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Modelling risk perception in ATIS context: a comparison of different Fuzzy Logic-based approaches

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Abstract

In this paper travellers' reactions to Advanced Traveller Information Systems (ATIS) are analysed. In particular two kinds of information (descriptive and prescriptive) and four levels of reliability have been tested. A web-based tool has been adopted in order to carry out a stated preference experiment for data collection. The presented research continues previous studies of the authors in the field of travellers' compliance with information and travellers' route choices under ATIS. In previous studies both a discrete choice theory approach and a Mamdani-type Fuzzy Inference System (FIS) were tested. Here several FIS approaches are analysed more in detail. Some preliminary analyses, are recalled from previous research work, furthermore collected data have been deeply analysed through the Sugeno FIS-type approach and by Adaptive-Network-Based FIS. The methods are applied to reproduce travellers' behaviour and are compared with each other to find the best approach.

Keywords: Travellers' behaviour; Travel simulator; Stated Preference; ITS; ATIS; Compliance; Information reliability; Uncertainty; Risk perception; Fuzzy Inference System.

Introduction

Advanced Traveller Information Systems (ATIS) are introduced in order to assist travellers in route choices. In order to be effective, dynamic information need to be provided to travellers instead of static information (see Avineri and Prashker, 2006). Furthermore different dynamic information can be introduced: *instantaneous information* refers to instantaneous travel times at a given time instant, while *predictive information* refers to travel time forecasts and, generally, to actual travel-time (the one the travellers actually experiment when travelling from the origin to

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destination). The information can also be *predictive and consistent (reliable information)* when also the travellers reactions to the information are accounted in forecasting network performances. Predictive and consistent information should ensure the travel times that travellers will actually experience are consistent with the suggestions (estimated travel times or predicted faster route) with which they are provided. In literature this last problem is also called the *anticipatory route guidance problem* (ARG problem, see Bierlaire and Crittin, 2001).

Of course, the solution of the ARG problem can be attained only if it is available a suitable model for travellers' behaviour in presence of information. One of the main topic when travellers' reactions to information is modelled is to deal with the *compliance* (trusting in ATIS advice and behaving according to that).

Compliance, in turn, is demonstrate to be affected by the reliability of information system (see Srinivasan and Mahmassani, 2002; Bifulco et al., 2011). Moreover, if travellers experience on the network significant randomness of route travel times, their choices are made in a context of significantly uncertainty, where any information coming from the ATIS is potentially helpful. Of course, if the information is reliable the uncertainty of travellers' choices decreases and the travellers' compliance increases, while if the information is not reliable it increases the uncertainty of the choice context. This pattern is exacerbated in case where the travel-times unreliability is high. Further than on compliance with information the effect can be observed also in terms of route choice behaviour. What is expected (and observed by some analysts, see for instance Ben-Elia and Shiftan, 2010) is that as the uncertainty of the system (because of travel-times or ATIS unreliability) increases, the behaviour of the travellers tends to be more risk-adverse. They tend to choose the most reliable route and not the faster one. In these cases, choices made by travellers become harder to be evaluated on the base of human reasoning and other alternative approaches can be adopted in order to model their behaviours.

In this paper the fuzzy approaches (see Teodorovic, 1999) have been applied. The same topic has been addressed by the authors in other previous studies, mainly by means of the random utility approach (e.g. Ben-Elia et al, 2010; Di Pace, 2008) or by Fuzzy approaches (Di Pace et al., 2011; Dell'Orco and Teodorovic, 2009; Dell'Orco and Marinelli, 2009). With reference to the fuzzy approach, this paper can be considered such as the development of previous ones in terms of more detailed analyses of *Fuzzy Inference Systems*. In fact we have considered two different fuzzy inference systems: one, based on the Mamdani's model and another one based on the *Sugeno's model*. Moreover, the model is also implemented in an *Adaptive-Network-Based FIS (ANFIS)* version, in order to evaluate the suitability of neural networks in enhancing the reproduction of travellers' behaviour.

