Investigating and modelling the effects of information accuracy on travelers' concordance with ATIS approach

Gennaro Nicola Bifulco
University of Naples "Federico II" (Napoli) Italy

Roberta Di Pace*
University of Salerno, Fisciano (Salerno) Italy

Stefano de Luca
University of Salerno, Fisciano (Salerno) Italy

ABSTRACT

ATIS (*Advanced Traveller Information Systems*) are aimed to provide information on traffic conditions to travellers so that they can keep their travel decisions with less uncertainty. The effects of ATIS can be analysed with respect to two interrelated levels: at a disaggregated/individual level, considering the effect that the information has on travel choices of a given traveller; at a network level, considering that the individual reactions to information interact each the other (and with the congestion phenomenon) leading to actual traffic patterns. The investigation of the effects of information on travellers' behaviours/choices at a disaggregated/individual level is a pre-requisite for any analysis on the impacts of ATIS on traffic networks. It is widely expected that travellers' behaviour can be strongly influenced by the ability of the information system in making accurate estimations of the actual travel times they will experience on the network. The paper is addressed to investigate the effect of the information accuracy (and of its dispersion over time) on travelers' concordance. A Stated Preference experiment has been made; the final objective has been to estimated the models addressed to simulate the respondents reaction to ATIS by considering the effect of information accuracy on travelers' concordance.
The discrete choice models based on random utility theory were developed, switching and holding approaches were investigated, homoscedastic and heteroscedastic models were estimated.

Keywords: *ITS, ATIS, Concordance, Information Accuracy, Homoscedastic Model; Heteroscedastic Model; Stated Preferences, Estimation*

1. INTRODUCTION

Advanced Traveller Information Systems (ATIS) are aimed at dispatching traffic information to travelers in order to assist them in travel choices.
ATIS can supply static information, such a strategy has also been tested and in some cases proofed to be effective by some authors (*Avineri and Prashker, 2006*), but we argue that this can happen only in very particular cases. In particular, we argue that static ATIS information is of little or none interest for the great part of the travellers, except for totally unfamiliar ones. It is generally more useful to provide dynamic information, which varies with traffic conditions of the network. The supplied information is said to be *instantaneous* when referred to instantaneous travel times or *predictive* if referred to actual travel times. *Instantaneous travel times* at a given time are the sum of all link travel-times that compose routes, computed at that instant; *actual travel times* are the ones that the travellers will have experimented at the end of their trip. Instantaneous and actual travel times coincide only when the network is in within-day-static conditions. Also in the simpler case that ATIS supplies information (descriptive or prescriptive) related to instantaneous travel times, some inaccuracies can result. These depend, for instance, on the fact that travel times are inferred from the ones monitored only on a part of the links of the network and, possibly, not directly measured but inferred from other variables (flows, densities, et cetera). When an ATIS tries to supply predictive information, the problem is much more complex, due to the presence of congestion phenomena. In fact, as the number of drivers receiving information (*market penetration rate*) and reacting to it (*compliance rate*, here referred both to the descriptive and prescriptive case, in accordance to *Chen et al., 1999*) increases, it becomes important in generating information to pre-emptively take into account the effects of the designed information on the traffic conditions from which estimation the information itself has been designed (*Bottom et al., 1999*). This is also known as the *anticipatory route guidance problem* (*Bierlaire and Crittin, 2001*), it is hard to be exactly solved for real networks in real (or fast) time and represents a further source of uncertainty. In summary, the dynamic information supplied by ATIS is intrinsically inaccurate and this is even more probable for predictive information. It is also worth noting that static information is likely *inaccurate by definition*, at least in cases of congested networks. It is evident that if the network is such that actual travel times have a very small dispersion and if all travellers are familiar to the network, the uncertainty of the ATIS information does not play a significant role, provided that travellers behave on the base of their own knowledge of the network. If, on the other hand, the uncertainty of the (non-ATIS) owned information is greater, travellers will probably use and react to ATIS information and the compliance increases according to the ATIS accuracy.

