Route Choice Behavior with Pre-Trip Travel Time Information

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Abstract

The purpose of this paper is to evaluate the potential benefits from real-time travel time information provision by gaining insights into and better understanding of the factors affecting the route-choice behavior of drivers possessing real-time pre-trip information. Both a field study and an in-laboratory experiment were conducted to obtain revealed preferences (RP) and stated preferences (SP) on route choice. The data collected from both experiments are inputs for a combined RP-SP route-choice model. The model also includes attitudinal factors describing drivers' personal characteristics. The results show that when experience seeking increases, individuals tend to prefer a route characterized by lower average but greater variance of travel time. Other results confirmed past studies showing that information has an impact on route-choice behavior although compliance with received information decreases with recent experience.

Keywords*:* travel information, human factors, information collection, information processing, travel time.

1. INTRODUCTION

The interaction between information and communication technologies (ICT), on the one hand, and human travel behavior, on the other, has constituted an important theme in transportation research in recent years. There is rising interest in the potential of increased ICT use to change the location, timing, and duration of people's activities [1,2,3,4,5]. Some of these analyses focus specifically on work activities (e.g., [6]) and some on other activities, such as shopping [7]. Included in the latter are studies of the increasing use of ICT to relieve congestion and improve the utilization of road-network capacity (see, for example, [8,9,10]).

Advanced traveler information systems (ATIS) or road traffic information (RTI), using pre-trip or en-route real-travel-time information, are efficient means of meeting these transportation goals.

Wachs [11] claimed that the growing role of information processing and telecommunications was recognized as the social trend with the greatest influence on transportation. Adler & McNally [12] stated that the process of acquiring information in order to help identify and solve problems should be a primary focus of driver-behavior research. Obtaining a greater understanding of the impact of information on driver behavior is, in turn, a key issue for evaluating ICT performance [10]. Like theories established in the field of travel behavior the ultimate route-choice decision is inherently a multiple-objective, decision-making process. That is, many factors other than travel time are involved that have a major impact on the decision process. These factors relate to trip attributes and a driver's socio-economic characteristics, examples of the former being cost, convenience, trip purpose, flexibility in departure and arrival time, traffic information availability before and en route; and examples of the latter including age, gender, car ownership, income, personality, route preference, and familiarity with alternative routes [13,14,15,16,17,18,19]. For example, Adler [20] claimed that the benefits of having route guidance diminished when drivers became more familiar with the travel network. Emmerink et al. [10], confirming earlier studies, found that women were less likely to be influenced by traffic information and more reluctant to alter their own predetermined choices.

The complexity of understanding travel behavior given the receipt of relevant road information is due to the many aspects involved: e.g., modeling drivers' behavior, decision-making theory, drivers' attitudes toward communication and technology and ICT reliability [10,13,21]. The decision-making process in regard to route choice is also dynamic; the learning process is central to a driver’s cognition, since the information acquired is processed through the experience of earlier travel choices before the next decision is made. This applies especially to commuters [13] as Yang et. al [22] for example, reported that most respondents made route choices based mainly on their recent experience.

In light of the still very limited implementation of information technologies around the world, it is difficult to evaluate changes in driver behavior based on directly observed travelers' responses to real-world information. A review of the literature shows that most studies in the area of route-choice behavior in a situation in which information is received are based on simulation methods, in-laboratory experiments, and stated-preference surveys rather than on revealed-preference studies [19,12,10].

More recently, Jan et al. [16] and Li et al. [19] expanded the study methods with the use of GPS-based data.

The reliability of stated-preference survey techniques for this purpose turns out to be questionable especially with respect to the information effect, since it is difficult to present well-defined SP scenarios which include information provision [12]. In-laboratory experiments and interactive simulations became well-liked tools, but they do not preclude the need for field testing [12]. However, very little work has been done that is based on field studies. One such field study, conducted in London, involved messages activated on a VMS sign; the objective was to focus on drivers' attitudes and responses [23]. As stated by Bonsall [24] and identified in the DRIVE Field Trials Manual [25], field studies have a unique value, since they are conducted under real conditions, and consequently their results are more "valid" than simulation exercises could ever be.