The paper is structured as follows. In section 2, a literature review is briefly described. In section 3, the experiment, carried out to collect data by using a Travel Simulator (Hoogendoorn, 2004) has been described and some aggregate analyses are recalled from a previous paper (Di Pace et al., 2011). In section 4, our models based on fuzzy logic approaches are described. In section 5, the results from the application of the models are presented and discussed. In section 6, general conclusions and future perspectives are briefly introduced.

1. Literature review

As described in a previous paper (Di Pace et al., 2011), several studies have been carry out in order to analyse travelers' behaviour in a context of choice in which they are provided with information. The travellers' choices are modelled such as the combinations of experiences made during previous choices and reactions to the information. Several not rational behaviours have been observed with reference to the level of perceived uncertainty of the context of choice. Indeed, in cases of context of choice without information the reliability of the actual travel times can induce different levels of risk perceptions. If the information system is also considerate, travellers choices will account the effect of information reliability (Dell'Orco and Teodorovic, 2009; Dell'Orco and Kikuchi, 2009; Bifulco et al., 200b; Di Pace and Bifulco, 2010; Shen, 1999). In several cases the effect of the unreliability of the information has been studied with reference to the discrete choice theory (Ben-Elia and Shiftan, 2010; Ben-Elia et al., 2008) and the most popular approaches are based on utility maximisation (e.g. Ben-Akiva and Lerman, 1986; McFadden, 1981).

Nevertheless, alternative approaches have been proposed in order to analyse different attitudes of decision makers. These have been explained by focusing on the inadequacy of the utility maximisation paradigm

(Kahnemann and Tversky, 1979; Avineri and Prashker, 2005; Katsikopoulos et al., 2002).

Furthermore, on the base of other approaches like *Fuzzy Logic* (Zadeh, 1965) *Fuzzy Inference* (Mamdani and Assilian, 1975; Takagi and Sugeno, 1975), *Artificial Neural Network* (Cantarella and de Luca, 2005; Dia and Panwai, 2010; Panwai and Dia, 2006), *Possibility Theory* different choice models have been introduced (Kikuchi and Chakroborty, 2006; Murat and Uludag, 2008), *Fuzzy Data Fusion* (Dell'Orco and Marinelli; 2009).

2. The experiment

Several tools have been proposed in the past in order to collect data about travellers' behaviour. Those much fitting our needs are based on a travel simulation (TS) approach, aimed at a Stated Preference survey. Different TSs have been developed (among them Hoogendoorn, 2004; Adler, et al, 2009; Abdel-Aty, 2002) and the authors have developed in last years their own (SP Platform, Bifulco et al., 2009a). The survey used in this paper is the same employed in a previous paper (Di Pace et al., 2011). The experiment and the sample composition are briefly recalled in the following.

The experiment have dealt with different reliability of information and different information types (prescriptive or descriptive). The information is prescriptive if a route is suggested by the ATIS; it is said to be descriptive in the travel-times of alternative routes are supplied by the ATIS to the travellers. The reliability of the information is intended as the closeness of the ATIS advices to the actual network performances (supplied travel-times well approximate actual ones or the suggested route actually is the faster one). With reference to the reliability of the information 4 levels have been considerate: High, Low and two Intermediate levels. Considering two different kinds of information, eight different scenarios result.

The SP-platform is a web-based tool, connecting to the experiment website, respondents are requested to choose among three alternative routes. Choices made by respondents are independent. Each respondent is asked to try the experiment for 40 consecutive trials. A panel-data approach is actually configured. At each trial random drawn (from known distributions) of actual travel times and estimated travel times are proposed. Drawn are such that all sequences are the same with reference to actual travel times and estimated travel times for all respondents of the same scenario.

At each trial, the respondent is asked to choose his/her departure time in order to arrive on time at destination for a scheduled job meeting (Bonsall, 1997). During the experiment the respondents are provided with information by a simulated Variable Message Sign. At the end of the experiment respondents are provided with a feedback on actual travel-times (see Chen et al, 1998).

Involved respondents were 160; 40% of the sample was composed by students (at a Master School level), 30% was faculty members, researchers and freelancers, 30% was employees.

