A Web 2.0 Platform for Experimental Research into Day-to-Day Route Choice Behavior in Advanced Traveler Information Systems

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ABSTRACT

This paper describes the architecture and uses of a web 2.0 platform for studying drivers' day-to-day route choice behaviors. In the study, we particularly focus on the heterogeneity of drivers' temporal decision-making frequencies in relation to a specific information provision framework. The platform was designed to be flexible, scalable, and inexpensive for the realistic experimental testing of drivers' route choice decisions. With this interactive and distributed Internet-based simulation environment, we aim to gain an insight into the interaction between trip-makers, network traffic dynamics, and information provision in Advanced Traveler Information Systems (ATIS). This study provides a framework and tools for evaluating the benefits of information and communication technologies. It also describes web-based experiments that test the impact of historical pre-trip information on the day-to-day dynamics of transportation systems and the lessons to be learned from previous experiments in two-route choice scenarios.

Keywords: day-to-day route choice; experimental research; Web 2.0 platform; decision-making frequencies.

1. INTRODUCTION

Drivers' route choice behaviors can significantly influence traffic congestion on a road network and is affected by the traffic information provided by Advanced Traveler Information Systems (ATIS). In the literature, many studies use route choice surveys *(1-3)* or route choice simulations and modeling *(4)* to study drivers' day-to-day behavioral responses under real-time information provision conditions. Numerous experiments have been carried out to study drivers' responses to provided information by simulating the actual driving environment in laboratories, particularly by using interactive computer simulations.

In the first generation of experiments, participants only interact with a computer in a totally simulated environment and not with each other *(5-12)*. Although these experiments provide many insights into various aspects of drivers' route choice behaviors, they are costly to implement and limited without considering interactions among drivers. The second generation of experiments are based on a Local Area Network (LAN), which simplifies the data collection process and enables real-time interactions among participants *(13-20)*.Yang et al. provided a detailed account of how these studies were carried out *(21)*.But these studies are limited in their scalability and efficiency: The difficulty in scaling experiments to a relatively large number of participants and rounds due to the cost of manually conducted experiments and of recruiting a large pool of participants is explained by Bogers, Viti, and Hoogendoorn *(18)*; In addition, different platforms cannot be easily adapted to people located in different parts of the world.

In the literature, behavioral studies have been carried out with the aid of the World Wide Web (WWW)*(22)*. Berners-Lee et al. *(23)* argued that the Web can be used as a universal medium for data, information and knowledge exchange. With the development of the Web 2.0 technologies *(24-25)*, people can use a variety of Web sites and applications to interact and share information online and control their personal data that are mostly stored in cloud-based tools *(26)*. This can lead to a more effective, interactive experimental platform, which can be used to explore individuals' behaviors in a realistic situation. Although many of these tools are still at an early stage of development, their implementation has proven to be highly effective for the Intelligent Transportation Systems industry *(27)*. One interesting application of social networks and smart phones is the person-to-person car-sharing network, enabling car owners to rent their vehicles to friends within their social networks *(28)*.

Web 2.0 is a dynamic, efficient, collaborative and interactive platform, where online users become participants rather than only viewers. Reips *(29)* provides a detailed description of the potential advantages and disadvantages of using WWW as an experimental platform (see Table 1), and we would expect the Web 2.0 platform to perform in a similar way. The main difference between the Web 2.0 platform and traditional LAN based platforms is that an interactive Web 2.0 based tool can allow experiment participants at different physical locations. However, the advantatges and disadvantadges of using one or another remain similar because the used technology and background framework are common between them.

Advantages	Disadvantages
Cost savings in terms of laboratory space, on-site working hours, equipment, and administration.	Multiple Submissions (check answer consistency).
Access to large samples (openness) implies a large statistical capability.	Lack of experimental control e.g. difficulties when interacting with participants.
Easy access to demographically and culturally diverse participant populations.	Drop-outs if no financial incentives are provided.
Avoidance of time constraints and organizational problems such as scheduling difficulties and possible involvement of hundreds of participants simultaneously.	Problems if instructions and directions are misunderstood (feedback important)
Ease of access for participants.	Self-selection and limited external validity of experiments.