With the goal of filling in some of the lacunae resulting from the lack of field studies, this paper is based on a study that included observations of actual behavior in a simple real-world network as well as on an in-laboratory experiment based on the same network. This enable to contribute to better understanding of the effect of real time information on route choice,. It aims to gain insights and a better understanding of the factors affecting drivers' route-choice behavior. The drivers received the most up-to-date pre-trip travel time information on substitute routes. This study tests the effect of sensation-seeking on drivers' route-choice behavior. The notion of sensation-seeking is commonly used in behavioral science, but to the authors' best knowledge has not yet been used in route-choice analysis. However, numerous studies consider sensation-seeking to be positively related to reckless driving behavior [26,27) and may be relevant to route-choice behavior in situations in which there is a trade-off between travel time and its variability.

2. METHOD

The methodology of this study included three elements. The first element was the design and performance of the field study and the in-laboratory experiment, which included data compilation and analysis. The second was a self-questionnaire that each participant was asked to fill out in order to identify factors influencing the participant's behavior and the choices made in the experiments. These factors focused on personal characteristics and attitudes toward risk, information, and experience with the study road network. Third, the data compiled from both the field study and the in-laboratory were combined with the personal characteristics data to estimate a route-choice model.

2.1 The study network

The study is based on a simple network located near the campus of the Technion - Israel Institute of Technology in Haifa, the largest city in Northern Israel. Figure 1 illustrates the network. In the experiment, participants were asked to drive (either as part of the field study or virtually in the in-lab experiment) from a neighborhood close to the campus to the rear campus gate. They had a choice of two alternative routes for this purpose: route A (in red, the lower one on the map) and route B (in blue, the upper one on the map). There are no other reasonable alternatives routes for this trip.

Route A crosses the Technion campus through the main entrance (main gate) and involves more turns and speed bumps. All intersections along this route are un-signalized. Furthermore, because of Technion traffic regulations, a passenger car’s eligibility to enter the campus is checked manually at the campus entrances; cars entitled to enter are equipped with an appropriate tag. Therefore, drivers may experience delays and queues at the main campus gate, especially during the peak hours. Route B bypasses the Technion and is considered the "main road," being characterized by wider lanes and signalized intersections. The two substitute routes are approximately similar in length: route A is 2.8 kilometers and route B is 3.0 kilometers.

2.2 Study design and performance

The study included two experiments that used the study network: A field study and an in-laboratory experiment. First, we conducted the field study and its data, mainly in regard to travel-time distributions on substitute routes, were later used in the design of the in-laboratory experiment to ensure valid travel times. All participants were also asked to fill-in a questionnaire that was designed to identify personality factors that may influence an individual's behavior and route choices. All participants were undergraduate students, between the ages 22-30, holding a driving license and they were introduced with the study overall scope.

2.3 The field study

Participants were asked to drive their own cars during the morning peak hour from the starting point in the neighborhood to the destination at the rear campus gate as described above. Immediately after arriving there, the participants were asked to drive back to the origin on one of the two routes.

At the starting point, participants received pre-trip information about the most up-to-date travel time on both routes, based on the data measured for the last participants arrived to the researcher at the rear gate, but only for the one-way trip from the starting point to the destination. Each participant had to perform the driving task six times during the morning peak hours over a couple of days.

Each participant performed the first trial without information. Two researchers were located at the ends of the routes: one at the starting point and the second at the rear campus gate and they were responsible for recording the travel times of all trips. Once a participant returned to the starting point, real-time travel information regarding the travel times on both routes was provided by the researcher located there, based on the most up-to-date travel time measured in earlier trials. Every participant received information at the end of each drive regarding his or her actual travel time on the chosen route.

2.4 The in-laboratory experiment

The same network used in the field study served the in-laboratory experiment. Participants were presented with a screen showing the network, the alternative routes, and their route-choice task. The participant was asked to choose one of the two alternative routes in twenty recurring trials. After each choice was made, the participant received feedback regarding his or her travel time in the previous trial and travel time information for both routes in preparation for the next trial. The travel time feedbacks and information were drawn from the distribution of travel times based on the field study. An example of a screen-shot used in this experiment is presented in Figure 2.

The sample population for this in-laboratory experiment consisted of two sub-samples: 25 Technion undergraduate students (none of whom had participated in the field study), who carried out the experiment at the Technion campus; and 39 undergraduate students from the Holon Institute of Technology (H.I.T), who carried out the experiment at their campus (located about 100 kilometers from the Technion campus).