For all scenarios, the (simulated) actual travel times were constant on average over the 40 trials. In particular the actual travel time of route 1 is around 36 minutes in about 40% of the 40 instances and is around 40 minutes about 30% of the times. It results that the great part of the times route 1 is the faster one; however, actual travel time of route 1 is around 72 minutes (that is dramatically high) about 25% of the times. Most of the times the travel time of route 2 is around 54 minutes and sometimes is around 58 minutes; route 2 can be also considerate the most travel-time reliable route. Actual travel time of route 3 falls in the whole range between 30 to 72 minutes; only in very few cases route 3 is better than both route 1 and route 2. In terms of reliability of information, in the highly reliable scenario the information is reliable in 37 trials over 40. At the first intermediate level the information reliability is 28/40, at the second intermediate level 24/40 and finally at the low level 13/40.

The results shown in Table 1 below are the ones already published in Di Pace et al. (2011). These results are here reported for readers' convenience in order to allow for comparison with data obtained by applying the fuzzy logic approaches here presented.

Table 1: Compliance and route shares for different information reliabilities

Information Type	Reliability	Compliance %	share of choices		
			Route 1 %	Route2 %	Route 3 %
Descriptive	High	69.0	49.2	25.0	25.8
	Inter. 1	60.8	44.3	29.6	26.1
	Inter. 2	53.4	39.8	30.2	30.0
	Low	47.9	38.9	39.1	22.0
Prescriptive	High	68.0	50.8	24.1	25.1
	Inter. 1	66.2	42.9	25.5	31.6
	Inter. 2	57.3	41.4	28.9	29.7
	Low	42.3	28.7	54.2	17.1

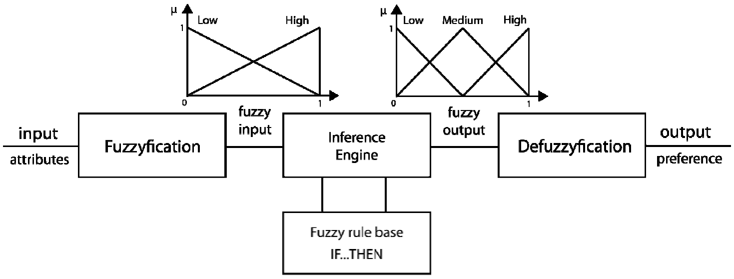

Figure 1: The Fuzzy Inference System Model

In Table 1, with reference to each scenario, the aggregate values of the compliance and of the route share are shown. For detailed discussion of the table refer to Di Pace et al. (2011). Here it should be noted that the compliance decreases according with the reliability of the information, and that the share of route 2 (the most time-reliable) increases in case of increased information unreliability (a risk-adverse behaviour is promoted by the information unreliability).

3. The Fuzzy Inference System modelling approach

In this section, we will show three different Fuzzy Logic approaches to model travellers' behaviour: a Mamdani-type (Zadeh, 1965), a Sugeno-type (Takagi and Sugeno 1985) and an ANFIS (Jang, 1993). We have discussed about Mamdani approach in Di Pace et al. (2011). In next sections, we will describe relationships found between provided information and route actual travel times on one hand, and travellers' preferences/ behaviours on the other hand. Fuzzy Logic allows us modelling through linguistic variables and rules the uncertain way of reasoning embedded in human mind.

3.1. The Fuzzy Inference System

The approach used here is aimed to model these features with a single Fuzzy Inference System, which takes into account the uncertainty related to the unreliability of the provided information and the drivers' behaviour, in order to compute route preference (Figure 1).

By the elaboration of estimated and actual travel times, we can obtain some useful parameters that could influence travellers' choice. Assuming the perfect rationality of travellers, they will choose the fastest or the most time-reliable route on the basis of a comparison between information, provided in terms of suggested faster route or estimated travel-times, and their own experience. Additionally, we assume that: *i)* travellers rely on information as much as information itself is reliable (in the meaning defined in previous sections); *ii)* travellers are able to (roughly) evaluate the degree of unreliability of the information system. Thus, ATIS unreliability is an input variable that influences travellers' choices.

