ENHANCING TOOLS FOR INTELLIGENT TRANSPORTATION SYSTEMS APPLICATIONS: MATCHING DATA ACQUIRED BY DRIVING SIMULATOR AND TRAVEL SIMULATOR

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ABSTRACT

Among ITS (Intelligent Transportation Systems) applications, a relevant interest has been devoted in recent years to ATIS (Advanced Travellers Information Systems). The prediction of travellers' route choice, in a context in which they are provided with information by different systems (VMS; route guidance; in car navigation systems), includes the study of travellers' compliance. In order to be effective, ATIS require appropriate levels of travellers' compliance with the dispatched information (Bifulco et al., 2007). Compliance and accuracy of information systems are implicitly related. It is worth noting that an appropriate level of compliance (as well as of familiarity with the technologically dispatched information) is reached also (maybe mainly) with respect to recurrent conditions. Accuracy of information systems can be evaluated by respondent, on the base of the discrepancy between suggestions received by ATIS, and experienced travel times. Putting in place accurate ATIS is not only due to technological matters but also (and mainly) to modelling issues, mainly related to the fact that the ATIS-information design problem is, in recurrent traffic conditions

and for dynamic and predictive ATIS, a typical anticipatory-route-guidance problem (Crittin et al., 2001).

The design of an accurate information system is obtained not only by advanced technologies but also with complex implementations of iterative procedures. In order to reach high-accuracy performances, it is required the availability of proper simulation models where the effect of the information accuracy on the compliance with information is explicitly and endogenously modelled. In order to study and model the travellers' response to the information systems, different approaches have been adopted for data acquisition. In particular, the difficulty in gathering data from the real world has induced many researchers to adopt the *Stated Preferences* approach.

Several researches have carried out experiments by adopting computer-based tools (travel simulators) or by designing a virtual reality in a driving simulator (Klee et al.); in both cases the main advantage is identified by the possibility to control the experiment variables (e.g. actual costs; accuracy of information; the set of choices characteristics, etc.). Different kind of models in ATIS' contexts have been already dealt with (Avineri, et al., 2003; Ben-Akiva et al. 1991; Emmerink et al., 1994; Ettema et al., 2006; Van der Mede et al., 1996), and the most common adopted simulators have been travel simulators; nevertheless, some studies have also been made by adopting driving simulators (Chang, H.L. et al., 2009; Katsikopoulos et al, 2000-2002).

In a driving simulator (characterized by very expensive technologies) the experiment designed is more complicated with respect to the travel simulator; besides, the experiment takes more time with respect to the travel simulator. However, the main advantage of the experiments made by driving simulators is that the virtual and immersive reality induces a more realistic behaviour of the respondents. Driving simulators are particularly suitable when the focus of the experiments is on driving choices and are very efficient also in reproducing the mental workload induced by driving. Rarely, results obtained by driving simulator and travel simulator are compared (Bonsall et al.,2000; Katsikopoulos et al., 2000). This, in order to improve the design of information (in terms of accuracy and quality), on the base of respondents' behaviour, and by identifying the biases introduced in the experiments (Koutsopoulos et al., 1995).

In our work, two experiments have been made by adopting both a driving simulator (route choice virtual simulator) and a travel simulator (SP Platform- Bifulco et al., 2009). In the experiment the respondents' reaction to variable message signs has been studied and modelled. Respondents have been provided with the same kind of information (mixed information – prescriptive plus descriptive) and at the same levels of accuracy (respondents have been tested in different scenarios, each of them characterised by a different level of accuracy). Therefore the running experiments is the same: respondents are asked to repeatedly make their choices.

By coupling the web-based and the driving-simulator-based experimental contexts, two main experimental strategies for observing drivers behaviours have also been coupled.

INTRODUCTION

According to literature review, it is possible to identify different approaches to travellers' behaviour, and the most popular one is based on the discrete choice theory (mainly random utility models).

Three modelling approaches can be identified: cross sectional models in which the utility values doesn't exhibit any dependency by a given time *t* (Bogers et al. 2006), weighted model in which attributes of the current utility are modelled as function of weighted values of previous attributes (Horowitz, 1984), and finally explicit dynamic models characterized by the adaptive expectation approach in which the current utility is updated by considering the utility value at previous day and the experienced attribute values (Cascetta and Cantarella, 1991-1993;; Van der Mede and Van Berkum, 1993) or the current propensity to choose a given route is updated on the base of the attributes at previous days (Erev et al., 1999). Some studies have also formalized the choice paradigm by going beyond the classical utility theory. This has lead to some alternative frameworks, all of them aimed at addressing more explicitly the fact that decision makers exhibit different attitudes under unreliable choice context, so that the utility maximization paradigm could result to be inadequate. In other terms, in case of travel time uncertainty (unreliability) it could be judged to be unrealistic that users make their choices in a perfect rational way. In the last few decades the study of strategies and decision-making processes have been also the subject of the Game Theory (Nash, 1950), and of the Prospect Theory (Khaneman and Tversky ,1979), both oriented to analyze people behaviour under risk and uncertainty. The unreliability effect on travellers' behaviour has been also analyzed by several authors (Avineri and Praskner, 2004; Kastikopoulos et al., 2002). In several cases the travel time unreliability effect on route choice is incorporated in the modelling framework (Small et al., 1982; Bogers et al., 2004). Other preliminary studies have been carried out by Ben-Elia et al. (2007). The enhancement of the drivers' behaviour modelling is also considered; mainly it's proposed to take into account that (often) decision-makers do not maximize the perceived utility, rather they make their choices by different criteria like habitual choices (see also Bogers et al, 2006). In fact, according to other research areas (particularly psychology), different studies deal with the bounded human rationality (Simon, 1957). In a case of bounded rationality it is considered that users maintain their choices from previous day as long as the outcomes do not exceed some threshold. Ettema and Timmermans (2006) developed a model to reduce the negative effect of travel time uncertainty. This model is based on the expected utility and includes the variation of travel time, the quality of travel time information and the travellers' perception of travel time. Several researchers (see Polak and Oladeinde- 2000) have studied the information effect on improving the quality and rapidity of learning.