2.5 Questionnaire outline

This study focused on a limited number of factors affecting route choice, excluding some by using a homogenous sample of students with no specified trip purpose and no flexibility in departure time. Although we could not test the effect of these latter variables on route choice, we were able to focus on three factors that may affect route-choice behavior under information and given conditions appearing in the field study:

- Driver's preference for routes as revealed in the first trial (without information). That is, we assumed that the route chosen for the first trip would indicate the driver's route preference in each direction.
- Experience gained from earlier travel choices regarding travel time and information.
- Compliance with information, i.e., did the driver choose the shorter route based on the updated information he or she received?

The main focus of the questionnaires distributed to all the participants was the personal attitudes and characteristics that may play an important role in route-choice behavior under information. In this regard, we employed the Sensation Seeking Scale (SSS), which is commonly used in the behavioral sciences in order to evaluate risk-seeking/aversion. Sensation-seeking is "A trait defined by the seeking of varied, novel, and intense situations and experiences, and the willingness to take risks for the sake of such experience" [28]. Several evaluation tests for measuring SSS in different domains have been developed, and we adopted one of the most common forms, Form V [28,29] which measures sensation-seeking in these four domains:

- Thrill and adventure-seeking (TAS) - in the area of sports and physical activity. It can be summarized as a positive response to the statement: “I sometimes like to do things that are a little frightening.”
- Experience-seeking (ES) - in the sensory and cognitive domain. An example of a question expressing sensation-seeking in this domain: “I like to explore a strange city or section of town by myself even if it means getting lost.”
- Disinhibition (DIS) – seeking sensation in the social and sexual domain. This can be represented as a positive response to the statement: “I like to have new and exciting experiences even if they are a little unconventional or illegal.”
- Boredom susceptibility (BS) - representing intolerance of repetition and routine of any kind (e.g., work). An example of a statement expressing sensation-seeking in this domain: “The worst social sin is to be a bore.”

The SSS is estimated based on a questionnaire that includes 40 items (10 for each sub-scale) where the score for each sub-scale range between 0-10 (higher score indicated higher sensation seeking). However, since the goal was to make adjustments to the driving task, we replaced the ten questions relating to the DIS domain with ten questions that might reflect sensation-seeking in the area of travel characteristics, such as time and comfort (TC). These questions were based on previous experience with such questions in regard to travel behavior; see, for example, Outwater et al. [30]. Examples of questions describing this factor are “I do not avoid traveling at certain times, because it is too stressful” or “I would change my mode of travel if it could save me some time.” Positive responses to such statements indicate sensation-seeking in this domain. The reason for replacing the DIS domain among the four domains is an earlier, well-known form used to measure SSS, called the “General Scale,” which includes TAS, ES, and BS, but no items representing DIS [28]. Other socio-economic characteristics, such as age and gender, that may have an impact on route-choice behavior, as well as a question regarding the extent of familiarity with the network, were included in the questionnaire.

2.6 Model estimation

The combined RP and SP data were used to estimate a binary Logit route-choice model. The probability $P_n(A)$ that an individual n will choose route A is specified as:

$$p_n(A) = \frac{e^{v_{An}}}{e^{v_{An}} + e^{v_{Bn}}} = \frac{1}{1 + e^{v_{Bn} - v_{An}}}$$

Where: V_{in} is the utility of route i (i=A,B). It is a linear function of the individual's socio-economic characteristics and the alternative characteristics:

$V_{An} = f_{i} (time_{An}, First\_Choice_n, TAS_n, ES_n, TC_n, BS_n, male_n)$

$V_{Bn} = f_{i} (time_{Bn})$

Where:

Time	=	travel time information provided prior to the trip;
First_Choice	=	dummy variable that equals 1 if participant chose route A, and 0 otherwise;
TAS	=	thrill and adventure-seeking
ES	=	experience-seeking;
TC	=	sensitivity to travel characteristics;
BS	=	boredom susceptibility;
Male	=	dummy variable that equals 1 if participant is male.

In order to properly account for the combined RP and SP data in the model estimation, the data was classified into three different groups: the RP experiment with Technion students, the SP experiment with Technion students, and the SP experiment with H.I.T students.