Input attributes, considered in both cases of descriptive and prescriptive information, are routes performances, in terms of actual travel times, as well as variances and errors generated by the information system. All these attributes are normalized in order to scale the values in the range [0, 1]. In our repeated choice experimental context, the normalization is obtained with reference to the values relevant to a specific interval of previous trials.

In particular, input attributes considered for a given route (*r*) in case of *descriptive information* are:

- the experienced estimated-travel-time error ($\mathbf{TTE}_r$); difference between actual travel time and estimated travel time, normalized with reference to the previous four trials (this attribute will be considerate only in case of descriptive information);
- the estimated travel time ($\mathbf{TT}_r$), normalized with reference to the previous four trials;
- the estimated travel time with respect to other routes ($\mathbf{TTC}_r$); it is normalized with reference to estimated travel times of current trial on all alternative routes;
- the experienced descriptive unreliability of the current scenario (**DIS**), calculated by applying the Eulerian distance among the vector of all-routes actual travel times and the vector of all-routes estimated travel times;
- the experienced variance of the route actual travel time ($\mathbf{TTV}_r$), normalized with reference to previous six trials.

Two triangular membership functions, which represent "Low" and "High" values of the attributes, are associated to each input attribute. The output variable is the traveller's route preference ($\mathbf{RP}_r$), which has three triangular membership functions ("Low", "Medium", "High") associated. The "Medium" membership function (MF) has been added to model travellers' intermediate preferences. Route preference is computed through a set of IF-THEN fuzzy rules, defined considering the overall travellers' behaviour resulting from collected data. The set of fuzzy rules is made of 33 rules, such as the ones below.

a. *IF* $\mathbf{TT}_r$ is Low and $\mathbf{TTC}_r$ is Low and $\mathbf{TTE}_r$ is Low and **DIS** is Low and $\mathbf{TTV}_r$ is High *THEN* $\mathbf{RP}_r$ is High;
b. *IF* $\mathbf{TT}_r$ is Low and $\mathbf{TTC}_r$ is Low and $\mathbf{TTE}_r$ is Low and **DIS** is High and $\mathbf{TTV}_r$ is High *THEN* $\mathbf{RP}_r$ is Medium;
c. *IF* $\mathbf{TT}_r$ is High and $\mathbf{TTC}_r$ is High and $\mathbf{TTE}_r$ is High and **DIS** is Low and $\mathbf{TTV}_r$ is Low *THEN* $\mathbf{RP}_r$ is Low;
d. *IF* $\mathbf{TT}_r$ is High and $\mathbf{TTC}_r$ is High and $\mathbf{TTE}_r$ is High and **DIS** is High and $\mathbf{TTV}_r$ is Low *THEN* $\mathbf{RP}_r$ is High.

In the previous example, the first two rules (a and b) represent that the faster (but time-unreliable) route has good chances to be chosen in case of high information reliability, while it has much less chances in case of low information reliability. At the opposite (rules c and d), the most time-reliable route has low chances to be chosen in case of reliable information and high chances in case of low information reliability. Of course more rules are required (in our case up to 33) to fully identify the set of the fuzzy rules.

In case of *prescriptive information* for each route five attributes have been considered, as described in the following. All attributes are normalized as in the descriptive case.

Considered attributes are:

- the experienced estimated–travel-time error ($\mathbf{TTE_r}$); difference between actual travel times and estimated travel times with reference to the previous four days;
- the frequency "is first" ($\mathbf{IS1_r}$); frequency with which each route has resulted the faster over last three days;
- the experienced reliability of information ($\mathbf{REL_r}$); it is 0 or 1 depending on the experienced reliability of the received suggestion; its value is the average reliability over last six days;
- the experienced unreliability of the current scenario (**PIS**); difference between actual travel times of the suggested route and travel time of the actual shortest route; it measures how relevant has been a possible error in choosing the route suggested by the ATIS;
- the experienced variance of actual travel times of a route ($\mathbf{TTV_r}$); value of variance of actual travel times of a route, with reference to previous six days.