In our approach we assume that travellers' update their choices on the base of their previous experiences and they can be exhibiting different attitudes with respect to route choice, based on their perception of information reliability and network performances. It is therefore essential to study and model drivers' behaviour in ATIS context.

TRAVEL SIMULATOR AND DRIVING SIMULATOR: PLATFORMS DESCRIPTION

It is worth noting that a limited number of studies that have been carried out with respect to travellers' reaction to ATIS by adopting the driving simulator approach. In most cases, data have been acquired by using a travel simulator. Moreover, the integration of collected data by using travel and driver simulators has not been widely studied. Travellers' reaction to the route guidance systems has been studied by Bonsall and Parry (1991), by mainly focusing on the design and development of an interactive driver simulators. Other studies have been made (Palmer et al., 1998; Bonsall et al., 2000) in order to analyze the drivers' behaviour by comparing different kind of experiments (made on paper questionnaire; on a route choice simulator and on a driving simulator). Other studies are also made by Katsikopoulos et al. (2000) in order to understand how data collected by travel simulator can be consided realistic and useful in modelling travellers' behaviour; they compare collected data acquired by a questionnaire made on paper and the one acquired by a driving simulator, concluding that driving simulators induce most realistic behaviours and enable researchers to acquire a more useful data base (Katsikopoulos et al., 2002).
All results confirmed better performances of the driving simulator approach, but no specific experiment has been made, as from literature, in order to compare the data sets acquired by the travel and the driving simulators, in different scenarios, and with reference to different levels of accuracy.
The aim of the proposed research is to compare the data on route choice collected by travel simulator and pc driving simulator, and to evaluate the effectiveness of the last one as support tool to analyze drivers' route choice.
In order to make our experiments, two simulators have been adopted: the Route Choice Driving Simulator (RCDrivingSim), using the same driving simulator software of the VERA driving simulator at Naples University (Galante, 2008; Pernetti et al., 2009) and the travel simulator (SP Platform, Bifulco et al., 2009).

Route Choice Driving Simulator

The RCDrivingSim is a pc driving simulator with a steering wheel pedal set designed as a desktop, route choice application support tool. RCDrivingSim simulates a passenger car with automatic transmission, rear view mirror, instruments and turn signals.
The simulator is controlled and operated from two personal computers connected by an Ethernet cable. The driver controls the driving tasks using accelerator and brake pedals and a steering wheel (Logitech™ MOMO Racing Force Feedback Wheel), able to provide force feedback to the steering wheel as well as six programmable buttons (ignition, horn, turn signals, etc.), sequential stick shifters and paddle shifters. The "control" computer also manages the data I/O.
The "graphic" computer renders, antialiased and at 60Hz, a full 19" monitor projection of the view from the driver's seat in the car.

The “graphics” computer also generates sound effects consistent with the roadway environment, including, but not limited to engine, turn signal, horn, road/tire, wind, tire squeals, and other traffic sounds. Instrument panel includes tachometer and speedometer as well as turn signals and gear setting.
The driving simulation software used in RCDrivingSim is SCANeR®II r2.22 from Oktal company.

Travel simulator Platform (SP Platform)

The travel simulator is a web-based tool aimed at observing travellers' behaviours in simulated ITS (Intelligent Transportation Systems) contexts. It allows for surveying samples of travellers by adopting SP (Stated Preferences) approaches. The tool has been developed with reference to cases where ATIS (Advanced Traveller Information Systems) have to be analysed. Several researchers have designed different travel simulators improving, step by step, on the base of previous experiences, several features (Adler et al.,1993; Mahmassani and Jou,1998; Bonsall and Palmer, 1999; Kitamura et al., 1999; Bates et al., 2001; Avineri and Prashker, 2006; Bogers et al., 2006; Avery et al., 2008; Ben-Elia et al., 2008).
For this research a travel simulator (SP Platform-Bifulco et al., 2009) has been adopted. The development of this tool has been strongly influenced by an existing one, the TSL (Travel Simulator Laboratory, Chorus et al., 2007), developed at the University of Delft, to which functionalities the authors have had access during previous researches (Bifulco et al., 2008; Di Pace, 2008). With respect to the TSL, the SP-Platform allows for a greater flexibility of the experiment and is based on state-of-art informatics technologies that ensure scalability and robustness of the experiment.

SUMMARY OF EXPERIMENTS

During the experiments, respondents were subject to two different scenarios. In each scenario there were two different levels of accuracy (high and low) based on the discrepancy between the estimated travel times and the actual costs. The tested information is *mixed information;* in this case respondents are provided with descriptive information (the estimated travel times on every route) and prescriptive information (they are at the same time informed on the estimated shortest route). The control variables of the experiment are the actual cost and the error made by the information system in the actual cost estimation.
Respondents are also requested to answer at the beginning and at the end of the experiment, to some preliminary questions (in order to capture some information on the sample description) and ex-post questions (in order to capture some latent information on the respondents' perceptions understanding).
During the experiment respondents are requested to make their route choices (among three alternative routes: a highway-Route 1-, an urban route -Route 2- and a rural road Route 3) on a given origin- destination pair; they are also asked to repetitively make the choices for several times. Before beginning the simulation, the respondent is asked to imagine that he

should arrive at his destination on time (09:00 a.m.) for a job meeting. The choice of motivation is to force the respondents to behave as realistic as possible (Bonsall, 1997).

DESIGN OF EXPERIMENT IN TRAVEL SIMULATOR (SP PLATFORM)

The experiment was designed assuming that the respondents can make their choices, for a given origin-destination pair, among three alternative routes. Routes are differentiated by their length and type of road: Route 1 (70 km) is a highway, Route 2 (90 km) is an urban route, the last one, Route 3 (85 Km) is a rural road.