Both binary logit (BL) model and mixed logit (MXL) models were estimated, the later accounting for taste variations among the participants by assuming a distribution of the travel time parameter over the population instead of a single value

3. RESULTS

Most of the Technion sub-sample (75%) reported being very familiar with the study network, while most of Holon Institute of Technology sub-sample (70%) reported being entirely unfamiliar with the study network. The two sub-sample populations had similar socio-economic characteristics: the majority single, age 22-29, possessing a driving license for between 3 and 11 years, and reported having car availability. Approximately 40% were female, which is comparable to their share in the student body of technical institutes in Israel.

3.1 Field study results

As reported by the majority of participants, route A is perceived as less convenient because of the alignment, which has more turns and speed bumps, and because of the uncertainty in regard to the delays that might occur at the campus entrance. However, as will be shown later, the variance in travel time was larger on route B, probably owing to the larger number of traffic lights along this route. Table 1 shows the information derived from the actual travel times, which were provided.

Restrictions associated with Technion requirements regarding the type of automobile insurance that participants in this experiment must have or acquire made recruitment for the field study very difficult and resulted in only 14 students who were entitled to participate. However, since each participant made 12 choices, the sample contained 168 observations; however, 7 observations with data problems were excluded, so that the final sample consisted of 161 records. The experiment was carried out each day only during the morning peak hour which enabled each participant to perform only three trials of roundtrips per day. In order to learn the effect of repeated choice decisions, each participant conducted the task in two days, resulting in six observations per participant. Similar environmental and traffic conditions occurred on all days of the experiment.

3.2 Travel-time approximation

The average travel times (minutes) and standard deviations for both routes and directions (the experiment direction and the return trip) that were compiled throughout the field study are given in Table 2**.**

Table 1 Example of the information provided on a specific day

Date : 19 June 2006	
Direction: 1	
Time	Information provided: Travel time (mins.)
	A B
Till 7:40	4.0 4.0
7:41 - 7:48	4.5 5.0
7:49 - 7:59	6.0 5.0
8:00 - 8:04	6.0 4.0
8:05 - end	6.0 5.0

Table 2 Travel times (in mins.), by route and direction

	Experiment Direction		*Return Trip*	
	Route A	Route B	Route A	Route B
Average travel time	4.9	4.5	5.9	7.8
Standard deviation	0.86	1.03	1.38	2.37
No. of traffic lights	0	2	2	4
No. of observations	26	55	64	15

Table 2 shows that route B has a time advantage, but route A has a variance advantage. On the return trip, route A has an advantage in both time and standard error, making route A clearly a better choice. The return trip has a longer travel time on both routes because of more traffic lights in this direction.

All the participants reported that the tasks were clear and confirmed that they preferred to drive along a route having the shortest possible travel time. Based on the participants' actual route-choices and travel-time data, the following observations may be made:

- A driver's rational behavior is revealed by means of the choices made on the return trip. As shown in Table 2, route A has an advantage over route B in this direction in both time and variance, clearly making route A a better choice. Accordingly, participants obviously favored route A over route B (64 vs. 15 choices). Furthermore, 5 of the 14 participants (36%) always chose Route A in direction 2. All the other participants generally (i.e., in 13 of 15 cases, or 80%) switched back to route A right after traveling along route B in the previous trial.
- In the first trial (in which participants did not receive information), 6 participants of 14 (43%) chose route A, and the rest, 8 participants (57%), chose route B. In the first trip back to the starting point, 2 participants of the 14 (14%) chose route B, and the others, 12 participants (86%) chose route A. This confirms that the participants are familiar with the network and that where there is a clear difference, as in the return trip, most choose route A, which is both faster and has a smaller variance. In contrast, in the in-lab experiment, where it is not clear which route is better, there is a more even split between the choices.
- In trials 2-6, 86% of the route choices were made in accordance with the information. That is, the route chosen was the shorter one in terms of travel time, based on the most up-to-date information provided. A detailed micro-analysis that was carried out for the cases where participants did not make their choice in accordance with the information shows that this behavior can be explained primarily (82% of the cases) because participants seem to prefer the longer route (i.e., it was the route chosen in the first trial); secondly, because of bad experience with information (i.e., the actual travel time was not in line with the information provided) in the previous trials (18% of the cases). Furthermore, most of these choices were revealed in later trials. This result may indicate that compliance with

information decreases with experience, while other factors, such as individual experience and preferences, become more relevant in the decision-making process.