As in case of descriptive information, two triangular membership functions are associated to each input attribute. The output variable is the traveller's route preference ($\mathbf{RP_r}$), which is computed through a set of IF-THEN fuzzy rules, defined considering the overall travellers' behaviour resulting from collected data. This set is made of 33 fuzzy rules such as these following three:

- *IF* $\mathbf{TTE_r}$ is High and $\mathbf{IS1_r}$ is Low and $\mathbf{REL_r}$ is Low and **PIS** is High and $\mathbf{TTV_r}$ is High *THEN* $\mathbf{RP_r}$ is Low;
- *IF* $\mathbf{TTE_r}$ is Low and $\mathbf{IS1_r}$ is High and $\mathbf{REL_r}$ is High and **PIS** is Low and $\mathbf{TTV_r}$ is Low *THEN* $\mathbf{RP_r}$ is High;
- *IF* $\mathbf{REL_r}$ is Low and $\mathbf{TTV_r}$ is Low *THEN* $\mathbf{RP_r}$ is High.

The first rule represents the worst case, in which travellers have inaccurate information and, at the same time, the slowest and unreliable route. The second rule represents the best case, with accurate information, and the fastest and reliable route. The third rule, like in the descriptive case above, includes cases in which travellers have an unreliable information system but a reliable route.

3.2. The Sugeno-type FIS approach

In order to compare different FIS approaches with respect to Di Pace et al. (2011), we have modelled travellers' choice behaviour also through a Sugeno-type Fuzzy Inference System (see *Figure 2*). This system differs from the Mamdani's one in the output type, which is crisp, and in the defuzzification method that has been set to *weighted average*. This FIS has been defined using the set of rules of the previous section and setting output (route preference) values as follows: 1 = *High*, 0.5 = *Medium*, 0 = *Low*.

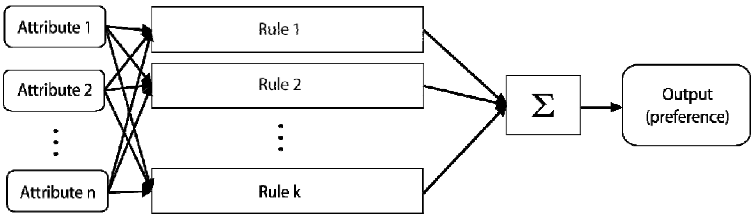

Figure 2: Structure of the Sugeno-type FIS model

3.3. The Adaptive-Network-Based Fuzzy Inference System (ANFIS) approach

In the previous models, shape and attributes of the Membership Functions have been set up by analysts, but it is possible to optimize their values through an Adaptive Neural Network. This technique provides a procedure to learn information from a data set, in order to compute the Membership Function parameters that allow the best fitting of the given data set by a Fuzzy Inference System. The basic idea is that, using Neural Networks, there is no need to assume explicit functions for the considered parameters, since Neural Networks learn directly from measured data.

In our ANFIS-based model, the output represents travellers' route preference. Input attributes are the same of previous FIS approaches, in order to make a comparison among them.

The number of membership functions (MFs) of each input has been set according to data variability: the higher the variability, the larger the number of MFs. The number of MFs was also determined to find a balance between computational complexity of training algorithm and training error.

ANFIS uses a multi-layer feed forward adaptive network. The learning procedure is based on the hybrid method proposed by Jang (1993). An acquired data record of specific trial and route has been used as training data sample, giving the route choice (0,1) as output target. The number of training epochs has been set to 10, which represents the lower limit of the training error value. At the end of the training step, RMSE reaches about 0.4. This is due to the fact that the output target is boolean in nature, and in this case adaptive network cannot find easily the optimal FIS parameters' set.