The experiment was designed so that, the respondents make their own choices for thirty days. Moreover, they are assisted by the information system from the eleventh day[1]. The respondent can use the map depicted in Figure 1 as a reference to route choice of location during the experiment; the same map, after the tenth day is displayed in the screen of a navigation system, and the suggested route and the estimated travel times are shown (Figure 1).

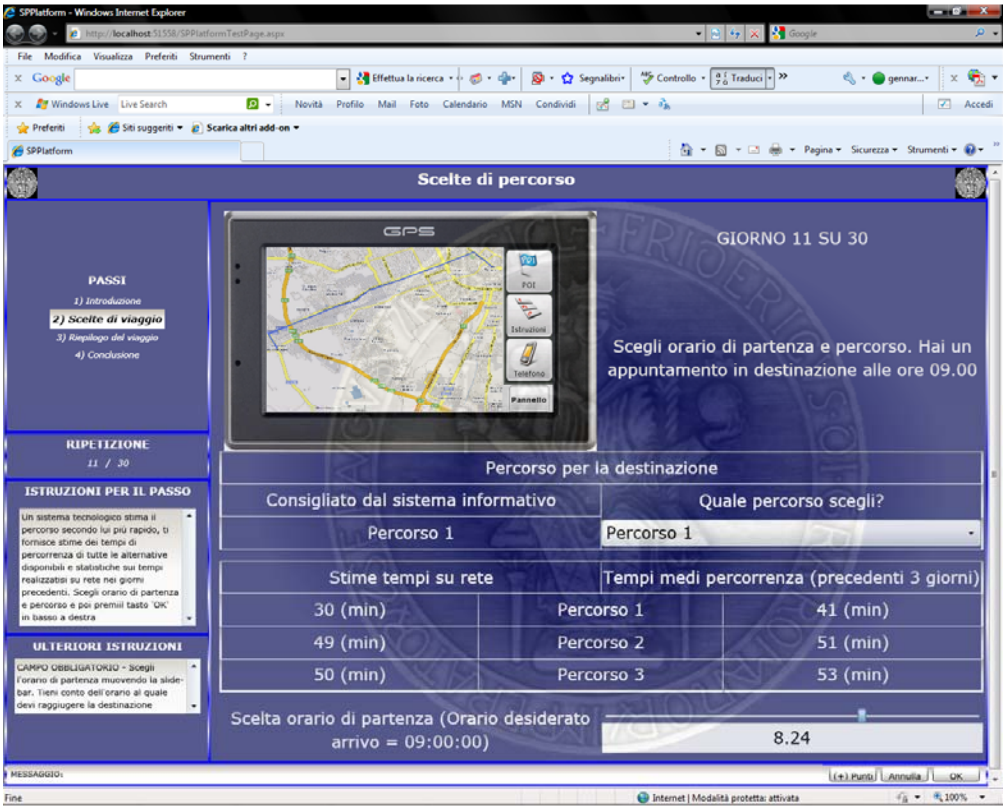

Figure 1: Screenshot of the experiment run in the SP Platform

[1] The reason for which the information system is made active only after the eleventh day, is related to the fact that, based on previous researches, it was deemed appropriate to allow the respondent to learn the characteristics of the network at a stage where he should not simultaneously focus on the presence of the ATIS system.

For this experiment, 20 respondents have been involved and assigned to each scenario. Respondent are requested to make repeated choice for 30 consecutive times. Each respondent at each run, can choose the departure time and the route (from the first day until the 10th, without suggestions from the information system and from 11th day on, until the end of the simulations, with the suggestions of an information system (the experiment has been designed in this way, according to previous experimental analysis on the base of which researchers have understood that respondents need 10 days to learn about the network performances).

After the choice, they are provided with a feedback on the actual network performances (not only with reference to the chosen route, but with reference to all routes). Two scenarios have been tested and for each scenario, respondents have been equally divided among the scenarios. All respondents in the experiment received the same actual costs; the respondents in the same scenario are provided with the same suggestions.

Moreover respondents involved in the experiment have been selected in order to establish a good level of heterogeneity of respondents.

Some criteria for stratification of the sample have been defined. Respondents have been divided on the base of: gender (male or female); on the base of the employment (class 1 composed by university lecturers, researchers, students; class 2 composed by freelancers, teachers, and non-university researchers); if they have the driving license for less than ten years (class 1) or for more then 10 years (class 2); on the base of age ([1990;1980]- [1981;1970]- [1971;1960]- [1961-1950]); on the base of qualifications (Bachelor degree; Master degree; PhD; Secondary school). Characteristics of respondents are showed in Table 1.

Table 1: Sample description

	Class	TOT (%)	F(%)	M(%)
Driving license	Less 10 years	53%	37%	63%
	Over 10 years	47%	29%	71%
Employment	1	67%	29%	70%
	2	33%	42%	58%
Age	1990-1980	53%	37%	63%
	1981-1970	27%	30%	70%
	1971-1960	11%	25%	65%
	1961-1950	9%	33%	67%
Qualifications	Bachelor Degree	33%	25%	65%
	Master Degree	39%	43%	57%
	PhD	17%	17%	83%
	Secondary school	11%	50%	50%
			28%	*62%*

The experimental design is essentially based on the definition of scenarios (type of information, accuracy, feedback, etc.) with varying levels of accuracy. In particular, it was necessary to design the actual cost and errors made by the information system in the estimation of the actual cost.

Actual travel times of different routes have been considered dispersed over time in a statistically independent way. Starting from a hypothesized random distribution of actual travel times, 20 draws have been realized for each route; the resulting samples' means and standard deviations are reported in the following Table 2. It can be noted that route 1 is on average the shortest, but its travel time can (rarely) drastically increase; route 2 is intermediate both in terms of average travel time and reliability; route 3 is the longest, but is very reliable.

