiness of route change	Easy	Multivariate	1
	Neutral		2
	Difficult		3
Feasibility of changing route later	Number of route changing nodes remaining till end of trip	Numerical	
Weather conditions	Dry	Bivariate	1
	Wet and/or low visibility		0

Light conditions	Light (day time or night with good illumination)	Bivariate	1
	Night time with poor or no illumination		0
Time of information provided	Pre-route	Multivariate	1
	En-route		2
	Both		3
Facility for which the information is provided	Freeway	Multivariate	1
	City network		2
	Both		3
Content of information	Qualitative	Bivariate	1
	Quantitative (and qualitative)		2
Information feedback	Yes	Bivariate	1
	No		2
Information reliability	The difference between the estimated and the actual travel time	Numerical	

DESIGN OF EXPERIMENT

The scenarios

Having determined the measurable parameters (model parameters), the ATIS scenarios have to be designed.
The number of ATIS scenarios, as these are cited in table II, depends on the following parameters: *time*, *location* and *type of information* provided. As far as time is concerned, information may be provided before the trip (scenarios ATIS1 and ATIS4), during the trip (ATIS2, ATIS5 and ATIS6) or both before and during the trip (ATIS3, ATIS7 and ATIS8). In terms of location, the ATIS scenario may provide information about the prevailing and the anticipated conditions on the route the traveller uses at the time of the information provision (thus only en route) (ATIS2, ATIS3, ATIS5 and ATIS7), or on all alternative routes (ATIS1, ATIS4, ATIS6 and ATIS8), which may be done pretrip or en route. The type of information is taken into account for the development of the ATIS scenarios. In this case, the information can be either qualitative or both qualitative and quantitative. Table II shows the three scenarios (ATIS1, ATIS2 and ATIS3) where the information provided is qualitative. In this case, the ATIS just informs the driver about the quality of the prevailing and anticipated conditions on the routes (road accident, demonstration, road construction, congestion, big delays etc). Alternatively, the information may provide even figures of the measured or estimated impacts, e.g. travel time, travel delays etc (ATIS4, ATIS5, ATIS6, ATIS7, ATIS8). Type of information also distinguishes between informatory and advisory strategies, as described in the previous paragraphs. Examples of informatory versus advisory strategies are given below. For each informatory message, the added advice is provided. Messages may be phrased as follows:

1. "expected delays on the [facility]". In case of advisory "...use [other facility]"

2. "incident on the [facility] and expected delays". In case of advisory, "...use [other facility]".
3. "expected delays on [freeway facility] due to adverse weather conditions". In case of advisory "...use [roads in city network]".
4. "increased risk on [freeway facility] due to bad weather conditions". In case of advisory "...use [roads in city network]". Here, another advice was given "reduce speed on freeway".

Table II – ATIS Scenarios (cont)

Code of ATIS scenario			ATIS 1	ATIS 2		ATIS 3	
Time of information		Pre-trip		En-route		Pre-trip and en-route	
Location of information		Used facility	All facilities	Used facility	All facilities	Used facility	All facilities
Type of information		qualitative					
Information content							
Informatory	Expected delay on facility (recurrent)		√	√		√	
	Incident of facility and expected delay (non-recurrent)		√	√		√	
	Bad weather conditions and expected delay on facility		√	√		√	
	Bad weather conditions and increased risk on facility		√	√		√	
Advisory	Expected delay on facility (recurrent)		√	√		√	
	Incident of facility and expected delay (non-recurrent)		√	√		√	
	Bad weather conditions and expected delay on facility		√	√		√	
	Bad weather conditions and increased risk on facility		√	√		√	
	Bad weather conditions - increased risk on facility – speed reduction required		√	√		√	

Table III– ATIS Scenarios

Code of ATIS scenario			ATIS 4	ATIS 5	ATIS 6	ATIS 7	ATIS 8
Time of information		Pre-trip		En-route		Pre-trip and en-route	
Location of information		Used facility	All facilities	Used facility	All facilities	Used facility	All facilities
Type of information		quantitative					
Information content							
Informatory	Expected delay on facility (recurrent)		√	√	√	√	√
	Incident of facility and expected delay (non-recurrent)		√	√	√	√	√
	Bad weather conditions and expected delay on facility		√	√	√	√	√
	Bad weather conditions and increased risk on facility		√	√	√	√	√
Advisory	Expected delay on facility (recurrent)		√	√	√	√	√
	Incident of facility and expected delay (non-recurrent)		√	√	√	√	√
	Bad weather conditions and expected delay on facility		√	√	√	√	√
	Bad weather conditions and increased risk on facility		√	√	√	√	√
	Bad weather conditions - increased risk on facility – speed reduction required						