Table 2: (Descriptive Information) Fuzzy inference systems and compliance (FIS-Mamdani and Sugeno; ANFIS-Sugeno)

Type of Information	FIS	Information Reliability	Route 1 %	Route 2 %	Route 3 %	Compl%
DESCRIPTIVE	Mamdani*	High	56.7	20.0	23.3	80.0
		Inter. 1	53.3	23.3	23.3	76.7
		Inter. 2	50.0	16.7	33.3	76.7
		Low	23.3	60.0	16.7	56.7
		All scenarios	*46.4*	*29.3*	*24.4*	*72.9*
	Sugeno	High	53.3	20.0	26.7	83.3
		Inter. 1	40.0	23.3	36.7	76.7
		Inter. 2	46.7	16.7	36.6	86.7
		Low	16.7	73.3	10.0	43.3
		All scenarios	*39.9*	*32.4*	*27.7*	*73.3*
	ANFIS	High	53.3	16.7	0.3	93.3
		Inter. 1	54.4	18.9	26.7	59.6
		Inter. 2	54.5	18.3	27.2	58.0
		Low	54.0	19.8	26.2	33.7
		All scenarios	54.0	18.4	27.6	62.3
		Observed**	43.1	39.2	26.0	57.8

**In order to facilitate all comparisons results also from published paper (Di Pace et al., 2011) are here reported.*
***The "Observed" values are obtained from Table 1, as average over scenarios for each kind of information.*

Table 3: (Prescriptive Information) Fuzzy inference systems and compliance (FIS-Mamdani and Sugeno; ANFIS-Sugeno)

Type of Information	FIS	Information Reliability	Route 1 %	Route 2 %	Route 3 %	Compl%
PRESCRIPTIVE	Mamdani*	High	73.3	3.3	23.3	63.3
		Inter. 1	80.0	3.3	16.7	56.7
		Inter. 2	63.3	20.0	16.7	50.0
		Low	6.7	86.6	6.7	26.7
		All scenarios	55.8	28.3	15.8	49.2
	Sugeno	High	73.3	3.3	23.4	56.7
		Inter. 1	50.0	16.7	33.3	46.7
		Inter. 2	26.6	36.7	36.7	46.7
		Low	3.3	90.0	6.7	33.3
		All scenarios	38.3	36.7	25.0	45.8
	ANFIS	High	76.7	0.0	23.3	63.3
		Inter. 1	64.8	19.7	15.5	42.9
		Inter. 2	48.6	37.7	13.7	32.3
		Low	59.5	28.4	12.1	31.7
		All scenarios	64.4	18.5	17.1	45.2
		Observed**	40.9	33.2	25.9	58.5

**In order to facilitate all comparisons results also from published paper (Di Pace et al., 2011) are here reported.*
***The "Observed" values are obtained from Table 1, as average over scenarios for each kind of information.*

4. Results

The modelling approaches proposed in the previous section have been applied and resulting route shares and compliance have been computed (see Table 2 and Table 3). The obtained results can be compared with the choices observed in the experiment (Table 1). Results of this comparison are reported in Table 4 and Table 5, in terms of percent-right (Mamdami and Sugeno FIS, and ANFIS). FIS seems to overestimate the compliance in case of descriptive information, especially at levels with higher information reliability. Instead, in case of prescriptive information, it seems to underestimate the compliance.

In terms of route share, by comparing Table 1 with Table 4 and Table 5, we observe that better results are obtained in scenarios with high information reliability. Results show that Mamdani-type FIS is prevailing with respect to other FIS approaches. We can observe that all used FISs reproduce better travellers' choices for scenario 1 than other scenarios, whose percent-right decreases as reliability increases. The overall percent-right is decreasing according to FIS considered: from Mamdani to ANFIS the percent-right passes from 55.4 to 48.9 in descriptive scenarios, and from 46.1 to 40.5 in prescriptive scenarios. In case of descriptive information, percent-right shows that compliance is reproduced better than not-compliance. In prescriptive information scenario, both compliance and not-compliance are reproduced in a satisfactory way. Results can be considered acceptable with reference to the column "Overall", in which percent-right values are obtained combining results of compliant – compliant (C-C%) and not compliant –not compliant (NC-NC %) for each scenario/ all scenarios. In accordance with Avineri and Prashker (2005), results highlight that uncertainty embedded in human reasoning, especially when affected by inaccurate information, leads travellers to highly dispersed choices, where a rational behaviour is not easy to be identified. We can also observe that, for each scenario, the fuzzy model shows almost the same trend of travellers' route choice percentage.