Table 2: Statistical parameters of actual costs

Route	Average [min]	Standard Dev.	Coeff. of Variation
Route 1	42.83	179.533	0.31282
Route 2	53.03	54.834	0.13963
Route 3	52.10	2.490	0.03029

On the base of previous distributions, the actual travel times for route 1 are, in a 26% of cases, between 58 and 66 minutes, in a 16% of times between 44 and 55 minutes, and in a 57% of cases less than 37 minutes; for route 2 in a 40% of cases between 48 and 40 minutes, in a 23% of cases between 58 and 44 minutes, and in a 36% of cases between 58 and 66 minutes; for route 3 actual travel times are in a 43% of cases between 48 and 51 minutes and in a 57% of cases between 51 and 55 minutes. The ATIS accuracy has been designed for the four considered levels of accuracy. In particular, it has been hypothesized that the ATIS estimate of route travel times are subject by an error with respect to actual travel times. Such error increases as the (in) accuracy level of the scenario moves from 1 to 2. For accuracy level 1 the standard deviation of the ATIS error for a generic route j is computed with reference to the coefficient of variation of the actual travel time of such a route. The distribution is normal for the first accuracy level and uniform for the second accuracy level. In case of the normal distribution, the average is equal to 0 and the standard deviation is equal to 0.25 CVj [2] , $\forall$ j$\in${1,2,3}. In case of a uniform random distribution (accuracy level 2), the error is such that the resulting instances of ATIS travel time estimates are between 85% of the minimum actual travel time and 115% of the maximum actual travel time, where minimum and maximum are computed over all routes and over all days. At first level of accuracy, information system is reliable 18/20 times, at second 6/20. The estimated travel times of each route at every level of accuracy, are showed in Table 2.

Table 2: Statistical parameters of estimated travel times at each inaccuracy level

Level of Accuracy	Route j	Average	Var
High	Route1	41.90	211.09
	Route2	54.20	58.560
	Route3	51.70	3.110
Low	Route1	50.85	144.03
	Route2	43.60	190.94
	Route3	60.60	117.74

[2] The standard deviation of the ATIS error for a generic route j is computed with reference to the coefficient of variation of the actual travel time of such a route

DESIGN OF EXPERIMENT IN PC DRIVING SIMULATOR

The experiment in RCDrivingSim has been scheduled in the same way than the travel simulator experiment did. Respondents can make their choices, for a given origin-destination pair, among three alternative routes: routes are differentiated by their length and type of road. Figure 2 shows some images from the 3D experimental scenario. Route 1 is a highway, Route 2 is an urban route and, the last one, Route 3 is a rural road (Figure 3).

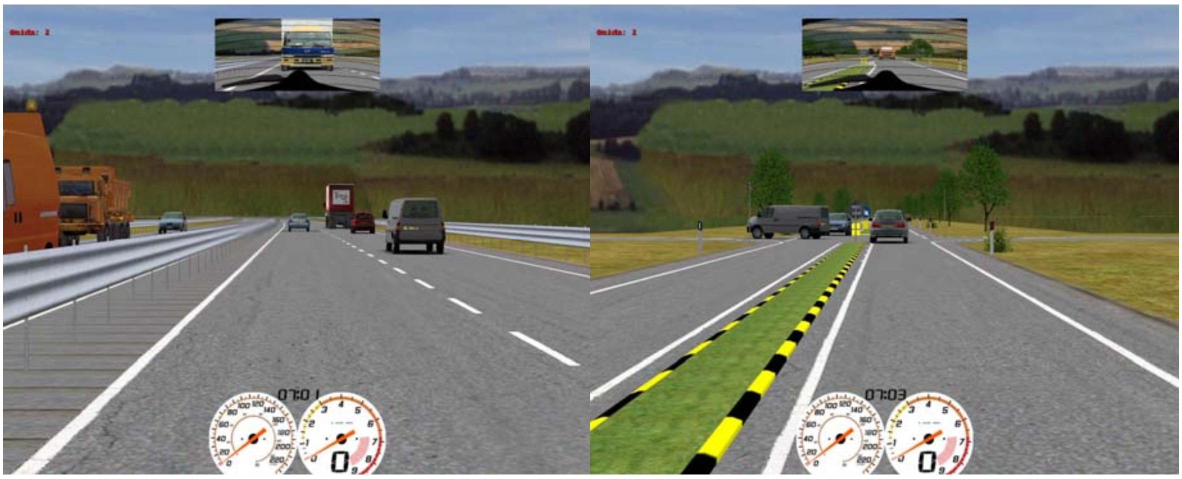

Figure 2: Experimental Scenario Screenshots.

The experiment was designed in a way that the respondents make their own choices for eight days. Moreover, they are assisted by the information since the start of simulations.

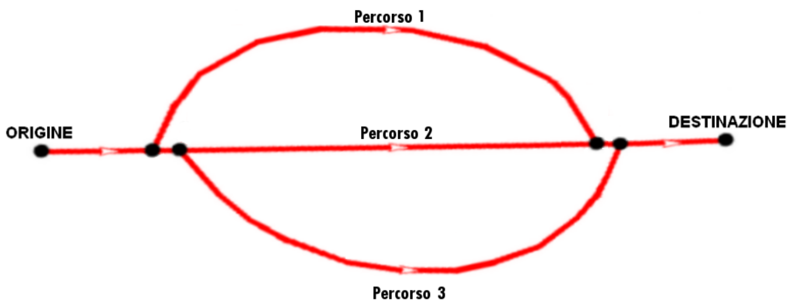

Figure 3: Network in *RCDrivingSim*

Before starting the simulation, they are informed on the ATIS-estimated travel times and on the shortest route; on the base of this preliminary information, they can choose, the departure time, then the simulation experiment runs. Respondents drive along the mainstream for a 1000 meters before the diversion node arrives, then they are provided again with information by a VMS (see Figure 4); at a 150 meters from the diversion node.