3.3 In-laboratory experiment results

All the participants reported that the tasks were clear, and they confirmed that they preferred to drive along whichever route had the shortest possible travel time**.**

- In the first trial involving the Holon Institute of Technology sub-sample, 30 participants of 39 (77%) chose route A. In the first trial of the Technion sub-sample, by comparison, 14 participants of 25 (56%) chose route A.

- In the next trials (2-20), a general tendency toward route B (the riskier route in terms of travel time variance) was noticed. The Holon Institute of Technology sub-sample chose Route B in 56% of these trials, while the Technion sub-sample chose Route B in 71% of them.

3.4 Combined RP and SP Model estimation

Maximum likelihood and simulated maximum likelihood methods were used for estimating the parameters of the binary Logit (BL) and mixed Logit (MXL) models, respectively, using the BIOGEME software [31]. Different utility specifications were tested to find the best possible utility function explaining the maximum variance in the data. Table 3 presents estimation results for these two models, using the same set of explanatory variables.

Table 3: Estimated model results

Variable	Model 1 - BL			Model 2 - MXL		
	Value	Std. err.	t-test	Value	Std. err.	t-test
Travel time (min.)	-1.06	0.306	-3.45	-1.66	0.312	-5.31
First Choice_dummy	1.22	0.35	3.48	1.38	0.211	6.55
Adventure_score (TAS)	0.00941	0.0224	0.42	0.0248	0.0258	0.96
Experience_score (ES)	-0.113	0.0444	-2.56	-0.135	0.0353	-3.81
TravelConditions_score (TC)	-0.0195	0.0252	-0.78	-0.0239	0.0295	-0.81
Boredom_score (BS)	0.0202	0.0336	0.6	0.0127	0.0392	0.32
Male dummy	-0.127	0.105	-1.21	-0.183	0.115	-1.6
Travel time - Standard deviation				0.962	0.267	3.6
Scale coefficient (Technion RP)	1	Fixed	0	1	Fixed	0
Scale coefficient (Technion SP)	0.979	0.299	-0.07	1	Fixed	0
Scale coefficient (Holon SP)	1.92	0.574	1.6	2.08	0.396	2.73
Number of draws:				1000		
Number of estimated parameters:	9			9		
Number of observations:	1283			1283		
Null log-likelihood:	-889.308			-889.308		
Final log-likelihood:	-566.555			-553.846		
Likelihood ratio test:	645.505			670.923		
Rho-square:	0.363			0.377		
Adjusted rho-square:	0.353			0.367		

The direction of influence of the travel time corresponds with the expectation that the utility of each route decreases as travel time increases. The First Choice dummy shows that, on average, the participants tended to prefer their initial choice instead of switching routes.

In regard to personality characteristics, the results of experience-seeking are interesting. This variable has a negative and significant coefficient at the 5% level. This indicates that when the experience score increases (i.e., individuals with more experience seek and prefer new experiences), the probability of using route A (the route with the smaller variance in each direction) decreases. The score for thrill and adventure-seeking, although not significant, has a positive coefficient, indicating the probability that using Route A also increases with a rise in this score (i.e., individuals with more thrill and adventure-seeking). It should be noted again, that route A involves more turns and bumps and, therefore, might be perceived as more appropriate for thrill and adventure-seeking individuals. Finally, the male dummy coefficient shows that male drivers preferred the riskier route (in terms of greater travel time variance) although this variable is significant only at the 15% level.

The scale coefficients estimated in the BL model show that there are no significant differences between the Technion RP and SP data. However, the scale coefficient for › H.I.T students is significantly different from 1. This means that the coefficients for the explanatory variables for H.I.T students should be divided by a factor of 1.92 (in the BL model) or 2.08 (in the MXL model). The behavioral interpretation of this result is that H.I.T students are less sensitive to travel time than are Technion students. This may be explained by the fact that the routes are not familiar to the H.I.T students.

As indicated in the previous section, the MXL model can accommodate taste variations across the population. This is accounted for in the model by assuming a normal distribution of the travel time coefficients. The standard deviation of the coefficient can be estimated, and the parameter is significantly different from zero at the 5% level, resulting also in an overall better likelihood.