TABLE 1. Main methodological advantages and disadvantages of using the Internet for experimental research as described by Reips, 2000 *(29)*.

In this study, we investigate a Web 2.0 approach for studying drivers' day-to-day route choice behaviors. Although we follow the experimental design described by Selten et al. *(19)*, the Web 2.0 platform could provide an effective alternative to implement the experiment. We believe that our experimental approach is much more effective in terms of obtaining and sharing information. In other words, our experimental framework is sufficiently scalable, effective and flexible to save time and money when carrying out day-to-day route choice experiments. The experiments can be used to study the system performance in efficiency and stability of traffic networks under information provision conditions.

In Section 2, we describe the proposed experimental framework. In Section 3, we discuss the set-up of a web 2.0 platform for experimental research into day-to-day route choice behavior. In Section 4, we present the results of our experiments and compare the effectiveness of our approach with existing ones. In Section 5, we summarize our findings and suggest some future research options.

2. EXPERIMENTAL FRAMEWORK

Unlike most existing studies, we designed an experimental platform based on the free Google Docs Form tool. The platform consists of four modules: a survey module, a data collection and storage module, a data processing and quality control module and a traffic information feedback module (see Figure 1). In the survey module, each participant is given a Google Docs Form, in which participants are asked to choose their route and to submit their choice in each round through the Internet (see Figure 2, left). After participants have made their final route choice submissions, they are requested to go back to the form before continuing the experiment (see Figure 3).

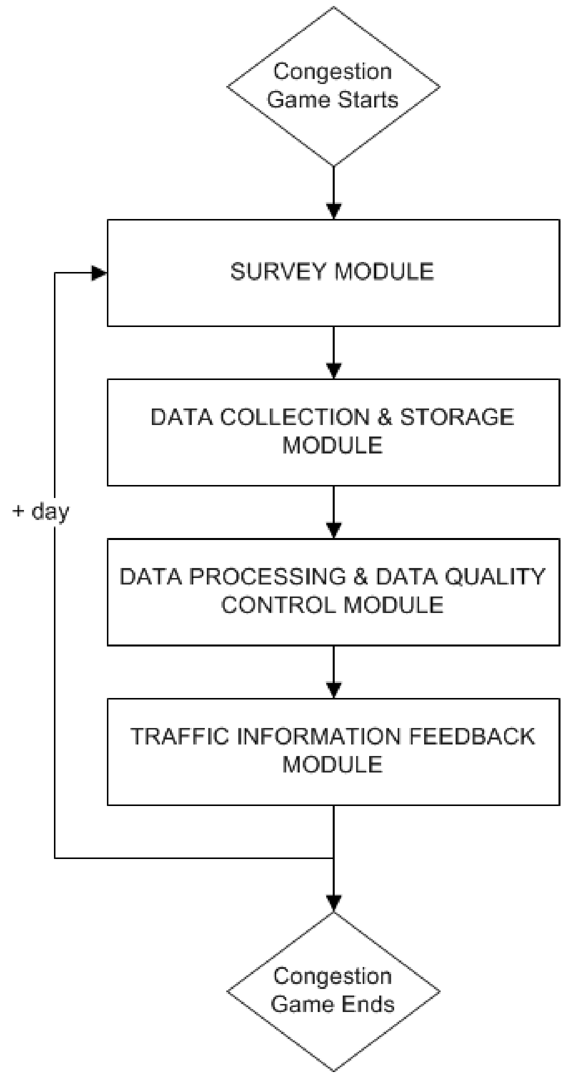

FIGURE 1. Experimental platform.

Participant IDs and choices are collected and stored in the data collection module. In the data processing and quality control module, a Google Docs spreadsheet has been designed to collect and check the consistency of all submissions, avoiding multiple submissions from the same participant in each round, and to calculate the travel costs of all routes through link performance functions. In the traffic information feedback module, travel costs on different routes are delivered to all participants using a Google Docs spreadsheet. The results are updated dynamically (auto refreshed and published as a webpage), enabling participants to access post-round information on a real-time basis (see Figure 2, right).