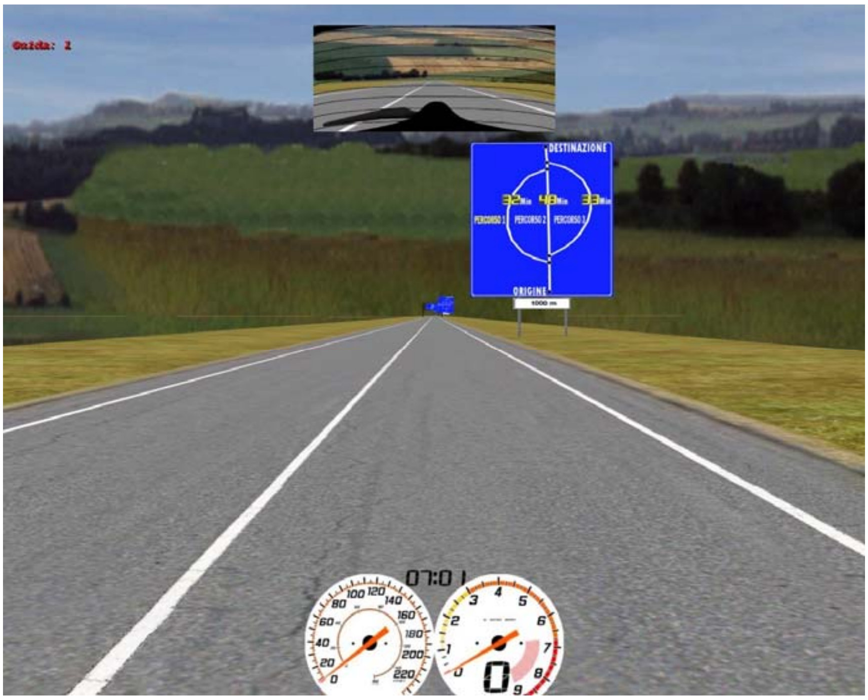

Figure 4: VMS with estimated travel times during test in *RCDrivingSim*.

At the end of each simulation respondents are provided with a feedback on the actual network performances (not only with reference to the chosen route, but with reference to all routes). Respondents are request to repeat the experiment for 6[3] consecutive times.

Moreover respondents involved in the experiment have been selected in order to establish a good level of heterogeneity of respondents. For this experiment, 16 respondents are involved and assigned to each scenario.

As in the travel simulator experiment, some criteria for stratification of the sample has been defined. Respondents have been divided on the base of: gender (male or female); on the base of the employment (class 1 composed by university lecturers, researchers, students; class 2 composed by freelancers, teachers, non-university researchers); if they have the driving license for less than ten years (class 1) or for over 10 years (class 2); on the base of age ([1990;1980]- [1981;1970]- [1971;1960]- [1961-1950]); on the base of qualifications (Bachelor degree; Master degree; PhD; Secondary school). Characteristics of respondents are showed in Table 3.

[3] Some preliminary investigation have been made in order to understand how many runs were necessary; at first respondent have been asked to repeat the experiment for 8 consecutively times, successively the number of runs was reduced from 8 to 6: the experiment needs a lot of time and an high level of concentration by respondents, consecutively inducing a high level of workload.

Table 3: Sample description

	Class	TOT (%)	F(%)	M(%)
Driving license	Less 10 years	85%	20%	80%
	Over 10 years	15%	50%	50%
Employment	1	86%	29%	71%
	2	14%	0%	100%
Age	1990-1980	56%	10%	90%
	1981-1970	38%	30%	70%
	1971-1960	6%	0%	100%
Qualifications	Bachelor Degree	31%	0%	100%
	Master Degree	31%	40%	60%
	PhD	38%	33%	67%
			25%	*75%*

As in the travel simulator experiment, actual travel times of different routes have been considered dispersed over time in a statistically independent way. Starting from the hypothesized random distributions of actual travel times, 6 draws have been realized for each route; the resulting sample means and standard deviations are reported in following Table 4. It can be noted that network performances in terms of actual cost are the same than those from the travel simulator experiment: route 1 is on average the shortest, but its travel time can (rarely) drastically increase; route 2 is intermediate both in terms of average travel time and reliability; route 3 is the longest, but is very reliable.

Table 4: Statistical parameters of error made by information system

	Average [min]	Var.	Coeff. of Variation
Route1	31.25	11.69	0,354446
Route2	40.00	209.75	0,362069
Route3	31.00	1.75	0,042673

On the base of these statistical parameters, route frequency distribution will be in a 37.5% less than 24.5, in a 25 % of cases will be between 24.5 and 29 minutes, and in a 37.5 % of cases between 42.5 and 47 minutes; route 2 will be in a 37.5 % of cases between 24.5 and 29 minutes, in a 12.5 % of cases between 29 and 33.5 minutes, in a 12.5% of case between 33.5 and 38 minutes, in a 12.5% of cases between 38 and 42.5 minutes, in a 25% of cases between 60.5 and 65 minutes; route 3 will be in a 87.5% of cases between 29 and 33.5 minutes, and in a 12.5% of cases between 33.5 and 38 minutes. On the base of these considerations, route 1 can be considered the shortest in a 37.5 % of cases but, at the same percentage of cases travel times increase more or less 20 minutes; route 2 is an useless route (unreliable and having the highest values of travel times, between 60.5 and 65 minutes, in a 25% of cases), and route 3 is the most reliable route because travel times are between 29 and 33.5 minutes in a 87.5% of cases and in a 12.5 % of cases between 33.5 and 38 minutes. It has been hypothesized that ATIS estimates of route travel times are subject to an error with respect to actual travel times. Such an error increases as the (in) accuracy level of the scenario moves from 1 to 2.