4. DISCUSSION AND CONCLUSIONS

This paper combined data from both a field study and an in-laboratory experiment to enhance our understanding of the impact of information and individual personal characteristics on drivers' route-choice behavior with pre-trip information. It adds to the limited research on route-choice behavior by being based on revealed preference as observed in a field study. Our research shows that the provision of information has a significant impact on the route-choice behavior of drivers who are faced with relatively short substitute routes in a simplified network.

The results of the study indicate that individuals use the information received to reduce uncertainty; in the present case, to lessen the greater variance related to route B and to opt for it. Most route choices were made in accordance with the information received. However, in line with the results of other studies (see, for example, [32, 20, 22), drivers in this study were found to be more reluctant to be influenced by the information provided if they had more experience with the routes. Our results may imply that although compliance with information decreases with experience, initial preference for certain routes becomes more relevant in the decision-making process; that is, individuals tend to choose the route chosen in the initial trial. The effect of bad experience with information (e.g., the actual travel time was not in line with the information provided) seems to have less impact on route-choice behavior in a simplified network than does initial preference.

The paper extends the common characteristics used in travel behavior analysis and provides more insight into the reasons that cause different drivers to choose their travel route and their compliance with information. To the best of our knowledge, these types of personal characteristics have not previously been used in route-choice analysis; furthermore, the notion of sensation-seeking is novel in this context. Generally, when experience-seeking (one characteristic of sensation-seeking) increases an individual tends to choose a riskier route (in terms of greater travel time variance). The results presented here show that experience-seeking has a significant effect on route-choice behavior. Gender was also found to have an impact on the route chosen, as male drivers preferred the riskier route (in terms of greater travel time variance).

Restrictions associated with the small number of participants in the field study, therefore resulting in a limit number of observations, prevent the results from being considered very robust. However, stronger validity is achieved by combining data from the field study with those obtained from in-laboratory experiments. Comparisons show that both sets of data are in accord. There is need for more studies based on revealed choice to analyze the effect of information on route choice. Such studies should use larger and more heterogeneous samples that would allow testing the relative contribution of a range of typical personal characteristics, and not just the sensation-seeking trait presented in this paper, to explaining route-choice behavior. An effort should be made to find more appropriate real networks, where different situations of mean and variance of travel time among parallel routes can be compared. It would also be interesting to follow participants' route choice over a longer period in order to study the combined effects of information and experience on route-choice.