The work here presented has been aimed to investigate in an analytical way the previously described accuracy issues and to develop a model able to simulate the effect of ATIS (in)accuracy on travelers' compliance. In order

Corresponding author – Via Ponte Don Melillo, 84084 Fisciano (SA); Italy; Tel: +39 089 963420; Fax: +39 089 964233:, E-mail: rdipace@unisa.it

to be more precise, we will distinguish between the *compliance* and the *concordance*. A compliant-with-ATIS traveler chooses the suggested route; a traveller could be observed to be concordant not only because he/she trusts in the system (is compliant) but also because he/she would have chosen the route in any case, because of his/her own considerations, independently on ATIS indications. Thus, because of the definitions of compliance and concordance, let's observe that compliant-with-ATIS traveller is always concordant-with-ATIS and the set of concordant travellers contains the set of compliant travellers. Furthermore the probability of being concordant is an upper bound for the probability of being compliant.
In conclusion, provided that strictly speaking the models that, we will propose refer to the concordance instead of to the compliance.

Relatively few studies can be found in literature with reference to model travelers' reaction to the information (see *Bonsall and Parry, 1990; Bonsall and Parry, 1991; Chen and Mahmassani, 1993; Bonsall, Firmin et al. 1997; Jha et al., 1998; Srinivasan and Mahmassani, 2000; Ben-Elia et al al, 2008; Chorus et al, 2009; de Moraes et al., 2010*).

In this paper, according to the previously quoted experiences, a stated preference (SP) experiment was built in order to observe and record route choices in presence of descriptive (system conveys information about network conditions) or prescriptive (system conveys a specific recommendation) ATIS. In the SP experiment different levels of ATIS accuracy were introduced in order to evaluate the effects on travelers behavior. Obtained data-set was used to compare two interpretative approaches (*holding* vs *switching*), and to estimate and compare different discrete choice models within random utility paradigm. For each interpretative approach and for each kind of information (descriptive vs prescriptive) Multinomial Logit models and Mixed Multinomial Logit models were estimated and some indicators were used to stand out approaches and models effectiveness.

Paper is organized as follow: in section 2, the stated preference experiment is briefly described; in section 3, the modeling approaches, estimation procedure is discussed; in section 4, conclusions and future work are discussed.

2. THE STATED PREFERENCE EXPERIMENT

The SP experiment has been made by using an internet based tool, the TSL (Travel Simulator Laboratory - *Hoogendoorn, 2004*).

In our experiment, 160 respondents were contacted and invited to connect to the TSL web-site in order to repeatedly perform their route choices in a simulated travelling context. A simple network composed by three alternative routes was submitted to the respondents. Within the network, the presence of a VMS (Variable Message Sign) was simulated in order to allow travelers to receive information at route diversion points, assisting the choice between the alternative routes. 40% of the sample was composed by students (at a Master School level), 30% was composed by faculty members, researchers and freelancers, 30% was composed by employees. Respondents were asked to make their choices repeatedly for 40 consecutive times (simulating, 40 successive days of the same type – e.g.: work-days). Respondents were randomly (uniformly) distributed across *eight* different information scenarios. For all the scenarios actual travel times (the ones that respondents will actually experiment on the simulation) changed across days according to the same random distributions, even the sequence of actual travel time draws across the 40 days is the same for all scenarios. Four of the scenarios were related to descriptive ATIS and four to prescriptive. At the end of each daily travelling simulation respondents were notified about travel times actually occurred (in the simulation context) on the network for all 3 alternatives.

The actual travel times and the error made by information system can be considerate such as *control variables*. Actual travel times instances show that route 1 (mainly) and route 3 are the best (44 min. and 47 min.) performing ones and that route 2 is the worst one (53 min). However, with reference to actual travel times variances routes 1 and 3 are not reliable (15.1min and 11.9min), in the sense that sometimes (for instance 10 times over 40 for route 1) they are much greater than the average and much greater than the one of route 2 of which the variance value is equal to 0.8min.
As regards ATIS accuracy (depends on the system estimation error with respect to actual travel times), this was designed to be increasing from accuracy level 1 to accuracy level 4. For each accuracy level, the ATIS error was considered distributed across days, independently across routes, according to a normal distribution (for the first three accuracy levels) or according to a uniform random distribution (for the last accuracy level). For accuracy levels 1 and 2, the standard deviation of the ATIS error for a generic route (j) is proportional to the coefficient of variation of the actual travel time of such a route ($0.25 * CV_j$ for level 1; $0.70 * CV_j$ for level 2).

In case of uniform random distribution (accuracy level 4), the error is such that the resulting instances of ATIS travel time estimates are between 70% of the minimum actual travel time and 130% of the maximum one, where minimum and maximum are computed over all routes and all days.

In case of prescriptive information, ATIS estimates of travel times were employed to compute ATIS-estimated best route, which was suggested to travelers; thus the ATIS reliability can be computed as the aggregate value over trials of the number of time suggested route is the actual shortest one. In our experiment, reliability performances of scenarios 1, 2, 3 and 4 respectively were 35/40, 28/40, 21/40 and 12/40.