For accuracy level 1 the standard deviation of the ATIS error for a generic route j is computed with reference to the coefficient of variation of the actual travel times of such a route. The distribution is normal for the first accuracy level and uniform for the second accuracy level. In case of normal distribution, the average is equal to 0 and the standard

deviation is equal to 0.15 CV_j [4] , $\forall$ j∈{1,2,3}, and in case of uniform random distribution (accuracy level 2), the error is such that the resulting instances of ATIS travel time estimates are between 65% of the minimum actual travel time and 115% of the maximum actual travel time, where minimum and maximum are computed over all routes and over all days. At first level of accuracy, information system is reliable 18/20 times, at second 6/20. The estimated travel times of each route at every level of accuracy, are showed in Table 2.
At first level of accuracy, information system is reliable 6/6 times at second level 2/6. The estimated travel times of each route at every level of accuracy, are showed in Table 5.

Table 5: Statistical parameters of estimated travel times at each inaccuracy level

Level of Accuracy	Route j	Average	Variance
High	Route1	32.125	180.1094
	Route2	31.25	2.4375
	Route3	39.875	207.6094
Low	Route1	29.00	64.00
	Route2	34.125	180.1094
	Route3	32.875	178.8594

EXPERIMENTAL RESULTS

Travel Simulator Results

The experimental results have been analyzed in order to verify the effect of different accuracy levels, on respondents' behaviour. In particular, researchers have analyzed the effect of inaccuracy level on respondents' tendency to choose to be compliant, to choose the most reliable route and to choose the best route (the shortest route). The considered data base is composed by the answers made by each respondent for 20 successive times, and for each scenario 10 respondents have been considered; data base is composed by a total of 600 valid records.
The first analysis has been carried out in order to assess if different accuracy levels of ATIS information can have effect on travellers' compliance. This has been carried out by comparing the cumulative compliance distributions at different inaccuracy levels. The cumulative compliance distribution at a given point *(x, F(x))* represents the fact that no more than *F(x)* of the respondents of the considered scenario are compliant *x* times and *1-F(x)* of the respondents are compliant more than x times. Figure 5 shows an evident effect of ATIS accuracy on compliance.

[4] The standard deviation of the ATIS error for a generic route j is computed with reference to the coefficient of variation of the actual travel time of such a route

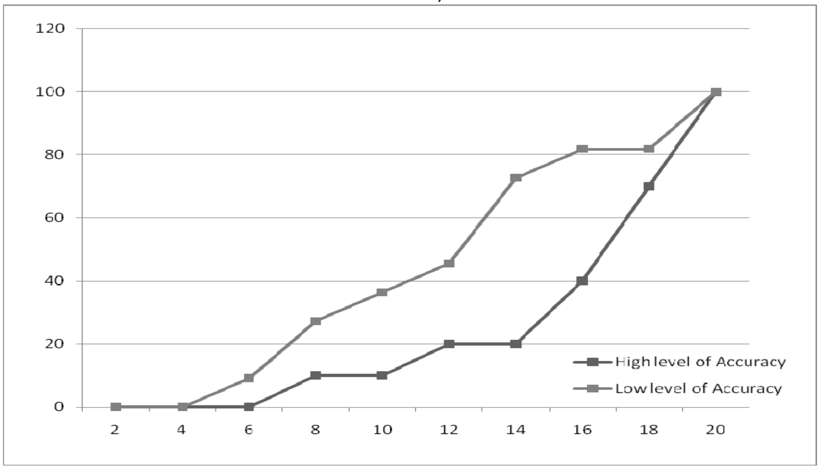

Figure 5: Effect of accuracy on compliance

The same analysis has been made on the respondents' tendency to choose the most reliable route and the shortest route: when inaccuracy decreases (Figure 6 and Figure 7) the tendency to choose the shortest route decreases, and at the same time the tendency to choose the most reliable route increases.

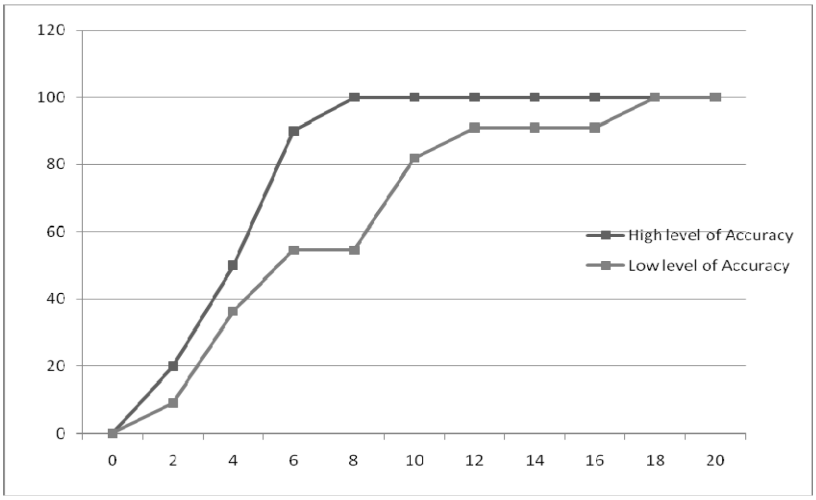

Figure 6: Effect of accuracy on tendency to choose the most reliable route (Route 3)