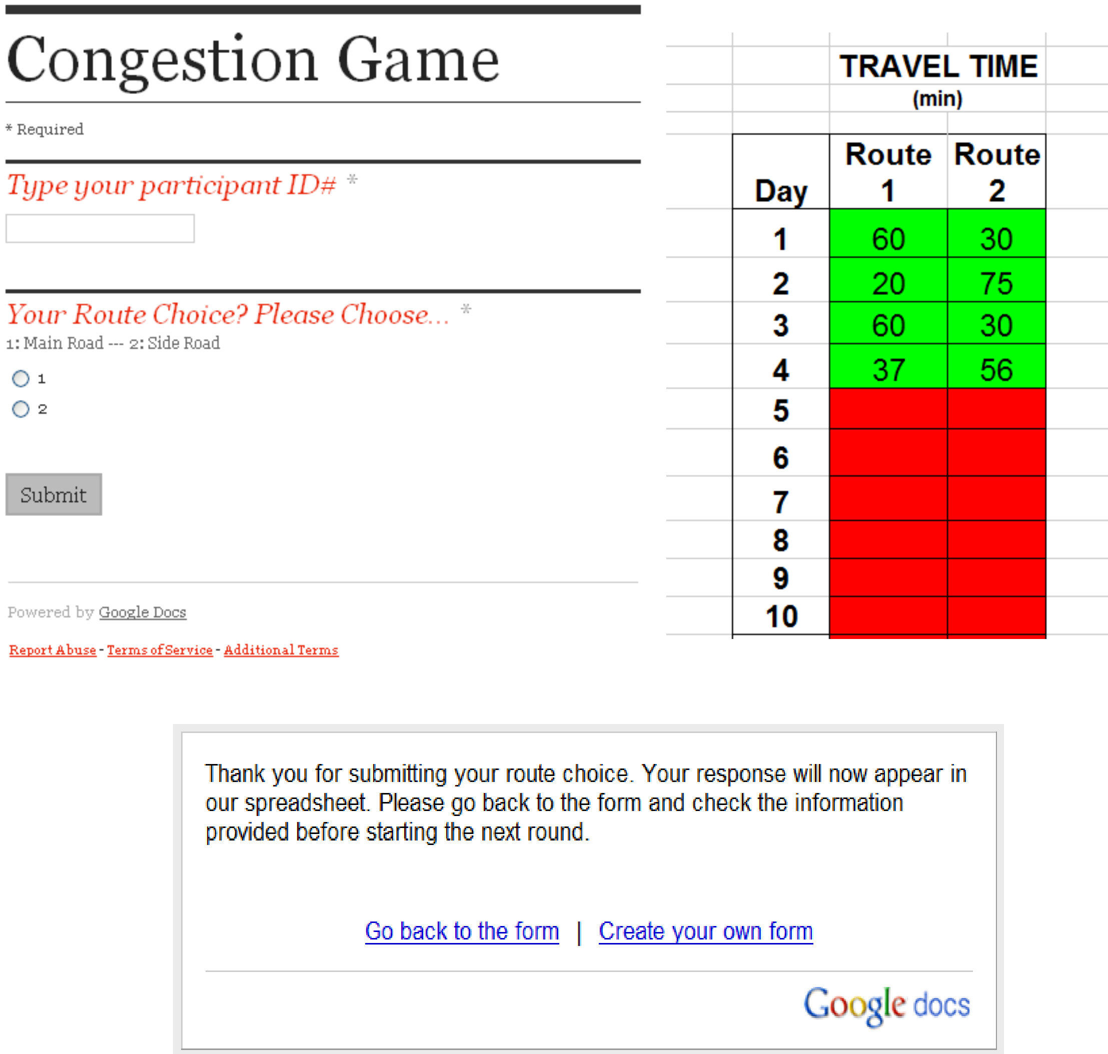

FIGURE 3. Answer submission acknowledgment screenshot.

