EVALUATION OF CHANGES IN INDIVIDUALS' ACTIVITY-TRAVEL BEHAVIOR INDUCED BY ADVANCED TRAVEL INFORMATION: DESIGN OF A STATED ADAPTATION APPROACH

Zahra Parvaneh, Urban Planning group, Eindhoven university of technology, Eindhoven, 5612 AZ, The Netherlands.

Theo Arentze, Urban Planning group, Eindhoven university of technology, Eindhoven, 5612 AZ, The Netherlands.

Harry Timmermans, Urban Planning group, Eindhoven university of technology, Eindhoven, 5612 AZ, The Netherlands.

ABSTRACT

There are high expectations among policy makers about the benefits of the provision of travel information to trigger particular travel behaviors that would contribute to sustainable mobility. Currently, travel information is mostly descriptive and distributed to a group of travelers. The tendency however is to move from descriptive information to prescriptive information. The goal underlying prescriptive information is to induce travelers to behave in particular ways. Moreover, whereas currently most travel information are static, the expectation is that in the near future information services will become dynamic and be able to describe the latest or even predicted situation. Finally, the increasing availability of smart phones allows one to issue context-sensitive, personal advice. In that sense, at least in principle, dedicated personalized recommendations could be provided. Such new technology, however, requires advanced data collection and a new generation of models about traveler strategic responses. In that regard, stated adaptation experiments are a proper approach to collect data when the technology still is not available to use in practice. In this paper, we introduce an innovative stated adaptation approach to assess possible behavioral changes in the presence of advanced forms of travel information. In the proposed SA approach, first, profiles of individual's habitual activities and travel pattern are collected. Second, different scenarios are given to subjects, who are asked how they would change these habitual patterns under information provision.

Keywords: Travel behavior, advanced travel information, stated adaptation.

INTRODUCTION

Provision of travel information and its impact on activity-travel patterns is receiving more attention among researchers and policy makers due to current developments in advanced information and communication technologies (ICT) and a rapidly increasing application of these technologies. This increasing interest partly comes from the expectation that providing travel information can decrease uncertainty about the state of the network. In addition, it can enhance sustainable accessibility and optimize current infrastructure usage.

During the past decades, travel information was mostly static, public and descriptive, e.g. information about congestion on a particular route would be given to the drivers via radio. Increasing availability of more advanced information services, such as web-services, navigation systems, and smart phones, emphasizes the possibility of providing personalized and prescriptive information or recommendations anytime and anywhere to the individuals using real-time travel information. Providing such information to travelers is considered to be a potential strategy for influencing individual behavior related to route, mode, departure time, destination choice or even entire trip patterns. Consequently this kind of travel information may impact behavioral dynamics behind activity-travel pattern (re)scheduling.

Though many literatures have investigated the impact of information on facets of activity-travel patterns, few studies looked at personalized and dynamic descriptive or prescriptive information. Most of the studies either discussed travel choices given static, public and descriptive information (e.g. Emmerink, et al. 1995; Yim and Khattak, 2002; Arentze and Timmermans, 2004; Chen and Mahmassani, 2004; Chorus, 2007; Sun, 2009) or described the process of information acquisition (e.g., Polak and Jones, 1993; Polydoropoulou and Ben Akiva, 1998; Hato, et al., 1999; Kenyon and Lyons, 2003). Basically, theories and models of travelers' response were not considered as a noticeable issue and the focus was mostly on willingness to pay. Hence, when it comes to advanced ICT tools, all these studies are somehow limited. It is still not clear how individuals respond to advanced travel information; how they cope with the uncertainty; how they assess the credibility of information; and how they consider these issues in the activity-travel (re)scheduling decisions. One of the issues that cause the lack of knowledge is that such new technology that provides personalized information doesn't exist yet. Therefore researchers are not able to investigate its impacts in the real world. In that regard, an advanced data collection technique and a new generation of models about traveller strategic responses are required. In absence of the technology to use in practice stated adaptation experiments are a proper approach to collect data.