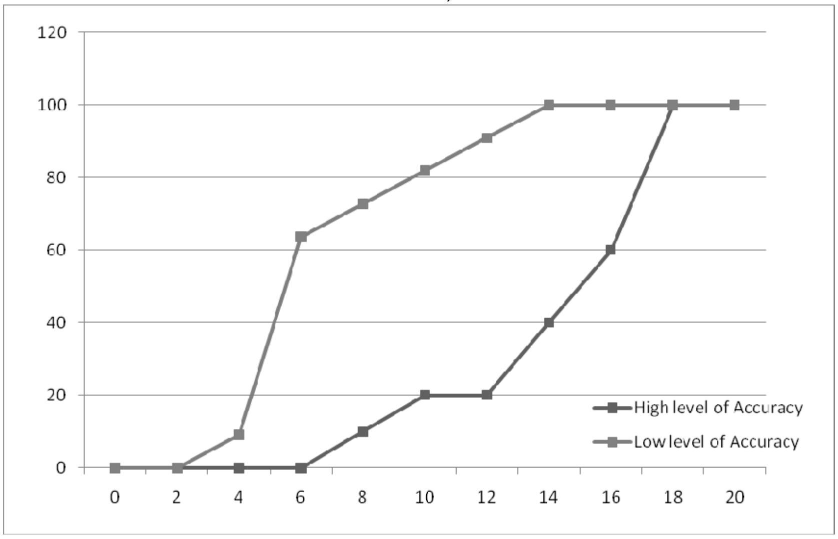

Figure 7: Effect of accuracy on tendency to choose the best-route

Some more formal aggregate analyses have been carried out also by applying non parametric statistical test. On A Kruskall-Wallis (non parametric test) testing approach has been applied to the following null-hypotheses on the only casual accuracy level (approximated by the scenario ID) influence on: (i) the travellers' compliance; (ii) on the ability to choose the route of minimum actual travel time; (iii) on the propensity to choose the most reliable route (Route 3).
In all cases, accuracy can have a non casual effect if the null-hypotheses can be rejected (asymptotic significance values as low as possible). The results of the tests are shown in Table 6[5], they suggest that accuracy plays a role (even if not so evident with respect to the propensity to choose the most reliable route in descriptive scenarios) and that further disaggregated analyses are worth.

Table 6: Kruskall-Wallis tests

	Compliant	**Most Reliable Route (Route 3)**	**Shortest Route**
Chi-Square	22,969	19,983	64,384
Asymp. Sig.	0,000	0,000	0,000

Driving Simulator Results

Obtained data by pc driving simulator, have been analyzed in the same way than the data captured by the travel simulator.
The same analysis made for travel simulator data base have been made for RCDrivingSim. The considered data base is composed by the answers made by each respondent for 6 successive times, and for each scenario 8 respondents have been considerate; in totally the data base is composed by 96 valid records.

[5] Not parametric test have been made because the Lèvene Statistic test on the Variance Homogeneity statistical test was not unsatisfied.

The first analysis has been carried out in order to assess if different accuracy levels of ATIS information can have effect on travellers' compliance. Figure 9 shows that the effect is evident.

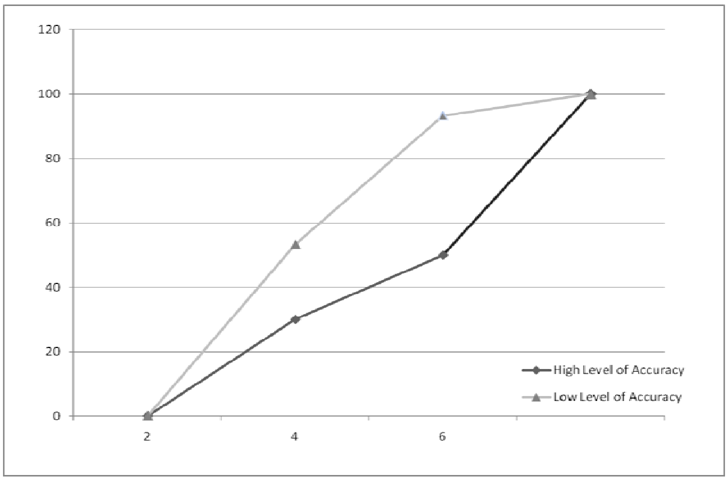

Figure 8: Effect of accuracy on compliance

The same analysis has been made on the respondents' tendency to choose the most reliable route and the shortest route: when inaccuracy decreases (Figure 9 and Figure 10) the tendency to choose the shortest route decreases, and in the same time the tendency to choose the most reliable route increases.

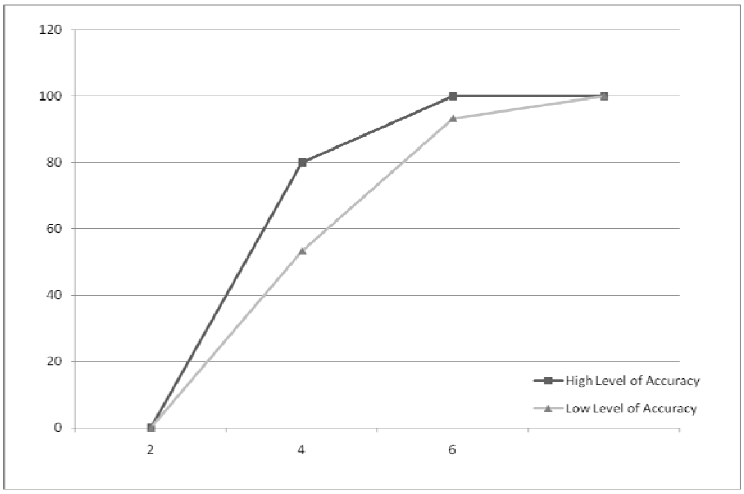

Figure 9: Effect of accuracy on tendency to choose the most reliable route (Route 3)