Using our framework, the congestion game experiment can be played with more than twenty people reading the results at the same time and submitting answers. This speeds up the output rate in terms of receiving responses and introduces decision-makers to a new, fast and easily manageable media environment. Since our platform is based on the Internet, it is not necessary for participants to be in the same physical location in order to conduct the experiment.

3. SPECIFIC CASE STUDY

We carried out a web-based experiment on route choice behavior in a two-route network involving a single O-D pair connected by two alternative parallel routes. This case study was carried out in order to demonstrate the potential of web-based tools for data collection. In these experiments, participants are repeatedly requested to simultaneously respond to hypothetical route choices under specific information provision conditions.

In the experiment, 21 senior civil engineering undergraduate students from the University of California, Irvine, play together in a computer laboratory and make choices during each of the 50 periods that the web-based experiment lasted. Participants were informed that they must travel from starting point A to destination B (see Figure 4) and were presented with a new route choice decision each day. They could choose whether to travel a main route or a side road to get from A to B as quickly as possible. Before starting the experiment, the participants double-check their internet connections and are also sent the online form and a link to the published data. Participants are advised not to communicate with each other to avoid cooperations. The game situation is the same for each participant.

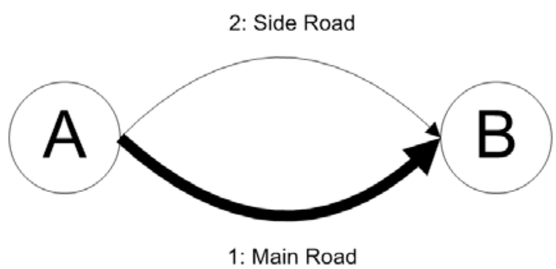

FIGURE 4. Day-to-day route choice scenario.

Variable day-to-day traffic conditions are expressed in terms of travel time. If traffic conditions are similar on both the main route and side road, travel time is shorter on the former, as side roads congest more quickly than main routes: $t_{Main} = 20 + 40\frac{N_1}{N}$,$t_{Side} = 30 + 45\frac{N_2}{N}$ where N is the total number of participants, and N_1 *and* N_2 are the number of participants traveling on main routesand side roads, respectively. Travel time computation depends on the number of participants on each route and road capacity. These formulas are not disclosed to the participants and computed in the background. As we know, the network reaches user equilibrium when $N_1 = 13.6$ and system optimal when $N_1 = 12.4$.

The conceptual diagram of the experiment is shown in Figure 5. After a round, the participants receive feedback from the traffic information feedback module about the day number and travel time on each route. Thus all participants are provided complete historical information. No forecast or additional information is provided in the experiment.

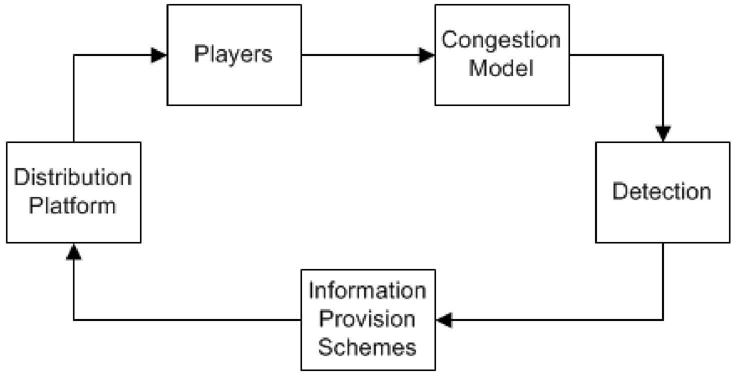

FIGURE 5. Conceptual diagram of experiment.

During the experiment, participants are advised to write down their route choice decisions in order to remember and track their day-to-day travel times from previous rounds and to choose the following day's route according to the information provided. Before the experiment, participants play several rounds to ensure they understand the instructions.