3. MODELS

Six models were specified and estimated in which travelers' concordance is the target variable and ATIS accuracy is one of the independent (explicative) variables. Respondents' behavior was modeled within the theory of discrete choices framework and within the theoretical paradigm of random utility theory.

In particular, choice alternatives were "to be" or "not to be" concordant, different interpretative approaches were tested (*switching* vs. *holding*), different model formulations were compared for each approach (homoschedatic and heteroschedatic).

3.1. Models specification

As stated before, two alternative modeling approaches were tested: the first one refers to a switching formulation while the other refers to an holding one.
The holding approach assumes that the concordance status at day t is directly computed as a function of the model attributes. Each day the traveler can choose if "to be" or "not to be" concordant; this depends on the attributes observed in previous days and/or on characteristics of the dispatched ATIS information at the current day. The formulation of the holding approach is:

$\lambda_t = Prob[C_t =1] = 1 - Prob[C_t =0]= P(C_t) = 1 - P(NC_t)$

where:

- λ_t; is the probability to be concordant at day t.
- Ct; is the concordance status at day t (1 if concordant, 0 otherwise);
- $P(C_t)$ and $P(NC_t)$ are respectively the probability to be concordant and to be not-concordant at day t.

The switching approach assumes that the probability a traveler is concordant [*not concordant*] at a given day t can be computed through the probability he/she is concordant [*not concordant*] at previous day t-1 and he/she remains in his/her concordant [*not concordant*] status or switches to the opposite one.

Following equations formalize the switching approach:

$P(FCTD_t) = 1-P(SC_t)$
$P(FDTC_t) = 1-P(SD_t)$
$P(SW_t) = P(FCTD_t) + P(FDTC_t)$
$1- P(SW_t) = P(SC_t) + P(SD_t)$
$\lambda_t = Prob[C_t =1] = C_{t-1} (1-P(SW_t)) + (1- C_{t-1}) P(SW_t)=$
$= C_{t-1} [P(SC_t) + P(SD_t)] + (1- C_{t-1}) [P(FCTD_t) + P(FDTC_t)]$

where

- $FCTD_t$ [$FDTC_t$]; is the choice to switch to not-concordant [concordant] at day *t* being concordant [not-concordant] at day *t-1*;
- SC_t [SD_t]; is the choice to stay concordant [not-concordant] at day *t* being concordant [not-concordant] at day *t-1*;
- $P(FCTD_t)$, $P(FDTC_t)$, $P(SC_t)$, $P(SD_t)$; are the probabilities to switch to not-concordant, switch to compliant, stay concordant and stay not-concordant at day *t*;
- $P(SW_t)$; is the probability to change the concordance status (from concordant to not concordant or from not-concordant to concordant) from day *t-1* to day *t*.

Different sets of attributes were tested in order to specify the binary switching sub-models and the holding model. In the following the description of the selected ones is enlisted; some of the attributes make sense only in case of descriptive ATIS, while others make sense also in case of prescriptive ATIS.
Attributes that make sense only in the descriptive case are:

- *DescriptiveInaccuracy*, is the sum of the square relative differences between the actual travel times and the ATIS-estimated travel times; it measures how much the supplied ATIS information is inaccurate;
- *ReliabInacc*, is the mean on previous two days of the Descriptive Inaccuracy, considered only if the informative system has been reliable in previous two days; it measures the fact that even reliable information can be accurate at different levels;
- *ProspectedGain*, is the relative difference between the shortest ATIS-estimated travel time and the second-best one; it measures the gain in terms of travel time prospected by the ATIS in following its information;
- *HighUnconcRisk*, is the ProspectedGain over the frequency in last 5 days the suggested route has been the best; it measures the fact that the systems induce a choice which has been viewed by the travellers to likely have been the best one;
- *TooOptimisticInfo*, is the relative difference between the ATIS-estimated travel time of the shortest route and the average of the actual travel times of all suggested routes in previous 5 days, computed only if the average of the actual travel times is greater than the actual travel time of the route suggested today and if the suggested route is chosen at the previous day, otherwise the value is 0; it measures the fact that the estimated travel time of the suggested route is too much optimistic with respect to the experience of the traveler;

Attributes that make sense also in the prescriptive case are:

- *Reliability*, the computed value is 1 if the suggested route actually is the best route with respect to the actual travel times; 0 otherwise; it measures if the information has been accurate enough to suggest the actually best route;
- *PrescriptiveInaccuracy*, is the relative difference between the actual travel times of the

suggested route and the one of the route (shortest) that have had chosen by the respondent if he/she have had knowledge of the actual travel times; it measures how relevant have had (or has) been the error (if any) in choosing the route suggested by the ATIS;

- *PrescrInacc_In5*, is the average PrescriptiveInaccuracy computed over previous 5 days;
- *Discrepancy*, for each it is computed as the relative difference between the actual travel time of yesterday and the average of the actual travel times of the previous 3 days; it is the measure of a sort of on-average-perceived ATIS inaccuracy;
- *SuggRouteDiscrep*, is the Discrepancy of the suggested route over the sum of the discrepancies of all route;
- *SuggRouteIncr*, is the square of the relative difference between the yesterday actual travel time of the suggested route, and the average of the actual travel times of all suggested routes in previous 5 days;
- *NearInacc*, is the yesterday PrescriptiveInaccuracy, computed only if the system has been unreliable in the day before yesterday, otherwise the associated value is zero; it measures that two consecutive negative performances effect the traveler and, more precisely, an unreliability occurrence alerts the traveler who is induced the day after to carefully look at inaccuracies;
- *Is2AndReliab*, its value is 1 if the suggested route is the most reliable route (route 2 on the base of our actual travel time) and the system has been reliable in all the previous 4 days; it accounts for the joint occurrence that the more reliable route is suggested and the ATIS accuracy level is high (so that the more reliable route, if suggested, also is likely to be the best one);
- *RecovReliab*, its value is 1 if the informative system has been unreliable two days before yesterday but then has recovered its reliability for the two successive days, 0 otherwise;
- *AtLeastOneUnrel*, its value is 1 if the informative system has been unreliable one or more times in the previous 3 days, zero otherwise;
- *Consec*, is the number of times in previous 5 days in which traveller chooses the same route if this route is the one suggested today by the system, zero otherwise; it measures the fact that the suggestion fits traveller's consolidated preference;
- *FreqChosen*, is the frequency the suggested route at current day has been chosen in previous 5 days; note that this attribute differs from the previous Consec attribute both because it is computed also if the route suggested today has not been chosen in the previous days and because it accounts also for not necessarily consecutive identical route choices;
- *FreqConc*, is the frequency with which the traveler has been concordant in the previous 5 days; it measures a sort of habit/inertia;
- *NotPreferredSugg*, if the suggested route is not the one chosen yesterday, it is the frequency over previous 5 days the suggested route has not been the actually best one; it measures the average poor performances experienced for the suggested routes if different from the route the traveler has chosen yesterday (likely, it is not the suggestion the traveler would have preferred).

3.2. Models estimation and validation

The estimation was performed for both modeling approaches, *switching* and *holding*, and separately for the two ATIS-information type, *descriptive* and *prescriptive*. MNL, MMNL-EC (*error component*) and MMNL-RC (*random coefficients*) models were estimated. Each choice model was estimated on different panel periods: [from day 16 to day 40]; [from 21 to 40]; [from 31 to 40]; [from 36 to 40]. Finally, MMNL models estimation was carried out by means of the BIOGEME software (Bierlaire, 2007) using log-likelihood procedure. In particular simulated log likelihood has been applied using random draws. In particular, the Halton sequences have been applied and different numbers of draws were experimented in order to address the identification problem (500, 1000 2000 and 4000 draws); 1000 draws iterations resulted to be sufficient.
Although all models formulation turned out statistically significant, validation results (not reported for brevity's sake) pointed out that MMNL models outperformed MNL formulation, and MMNL-EC formulation outperformed MMNL-RC.

Results shown that: the *pseudo ro-square* values are acceptable, all systematic utility coefficients are statistically significant, the panel-data parameter (the variance of the error-component count-part) used to simulate the correlations generated by the panel data structure of the experimental context, is significant in all cases.

With reference to descriptive information the main attributes that induce a not-concordant choice relate, as expected, to the experienced (in)accuracy in past days (*ReliabInacc* and *NearInacc*), to the suspect the respondents has that the current ATIS information is erroneous (*TooOptimisticInfo*, *SuggRouteDiscrep*, *SuggRouteIncrement*) and to how much could be risky to follow (or not to follow) the supplied information (*NotPreferredSugg*). In case of choice related to not-concordance, attributes *RecovReliab* and *Is2AndReliab* refer to the inaccuracy in past days, attributes *FreqChosen* and *Consec* refer to the suspect toward the current ATIS information (or, in this case, to the confidence toward the information) and attribute *HighUnconcRisk* refers to the risk for not following the supplied information; moreover the attribute *FreqConcordant* can be interpreted a sort of inertia (or habit) in being concordant.