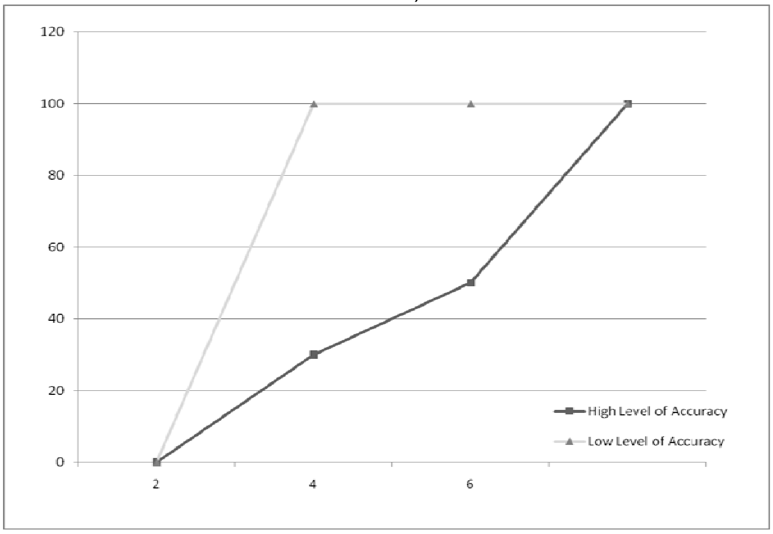

Figure 10: Effect of accuracy on tendency to choose the best-route

Moreover, statistical tests have been made. In Table 7 results of test on homogeneity are being showed. When the Lèvene statistical test is unsatisfied, non-parametric test (Kruskall-Wallis) has been done. In particular ANOVA test has been applied in case of the analysis for the Inaccuracy effect on the Most Reliable route, and significance is 0,014. Thus, the hypothesis that average assessment scores are equal can be rejected.

Table 7: Test of Homogeneity of Variances

	Lèvene Statistic	Asymp. Sig.
Compliant	18.004	0.000
Most Reliable Route	0.000	1.000
Shortest Route	1.923	0.169

In case of the Inaccuracy effect in the respondents' compliance and on the tendency to choose the shortest route, non-parametric test has been made and results showed a significant effect of the treatments (see Table 8).

Table 8: Non-parametric test: Kruskall Wallis test

	Compliant	Shortest Route
Chi-Square	5,529	21,898
Asymp. Sig.	0,019	0,000

The results demonstrate that there is a significant effect of level of accuracy on respondents' behaviour in both case of compliance and on the tendency to choose the shortest route. Another analysis has been made in order to verify the effect of RCDrivingSim on the capability of respondent to learn about the network performances (in terms of actual costs and accuracy of information system). Respondents need several runs in order to define their behaviour. In particular, according to the accuracy, respondent can decide to explain the attitude to be compliant with the suggestions provided by information system (in this case information system provide respondent with the shortest route and for this reason respondents are expected to mainly choose the shortest route) or to choose (according their expectations) the shortest route or the most reliable route (e.g. Route 3 in this experiment). According to previous analysis when the accuracy of estimated information decreases, the

percentage of respondents that decide to choose the most reliable route increases. In both cases, the respondents' behavior is fixed by the route mainly chosen during the experiment.
In order to understand how many runs need the respondents to fix their attitude, some aggregate preliminary analysis (Table 9) and some non-parametric test[6] have been made (Table 10 and Table 11).

Table 9: Percentage of learnt respondents: effect of number of runs

	All scenarios	High Accuracy	Low Accuracy
Runs>3	38%	12%	63%
Runs>2	25%	38%	13%
Runs≤2	37%	50%	24%

In both cases of *High Accurate* and *Low Accurate* scenarios, the runs "seem" to have a non casual effect.

Table 10: Non-parametric test (Kruskall- Wallis test): effect of runs on respondents' learning

	Chi-Square	Asymp. Sig.
High Accuracy	39,221	0,000
Low Accuracy	39,191	0,000

Some analysis has been made by considering not all runs for each respondent, but only the first three runs in order to confirm that in this experiment respondent (more or less) need three runs to learn about the network performances and then to fix their behaviors. As described in Table 11, results showed that during the first three days in case of accurate scenario respondents are a less dispersive attitude (induced by the high accuracy of information system), and they shortly start to fix their behavior; in case of inaccurate information system during the first three day respondent will have a more casual behavior (run have a not complete significant effect on their choice).

Table 11
Not parametric test (Kruskall- Wallis test): effect of first three runs on respondents' learning

	Chi-Square	Asymp. Sig.
High Accuracy	14,065	0,000
Low Accuracy	6,046	0,049

CONCLUSIONS AND FUTURE WORK

Although the two experiments cannot be considered as perfectly equal, some preliminary observations can be made.
The results obtained in the virtual simulation confirm the results previously obtained through the travel simulator. In particular, the accuracy of the information system has an effect on respondents' behaviour. Another result is referred to the effect of the environment of simulation on respondents' choices and on their speed to learn about the network performances. In this preliminary research, in accordance with previous results stated in the

[6] Non-parametric tests have been made because the Lèvene Statistic test on the Variance Homogeneity statistical test was not unsatisfied.

literature, respondents of the driving simulator approach seem to need 3 runs to start to learn and fix their behaviours. The first goal of future research is to increase the number of respondents for each scenario, moreover researchers would like to analyze also the respondents' behaviour in absence of information system, and in case of descriptive or prescriptive information, in order to test the effects of different kind of information (or no information systems).

In a next step, the two data sources are coupled not only in order to compare travellers' attitudes in different simulation approaches to the same traffic context, but also to overcome the limitation of travel simulator by using the driving simulator and vice versa. The main step for future research can be identified in data matching, and in the use of this data set for a calibration and a validation of a route choice model in ATIS context in which the compliance can be considered as an endogenous variable.

The aim of this research was to start a preliminary study of the different effects of simulation route choice tools, in relationship with the inaccuracy of information. No further investigation on the design of information has been made. Moreover, in further studies researchers will investigate also the effect of different kinds of information. A more immersive driving simulator could be used in future works in order to further improve the realism of the drivers' behaviour, also at route choice level.

It's finally important to observe that a future field of research can be also identified thanks to this first step of validation of the RCDrivingSim, i.e. RCDrivingSim can be used not only to model ATIS systems but also (in Intelligent Transportation Systems field) driving assistant systems.

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