Although SA has been implemented in several studies assessing changes in individuals' activity-travel behavior (e.g. Arentze et al. 2004; Cools et al. 2011; Weis et al. 2010a; Loukopoulos et al. 2004; Nijland et al. 2009; Weis et al. 2010b), it has been barely used to study the travel information impacts in contrast to revealed preference and stated preference or choice experiment. Using a RP survey Dia (2002) developed an agent-based approach to model driver route-choice behavior under the influence of real-time information, both prescriptive and descriptive. Hato et al. (1999) employed a RP experiment to incorporate an information acquisition process into a route choice model with multiple information sources. In a SP study Polak (1993) investigated that how would pre-trip descriptive travel information acquisition affect travel behavior. SP approach has been employed in several studies assessing travel information impact on different aspects of route choice problem. Ben-Elia et al (2013) studied travel information accuracy on route-choice. Lu et al (2010) evaluated the individuals learning behavior. Avineri and Prashker (2006) investigated impacts of descriptive travel information on travellers' learning behavior under uncertainty. So many of the studies that adopted SP approach used a traffic simulator to represent the hypothetical scenarios to the respondent (Nathanail et al. 2011; C. Chorus et al. 2007; C. Chorus et al. 2013; Srinivasan and Mahmassani 2003; Tian et al. 2010). Although that these studies assessed different dimension of effects of travel information on activity-travel behavior, but mostly they are limited to the route choice, they considered just one type of the information, they used hypothetical scenarios that decreases the realism in the results. In addition in most of the cases individuals' habitual activity-travel pattern and daily agenda is neglected.

The present study introduces an innovative SA approach to evaluate effects of advanced travel information on individuals' daily activity-travel behavior. We visualize the real world and possible changes in a way that the introduced situation would feel as close as possible to the reality. Furthermore, we give the respondent the possibility to induce changes in his/her activity travel pattern using an interactive system. The result would be a system that captures in details individuals' activity-travel pattern and the changes they would apply to their pattern if they would be confronted by changes in their environment.

The paper is organized as follows. First, we will outline the approach and method that are developed to analyze the activity-travel behavior. Next, we will discuss the web-based stated adaptation experiment design. Furthermore, we will point out the strength and weakness points of the proposed approach and design. Then, we will end the paper by giving a summary of the proposed approach and design and possible future developments.

RESEARCH OBJECTIVE AND METHODOLOGY

Background

How individuals define their daily activity-travel pattern and choose between routes, modes, departure times, etc. has been always an important question in transportation management and planning. In general, individuals are assumed to make decisions based on their perception or beliefs of reality, their knowledge of their environment and their past experiences (Koppelman & Pas, 1980; Golledge 2002). Individuals are not always aware of all possible alternatives and they make their choice among their known alternative sets. Providing travel information to individuals may change their beliefs, increase their knowledge of the environment and introduce them to new alternatives. In addition, it is argued that travel information may decrease uncertainty about the state of the transportation network (Sun et al. 2005). However, travel information itself may induce some uncertainty related to the credibility of the provided information, or to an individual's beliefs about credibility of the travel information.

In addition, the travel information itself and more specifically the type of travel information that is provided to the individual can affect the decision-making process. For decades different types of travel information have been introduced to the travelers: pre-trip or en-route, public or personal and recently prescriptive information versus descriptive one. It has been argued that depending on the type of information, individuals may respond to the information differently and they may change or not change their activity-travel pattern (Parvaneh, et al. 2011). In this paper we study effects of advanced personalized travel information. We define personalized travel information the kind that in which individual's personal (habitual) activity-travel behavior is considered in generating the information. Moreover, we mainly focus on the prescriptive and descriptive information. Therefore we just look at the impacts they might induce on the individuals' decision-making process.

The difference between descriptive and prescriptive information in general is that in the latter case, individuals have to translate the recommendation into their mental representation of the activity-travel scheduling decision and assess the expected utility of alternative activity-travel schedules, at least comparing the planned schedule against the recommended schedule. Usually, the recommendation will not involve all facets of the complete activity-travel schedule and therefore an individual will have to consider a set of alternative schedules, including the recommendation. In addition, there is a difference in the belief updating process when the information is descriptive or prescriptive. Descriptive information gives more and updated information about the state of the network, e.g. real travel time of a particular route (Chorus et al. 2009; Parvaneh, et al. 2011). As a result, the individual will process the received information, and then update his/her beliefs about the network state. In other words, information directly impacts the individual's beliefs, which may lead to changing his/her activity-travel schedule. As argued by Chorus et al. (2009), this belief updating will be dependent on the objective of the recommender system as perceived by the traveler. In contrast, prescriptive information does not give quantitative information and may introduce new choice alternatives to the individual. As a result, the individual will evaluate the choice alternatives and compare them with known ones, and then choose among the choice alternatives.