The experiment

The experiment aimed at identifying the impact on route choice of commuters of a network under the provision of information through ATIS. For this reason, an in-laboratory experiment was conducted using a driving simulator. The network that was used in the simulation procedure was a representation of an actual network in the city of Thessaloniki, Greece, consisting of a freeway, a city network links and the connectors which accommodate connection of these types of facilities. Both the freeway and the city network links have three lanes (3.75 m) per direction. The mean speed on the freeway is 80km/hr and 40km/hr during off-peak and peak hours, respectively, while on the city network 50km/hr and 30km/hr. Both the freeway and the city network may be used for the commuter trips.
Before the beginning of the experiment, a sample of 100 subjects completed a brief questionnaire including a number of background/demographic questions, so as to develop a database with characteristics of their status (age, income, level of education, etc). After the

registration of these attributes, the next step was the subjects to get familiar with the simulator and the procedure that they would follow during the experiment. The researchers presented to the subjects the simulator and the way it works, as well as the "driving" scenarios that would be examined during the experiment procedure.
The driving scenarios that the subjects had to follow during the experiment were conducted during morning and evening peak hours. During the morning peak, the trip direction was from home to work, and during the evening, the return trip. The morning peak-hour was determined at 07:30-08:30 a.m. and the evening at 16:30-17:30 p.m., and relevant traffic volumes were used for the driving simulator, as generated by a traffic simulator, where the network was modelled and run. In both time periods, the subjects were informed before the beginning of their trip, during their trip, or both before and during their trip. The purpose of the development of these two time periods was to test and evaluate the impact of information when different trip purposes apply. It has to be mentioned here that all trips of the subjects originated and terminated at the same nodes. The difference between the two scenarios (morning and evening peak-hours) was that the origin and the destination switch places. Also, the trip destination was predetermined, thus destination change was not feasilbe.
The ATIS scenarios under which each trip was made was selected arbitrarily. Each participant made 32 round trips, thus 64 trips all together. In the beginning of the experiment, each subject had to drive assuming a "NO ATIS" scenario where he/she was getting familiar to the simulator and the network, as well as the traffic and environmental conditions.
The ATIS scenarios tested, were presented in the previous paragraph and in table II. As said before, the main categorization of these scenarios was based on the type of the information provided, thus whether it was qualitative or quantitative (part 1 and part 2 of table II). Apart form the type of the information content, variables like the time of information (pre-trip or en-route or both), the location of information (used facility or both facilities), and the qualitative content of information (informatory or advisory) were taken into account for the development of the ATIS scenarios that were tested during the experiment. Pre-route information, when assumed, was provided before the first node of the trip (the trip origin), whereas en-route information was provided at every node before the final node, which composes the destination of the traveler. The subjects were provided enough distance (and time) to change itinerary at a subsequent node, if they decided to do so. Based on the logical diagram (figure 1), the procedure assumed a starting point on the first day of the experiment, while the data were collected after the completion of each trip. In every subsequent trip, a feedback was given to the traveller, related to the actual time of his/trip trip, as formulated based on his/her choice.
Two types of data are collected; the input data, thus the traffic, environmental and ATIS attributes, as defined by the time of the day and the ATIS scenario, and the output, which are the user decisions depending on the provided information and advice. Actual and average travel time and delays were recorded, The procedure was repeated until all days of runs were completed.

PRELIMINARY RESULTS

Statistical results

Preliminary results consist of a statistical analysis of the results, aiming at identifying the trends of ATIS influence and the travellers' behavioral changes. Significance testing was conducted, for the user categories, trip and route attributes and ATIS characteristics. Here, the behavioral changes as related to the user categories is depicted in table III. The relevant analysis showed that females (all categories) complied to the information provided more than males did. Also, males who are highly educated had significant differences in the NO ATIS and ATIS scenarios, where in the latter case, their choice was affected by the information. Similarly, significant changes were shown in male subjects of high income level who had previous experience of delays on the route (as resulted from the questionnaire). As far as the female subjects, significant changes were observed only in those who had previous experience in route.