With reference to prescriptive information the parameters that are relevant for the not-concordant choice of the holding approach play a consistent role in the switching sub-models. Parameters *PrescrInacc_In5* and *AtLeastOneUnrel* relate to inaccuracy; parameters *NotPreferredSugg*, *SuggRouteIncr*, *FreqChosen* and *Consec* relate to the suspect toward the current suggestion (or to the confidence toward it); also in this case, the habit/inertia toward the concordance status is taken into account by the parameter *FreqConcordant*.

4. Conclusions and future work

This work shows that information accuracy sensibly affect travellers' choices and their concordance. The proposed modelling framework has been specified and calibrated against a SP survey and all the findings, deeply discussed in the paper, show that it is consistent and robust.
Modeling the travellers' concordance in an *elastic* way is not a trivial task; here we have presented some attempts that have lead to satisfactory results. Still several open issues remain among others.

In future work researchers would like consolidate the obtained results by making an accurate validation of estimated models. In particular models goodness-of-fit will be validated through consolidated static tests and through specific indicators, furthermore the validation protocol proposed by de Luca and Cantarella (2009) will be applied.

As in following described, further analyses and refinements seem worth of interest:

- Integrate the concordance model in a more general framework in order to observe the network effects by assignment model;.
- Investigate alternative approaches, such as models based on the fuzzy utility or fuzzy logic;
- Understand and model the phenomena related to the *learning-phase* of the travelers' behavior.

Acknowledgments

The authors are grateful to Prof. H. Van Zuylen, Prof. S. Hoogendoorn, Dr. F. Viti and Dr. E. Bogers by the Technische Universiteit of Delft; they made available the web-based SP survey tools (TSL), helped in understanding its use for the specific needs of our analyses and supported the experimental phase of the study with their experiences.

References

Avineri, E., Prashker, J.N. (2006) The impact of Travel Time Information on Traveler's Learning under uncertainty. *Transportation 33(4)*, pp. 393 - 408

Ben- Elia, E., Erev, I. and Shiftan, Y. (2008) The combined effect of information and experience on drivers' route- choice behavior *Transportation* 35: pp. 165- 177

Bierlaire, M., Crittin, F., (2001) New algorithmic approaches for the anticipatory route guidance generation problem. *In: 1st Swiss Transportation Research Conference*

Bierlaire (2007) M. Bierlaire's Optimization Toolbox for GEV Model Estimation- Biogeme; http://transp-or.epfl.ch/page63023.html

Bonsall, P.W. (1997) Motivating the respondent- how far should you go? *Paper presented at the Conference of the International Association for Travel Behaviour Research.* Austin. Texas. Sept. 1997

Bonsall,P., Firmin, P., Anderson, M., Palmer, I., Balmforth, P. (1997) Validating the results of a route choice simulator *Transportation Research Part* C vol.5 Issue 6 pp. 371-387

Bottom, J., Ben-Akiva, M., Bierlaire, M., Chabini, I., Koutsopoulos, H.N, (1999) Investigation of Route Guidance Generation Issues by Simulation with DynaMIT. *In: 14th International Symposium on Transportation and Traffic Theory,* Jerusalem

Chen, PS.-T.; Srinivasan, K.K; Mahmassani, H.S. (1999) Effect of information quality on compliance behavior of commuters under Real-Time Traffic Information. *Transportation Research Record 1676*, 53-60

Chorus, C., G., Arentze, T. A., Timmermans, H.J.P. (2009) Traveler compliance with advice: A Bayesian utilitarian perspective, *Transportation Research E,* pp. 45, 486-500

de Luca S., Cantarella G. E. (2009) Validation and comparison of choice models. *In Success and Failure of Travel Demand Management Measures, W. Saleh ed. Ashgate publications. Forthcoming*

de Moraes Ramos, G. Daamen, W. and Hoogendoorn, S. (2010) Towards better a understanding of the reference point in a travel behavior context *11th TRAIL Congress November 2010*

Hoogendoorn, S.P. (2004) Travel Simulator Laboratory, TSL Website: http://www.tsl.tudelft.nl

Jha, M., Madanat, S., Peeta, S. (1998) Perception updating and day-to-day travel choice dynamics in traffic networks with information provision. Transportation Research Part C (6) pp. 189-212