4. RESULTS

Although we endeavored to reproduce the conditions and methodology described by Selten et al. *(19),* the proposed approach is more efficient than those used in existing studies (see Table 2).

	# of participants	# of rounds	Time to complete one round (sec.)	Advantages /characteristics	Limitations
This study	21 (collaborative)	50	Less than 20 sec.	Internet-based platform: scalable, efficient and flexible. Saves money/time. Simple set-up. No equipment or computer lab required	Difficulty in recruiting participants (incentives needed)
Selten et al. (2007)	18 (collaborative)	200	Unknown but short	LAN-based experiment. Interactive tool* Easy to play. Collaborative	Platform not Internet-based (not scalable)
Avineri et al. (2003 & 2006)	46	100	Decision time: at least 2.5 sec after information is provided	PC-based.	Not interactive or collaborative**
Bogers et al. (2005)	14-21 (collaborative)	25	Unknown. Complicated step sequences during experiment.	PC-based. Collaborative experiment.	Tool not interactive. People tend to give up after 20 repetitions
Berninghaus et al. (1998 & 2001)	48 (participating collectively)	10-90	90-10	LAN-based experiment. Test time pressure by reducing decision time interval. Interactive tool*. Collective experiment.	Platform not Internet-based (not scalable)
Vaughn et al. (1992 & 1993)	23-29	32	Avg. decision time: 2.1 sec. after information is provided	PC-based experiment. Advice compliance under different information accuracy provision conditions	Not an interactive tool. Not a collective experiment**.
Iida et al. (1992)	40 (participating collectively)	20-21	200 sec. per round aprox.	Pen & paper experiment. Interactive tool* Collective experiment	Pen and paper experiment (not PC based). Slow/manual procedure.
Bonsall (1992)	350	37	Unknown	PC-based experiment. Advice compliance under different information accuracy provision conditions.	Tool not interactive. Not participating collectively**.

**interactive tool: traffic conditions are purely affected by players' route choices (dynamic game / participant real time interaction). ** participants not playing together.*

TABLE 2. Comparative efficiency of new and previous approaches.

The number of participants on each route tends to be close to equilibrium, in which the number of users on the main road is around 13.5 (see Figure 6, left). Nevertheless, the density of participants observed on the main route shows a high level of variability (see Figure 6, right), meaning that equilibrium is not reached and the system experiences oscillation until the end of the experiment.

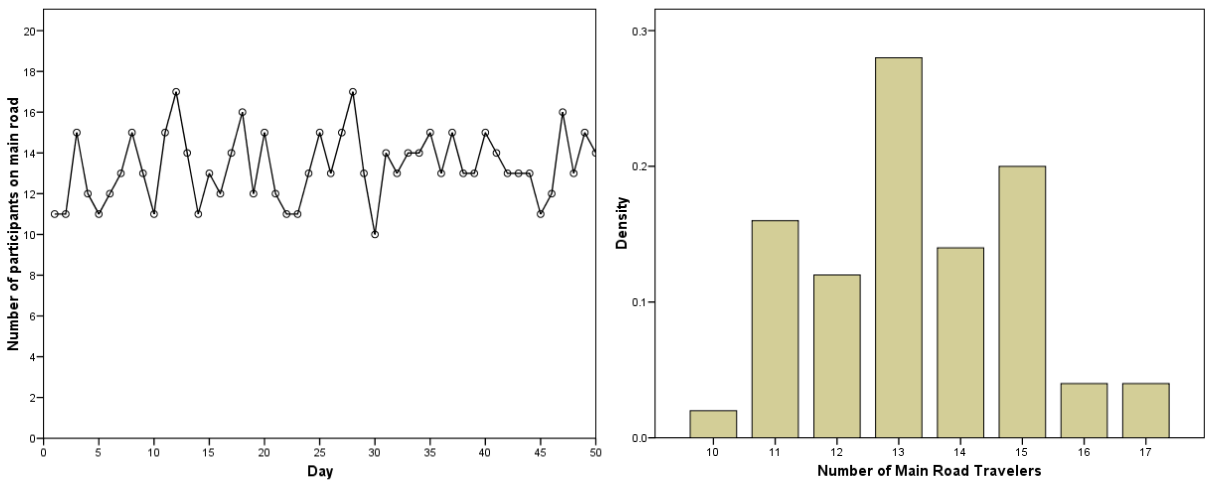

FIGURE 6. Number of participants on main road at each iteration (left). Distribution of number of main-road travelers with a wide range of dispersion (right).