Table III– Significance testing in route change

Variable		**p value**	**p value**
		Male	Female
Gender	Male		
	Female	0.044*	
Age	18-25	0.227	0.368
	26-39		
	40-59		
	>60		
Education	High school or less	0.001*	0.371
	Vocational or technical school		
	Undergraduate degree		
	Post-graduate degree		
Income	Low (<15000 €)	0.025*	0.279
	Medium (15000-40000 €)		
	High (>40000 €)		
Previous experience	YES	0.029*	0.041*
Previous experience	NO		
***significant**			

Model categorization

Although, socioeconomic characteristics are taken into account in studies attempting to understand what and how it affects driver behavior (e.g. route choice), it is stated that the significance of these characteristics depends on the experimental design and the selected sample. In experiments, where the sample (and consequently, the population) is considered homogenous, the usage of socioeconomic characteristics is minimized or even eliminated. Especially, in models that attempt to forecast the driver behavior under an ATIS strategy, such parameters would be impossible to estimate during the implementation of the models. Taking these into account, apart from models containing all the parameters listed in table I (full models), alternative formulations are considered, excluding user characteristics (short models). In this case, it is interesting to examine the predictability power of these models versus the one of the full models.

Furthermore, the preliminary results of the present paper indicated a grouping of the travellers, depending on their characteristics. Thus, separate models may be developed for each of the formulated groups, in which case the implementation of all of them will result in the prediction of the impact of ATIS. Three groups, or clusters of travellers were identified, and these indicate the relevant number of models associated with them, specifically:

Cluster model 1 is developed for male travellers with high income, high education level and having previous experience on delays on the route,
Cluster model 2 is developed for female travellers having previous experience on delays on the route,
Cluster model 3 is developed for all other travellers.

Table IV summarises the three clusters of travellers and their attributes

Table IV – Travellers groups of cluster models

Cluster	**Subjects' characteristics**			
	Previous experience	Income	Education level	Gender
C1	Yes	High	High	Male
C2	Yes	All	All	Female
C3	No	All	All	All

The model formulation

In order to examine the driver behavior models, the multinomial logit model testing will be used, according to which, the values of the estimated parameter, the t-value, and p-value, the log-likelihood at zero and the log-likelihood at convergence will be calculated. The model formulation is shown below:

Let j E J denote the alternative choices that the driver may choose from.
Let d E D denote the drivers.
Let k E K denote the parameters which affect the drivers choice.
The general form of the MNL model is then given below:

$$P_i^d = \frac{\exp(U_i^d)}{\sum_j [\exp(U_j^d)]}$$

Where:

P_i^d = The probability of driver d to select alternative i
U_i^d = The utility to driver d of choosing alternative i
U_j^d = The utility of driver d of choosing any alternative j

The utility function is as follows:

$$U_i^d = a_i + \sum_\kappa \gamma_\kappa x_i^{\kappa,d} + \sum_\lambda \delta_\lambda x^{\lambda,d} + \sum_k \beta_k x_i^k + \sum_\pi s_\pi x_i^\pi + e_i^d$$

Where:

U_i^d = The utility to driver d of choosing alternative i
$x_i^{\kappa,d}$ = The value of variable κ for driver d and the alternative i
$x^{\lambda,d}$ = The value of variable λ for driver d
x_i^k = The value of variable k for alternative i
x_i^π = The value of variable π for alternative i
$a_i, \gamma_\kappa, \delta_\lambda, \beta_k, s_\pi$ = Parameters
e_i^d = Error term

The developed models will be compared based on the index ρ^2, which resembles the R^2 of regression models. This index is estimated as follows:

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)}$$

Where:
LL(β) = Log likelihood at convergence with parameter vector β
LL(0) = Log likelihood with all parameters equal to zero

It is obvious that the closer the index is to one, the better the model is predicting the dependent variable. Of course, this by itself may not be used for the selection of a model, since it has to be used in conjunction with the significance testing of the individual parameters of the model. A transformation of the above equation to reflect the impact of the parameters of the model is given in the equation below:

$$corrected\ \rho^2 = 1 - \frac{LL(\beta) - K}{LL(0)}$$

Where K is the number of the parameters used in the model.
Finally, the elasticity of the model is estimated as:

$$E_{x_{ki}}^{P_i} = (1 - P_i)\beta_{ki}x_{ki}$$

Which indicates the effect of the change of the value of variable k for option i in the probability of the selection of the option i.