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FIGURES

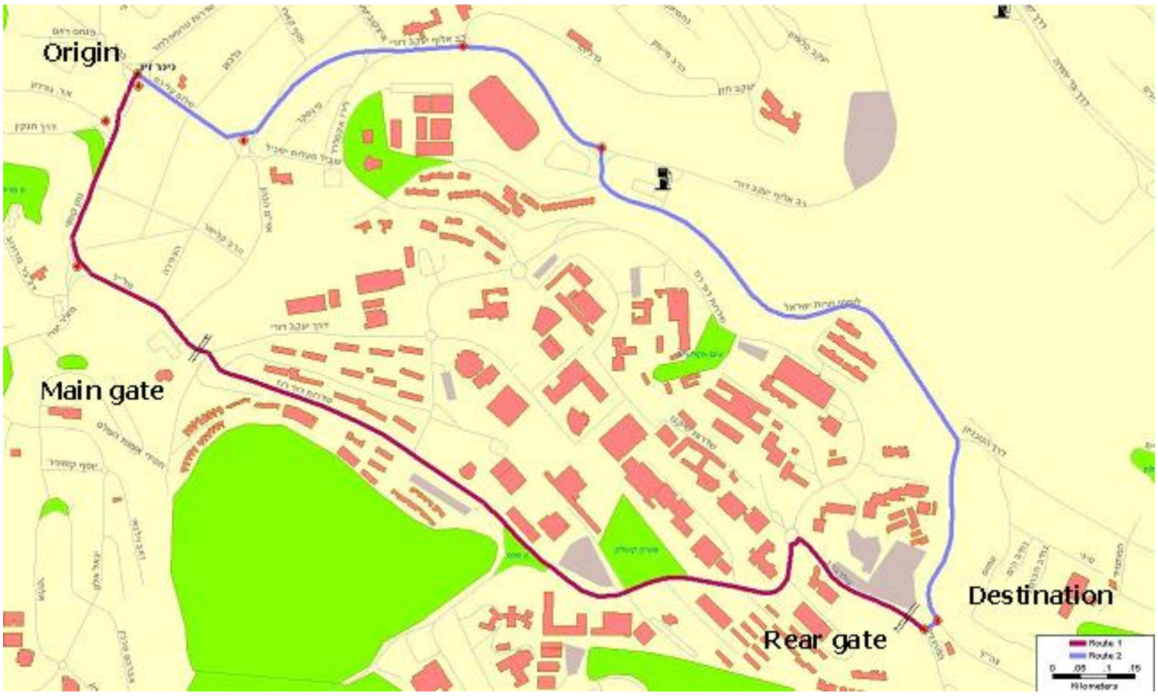

Figure 1 The study network

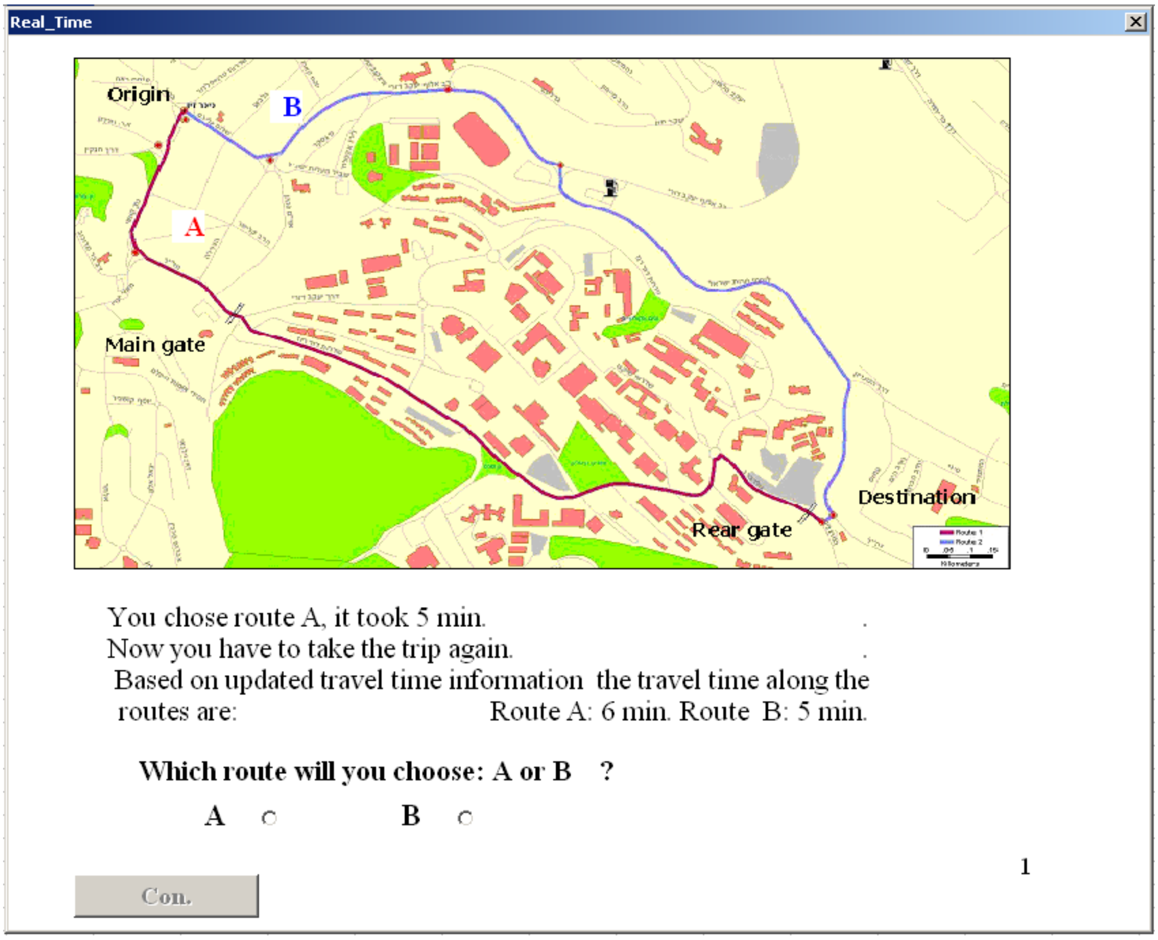

Figure 2: Example of a screen presented in the in-laboratory experiment