With higher frequency rates, we observed that N_1=13 and N_2=8, meaning that the system average travel time of t=45.7min is located between the UE and SO values. However, due to variable frequency, the system itself does not converge to a specific stable state, indicating that travel times vary greatly from day to day (see Figure 7, left). Thus, the cumulative average system travel time is greater than the desired specific UE/SO values. This shows that the system does not converge or behave as theoretically expected (see Figure 7, right).

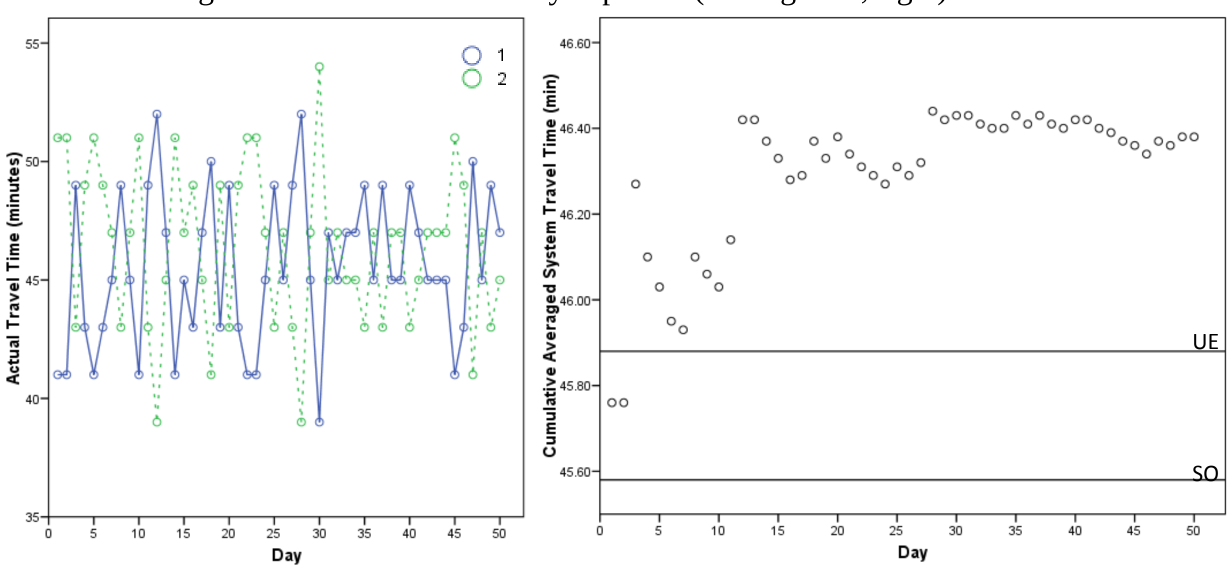

FIGURE 7. Evolution of travel time on each route (left). Evolution of cumulative average system travel time (right).

Like Selten et al.*(19)*, we studied the relationship between cumulative averaged system travel times and the number of route changes, which was found to decrease as a function of time (see Figure 8, left). This is consistent with the findings of Iida, Akiyama, Uchida and Selten (12, 19). When participants decide to switch routes, most of them tend to move to the less time-consuming route on the last simulated day (see Figure 8, right). We can therefore infer that 64% of the switches turn out to be moves to the shortest route, in travel time terms, on the last simulated day. Participants take into account the final day's information provision in their decision-making and expect the tendency to remain the same when taking the shortest route.