Table 4: (Descriptive Information)%-right for route choices and compliance (Observed choices vs. predictions by FIS-Mamdani/FIS-Sugeno/ ANFIS)

Type of Information	FIS	Compliance	% right	C-C %	NC-NC %	Overall
DESCRIPTIVE	Mamdani*	High	65.2	84.9	30.8	67.9
		Inter. 1	59.3	83.2	33.5	63.7
		Inter. 2	51.0	82.8	30.3	58.3
		Low	45.0	61.8	48.1	54.6
		All scenarios	55.4	79.5	36.2	61.3
	Sugeno	High	65.4	87.3	25.3	67.8
		Inter. 1	54.4	79.0	26.9	58.5
		Inter. 2	51.5	90.0	17.1	56.0
		Low	40.2	45.6	58.7	52.4
		All scenarios	53.3	77.8	33.0	59.0
	ANFIS	High	65.6	98.6	16.2	69.2
		Inter. 1	49.3	70.9	52.2	61.8
		Inter. 2	45.8	63.4	48.2	56.3
		Low	32.6	33.3	66.0	50.1
		All scenarios	48.9	70.4	47.3	59.8

**In order to facilitate all comparisons results also from published paper (Di Pace et al., 2011) are here reported*

Table 5: (Prescriptive Information) %-right for route choices and compliance (Observed choices vs. predictions by FIS-Mamdani/ FIS-Sugeno/ ANFIS)

Type of Information	FIS	Compliance	% right	C-C %	NC-NC %	Overall
PRESCRIPTIVE	Mamdani*	High	50.5	85.0	58.7	71.9
		Inter. 1	41.1	79.2	59.0	67.3
		Inter. 2	42.0	72.9	66.6	69.2
		Low	48.4	33.0	79.2	56.8
		All scenarios	46.1	67.5	68.9	66.9
	Sugeno	High	46.6	59.0	47.6	55.0
		Inter. 1	35.6	45.9	52.3	48.6
		Inter. 2	40.8	48.6	56.0	51.8
		Low	49.3	42.9	73.6	60.7
		All scenarios	43.3	51.0	58.0	54.0
	ANFIS	High	51.1	66.7	42.7	58.2
		Inter. 1	33.9	41.5	55.3	47.3
		Inter. 2	36.9	35.9	72.5	51.6
		Low	34.7	33.8	69.7	54.6
		All scenarios	40.5	48.8	59.4	53.4

**In order to facilitate all comparisons results also from published paper (Di Pace et al., 2011) are here reported*

5. Conclusions and future work

According with the scientific literature, reliable information can have significant effects on travellers' behaviours in terms of compliance with information and route choices. In this work, the effect of two kinds of information, descriptive and prescriptive, with four levels of information reliability has been studied. With reference to previous paper Di Pace et al. (2011), results show a significant effect of information reliability on travellers' compliance and on route shares. Reliability seems to affect route preferences if the context of choice is perceived as uncertain. In fact, in high information reliability scenarios, compliance is high and travellers prefer the fastest route, which is also the most suggested one

Instead, at the lowest reliability level, respondents perceive the context of choice as uncertain and, for this reason, they prefer the most time-reliable route. At intermediate information reliability levels, travellers' behaviour is rather confused: compliance decreases as information reliability decreases, even if observed routes' preferences are confused.

Travellers' behaviours have been analysed and modelled by Fuzzy logic in order to reproduce travellers' compliance and route choices. Different approaches, based on different fuzzy logics, have been compared, as well as an ANFIS approach. Obtained results highlight that Mamdani-type FIS is able to model better travellers' choice behaviours with respect to other considered approaches. This approach seems useful and deserving future deeper investigation.

In future works, authors would like to improve input attributes and rules of the Mamdani-type FIS, and to consider different types of adaptive neural networks. Moreover, in order to consolidate the validations of models, more indicators will be adopted (as also suggested in de Luca and Cantarella, 2009).

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