The parameters used in the models, as previously described are coded as shown in table V.,for modelling purposes.

Table V– Coding of the models' parameters

Parameter	**Code**
Change of route	CR
Gender	GENTER
Age	AGE
Level of education	EDUCATION
Income level per capita	INCOME
Type of user	USER
Previous experience on delay on this route and this direction	EXPERIENCE
Trip purpose	PURPOSE
Traffic conditions	VOLTOCAP
Estimated – perceived proportion of remaining on same route over total trip	REMAIN
Type of facility currently used	FACILITY
Easiness of route change	EASINESS
Feasibility of changing route later	D_NODES
Weather conditions	WEATHER
Light conditions	LIGHT
Time of information provided	INFO_TIME
Facility for which the information is provided	INFO_FAC
Content of information	INFO_CONT
Information feedback	FEEDBACK
Information reliability	INFO_REL

The utility function of the model is simplified, by grouping the above parameters, depending on their nature, as depicted in table VI.

Table VI – Parameter grouping

Variable group	Variable codes
$x_i^{\kappa,d}$	EXPERIENCE
	REMAIN
	FACILITY
	EASINESS
$\mathbf{x}^{\lambda,d}$	GENDER
	AGE
	EDUCATION
	INCOME
	USER
x_i^k	VOLTOCAP
	D_NODES
	WEATHER
	LIGHT
	PURPOSE
x_i^{π}	INFO_TIME
	INFO_FAC
	INFO_CONT
	FEEDBACK
	INFO_REL

NEXT STEPS OF THE RESEARCH

Based on the theoretical framework and the preliminary results of this paper, future work is focused on two main aspects in the domain of examining the impact of ATIS on travellers' choices and behavior: the first aspect includes the development of behavioral models on route choice upon information provision and evaluation of the degree of their accuracy and the second one, focuses on the examination and evaluation of alternative ATIS scenarios for the optimization of traffic under specific network and traffic characteristics, based on the above models.
Apart from the multinomial logit (MNL) modelling, the use of the artificial networks is a new approach in the field of route choice modelling and seems to be a valid alternative of the logit or probit models used in route choice. In the framework of the future work, artificial neural networks (ANN) will be developed, and they will be compared and evaluated against MNL models.

OVERVIEW AND CONCLUSIONS

Advanced Traveler Information Systems (ATIS) is an effective way to inform drivers to make route choices and avoid traffic congestion. The a priori evaluation of the effectiveness of such systems requires the simulation of the drivers' behavior, through the development of prediction models for the individual driver behavior, as well as for the impact of such behavior on traffic. The present research aims at developing a framework which is used to develop drivers' prediction models, modelling mainly the decision of the drivers in route choice. The present paper investigates and analyses the effect ATIS may have on travellers, by evaluating, at the same time, the impact of ATIS in drivers' decisions. Towards this direction,

a platform is developed to collect and process data which lead to the development of driver behavior models. More particularly, the present paper is the first of two papers designated to modelling drivers' behavior and assessing the impacts of alternative information systems. Furthermore, the structure of the models as it is affected by the parameters used, and the population groups, is presented and discussed. Also, following a literature review, the framework of the research is established and the experimentation and some preliminary results are expressed.
These results showed that females (all categories) complied to the information provided more than males do. Also, males who are highly educated had significant differences in the NO ATIS and ATIS scenarios, where in the latter case, their choice was affected by the information. Similarly, significant changes were shown in male subjects of high income level who had previous experience of delays on the route (as resulted from the questionnaire). As far as the female subjects, significant changes were observed only in those who had previous experience in route.
Continuing research of the authors focuses on the development of alternative models and the comparison of their predicting power. These models may include social characteristics, or even be developed for specific clusters, as they seem to better predict driving behavior. However, models not relying at all on social attributes of the drivers are also anticipated to be tested, as they are considered more useful when implemented by a dynamic traffic management system.
The traffic and information conditions (scenario), which are considered in the development of the drivers' behavior models, will be replicated in a microscopic traffic simulation environment. The selected drivers' behavior model will also be embedded in the traffic simulator. Evaluation of the alternative scenarios will be based on the estimated measures of effectiveness, as they result from the runs of the traffic simulation. These results will provide assistance to the decision process of selecting the optimum alternative information strategy.

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