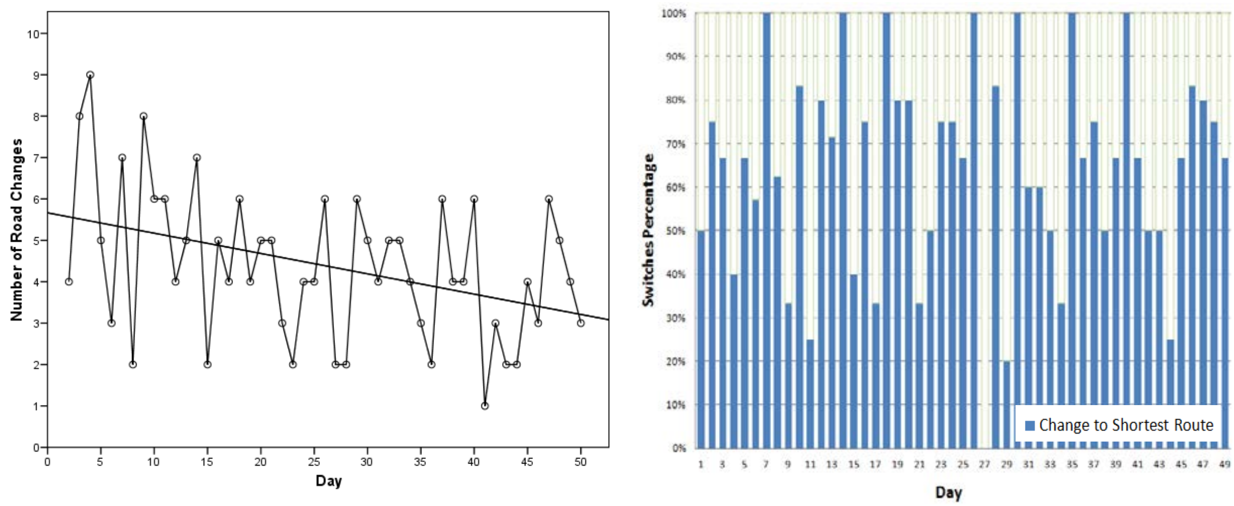

FIGURE 8. Number of route changes (left); straight line corresponds to the linear regression of the number of route changes as a day-to-day function. Percentages of switches to the shortest route as a day-to-day function (right).

Almost 50% of the respondents show a low frequency of route switching (less than 6 times during the whole experiment), as they see no reason to switch routes in order to lower their individual travel times for example. We need to increase the size of the sample in order to understand decision time interval distribution patterns (see Figure 9, left). However, preliminary results indicate that drivers are prone to heterogeneous decision time periods in relation to temporal decision-making and route changes and show a wide diversity in route choice behavior frequency. On the other hand, the number of route changes correlates positively with the cumulative travel time. This means that participants who tend not to change route save more travel time than those who switch routes from day to day. Similar results have been observed in the experimental study carried out by Selten et al. (19) who reported that the number of route changes negatively correlates with participants´ final payoff. We can therefore conclude that the results shown in Figure 9 (right) are highly consistent with the findings reported by Selten et al. (19).

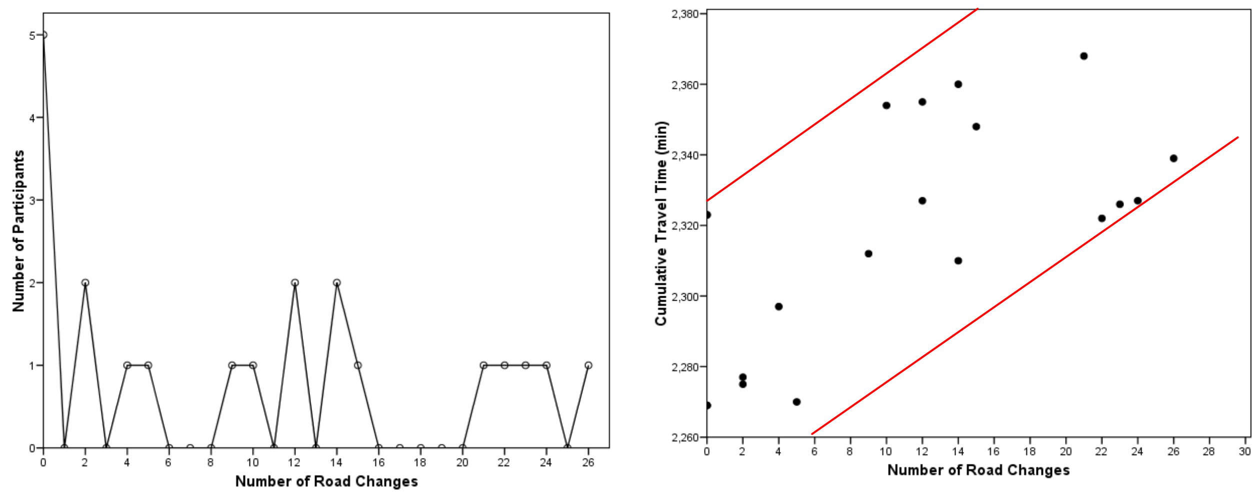

FIGURE 9. Route change distribution (left). Scatter diagram of cumulative travel time / number of route changes (the data clearly fits into the band defined by the plotted red lines) (right).

5. CONCLUSIONS

This study provides promising lines of extensive experimental research in the future using web-based dynamic experimental tools to study drivers' route choice behavior. It also provides a tool for evaluating the benefits of information and communication technologies. One of our most important findings is that drivers consult traffic information and choose their routes with different frequencies (asynchronous decision-making), which means that decision intervals vary. We intend to use our newly developed simulation platform to further test this hypothesis and its implications in order to gain a greater insight into the rhythm and nature of drivers' route-changing frequency. This would provide us with possible ways of improving and realistically evaluating ATIS services in order to make transportation systems more stable and efficient.

Our low-cost method has proven potential benefits and would be an effective starting point for introducing web-based information and communication technologies to improve and scale experimental day-to-day route choice studies to study and resolve specific route choice behavior problems. After developing effective information provision schemes for making systems stable and efficient we aim to carry out real-world in-field experiments using smart phone applications. The framework, methodology and tools we have developed could be extrapolated to larger scale experiments and other fields of study such as experimental economics. To ensure that the participants around the world communicate effectively, we suggest using one of the many communication tools available online such as Twitter, Google Buzz, Skype and the recently implemented webinar tool Dimdim for conferencing purposes before and during the experiment. These tools allow participants to question those carrying out the experiment, share information, make any necessary comments and provide explanations during the entire experimental process by, for example, repeating answer submissions for any specific round if required.

Most importantly, our study enables experiments to be carried out on the collection of data concerning drivers' route choice behavior under an information provision scheme that were difficult to perform previously.This can now be done in a more efficient web-based platform that is scalable, fast and more user friendly for respondents. The platform is inexpensive, consistent, sufficiently flexible for modeling different operating scenarios and is easier to implement. It also considerably reduces the processing required since the data is obtained directly from the electronic form (Excel spreadsheet). All the data mining needed to perform the experiment and to obtain results is therefore more straightforward.

There are still certain limitations in our study and challenges to be faced. For example, all the participants were undergraduate students with relatively homogeneous characteristics. There are other limitations related to the experimental environment and control issues. For example, although participants were not allowed to communicate with one another, they could find out about the route choices of other participants as they were seated close to each other. In later studies, we could overcome the difficulty of recruiting participants by emailing student groups in different universities and by organizing events through various student groups and forums.

Future research work will include an environmental and energy consumption perspective. Route types, such as freeways and arterial roads, as well as the level of traffic congestion have a major impact on fuel consumption and CO_2 emission *(31)*. In light of the work carried out by Ahn and Rakha *(32)*, we will study the trade-offs between traveling longer but faster routes and traveling shorter but slower routes in terms of energy consumption and emission rates. Using our newly developed experimental platform we aim to study the impact of route choice decisions on vehicle energy consumption and pollution caused by greenhouse gas (GHG) emissions.

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