In order to evaluate changes in individuals' activity-travel behavior induced by advanced prescriptive and descriptive travel information it is important to consider individuals' characteristics, perception of the reality, preferences, knowledge of the environment and their past experiences as well as the characteristics and attributes of the new situation that they are being exposed to. Regarding, the information attributes and whether it is accurate or not and consistent with the reality perform a significant role to stimulate any changes. Looking at the studies on activity-travel behavior, barely they considered all these factors together. In the case of RP studies there are almost none that evaluates impacts of advanced personalized travel information since the technology to provide this kind of information is not available yet. In the case of SP and SA studies, mostly hypothetical scenarios are introduced to the individuals using a travel simulator. Accordingly, effects of individuals' habitual activity-travel behavior on their choices are overlooked.

Methodology

Comparing SP and Stated Choice to SA as it is argued by Arentze et. al. (2004), the latter provides respondents the freedom to indicate how they will change/adapt their activity-travel behavior as a response to the new state. While in SP and SC experiments a set of choices is provided to the respondents and they will rate choices according to their preferences or choose the best alternative. Considering that in this study we provide personalized travel information and we aim to maximize the realism of the experiment, SA approach seems to be the best approach to follow. Since, first providing personalized information means that scenarios presented to the respondents would not be necessarily identical. Second, having the freedom to adapt the behavior would increase the authenticity of the responses. We propose a three phases SA approach. Phase 1 includes collecting individuals' socio-demographic information, which will specify their characteristics. Phase 2, includes collecting individuals' habitual activity-travel pattern. That will specify their preferences, experiences and knowledge of the environment. Phase 3, includes introducing new situation to the individuals by providing personalized travel information and observing how they may adapt their activity-travel behavior. Figure I depicts the proposed SA framework.

In the proposed approach:

- Individuals are the selected unit of the evaluation since an individual has certain beliefs, preferences, characteristics and even constraints which play the main role in the decision making process,
- The habitual activity-travel pattern of the individuals is observed, since we assume that the individuals modify their behavior on the basis of original pattern,
- One activity is selected, since we aim to evaluate the short term and direct effect of provision of advanced travel information on individuals' activity-travel behavior,
- Prescriptive and descriptive travel information are provided to the individuals, which are generated taking into consideration individuals' activity-travel pattern.

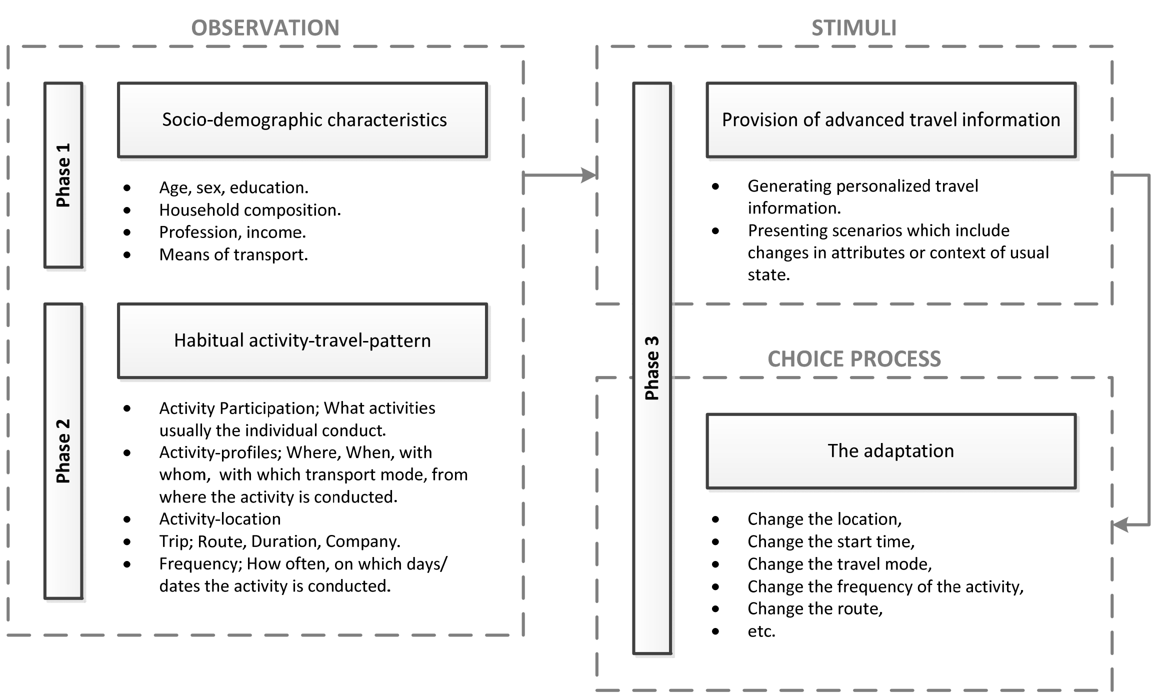

Figure I, framework of the proposed SA experiment.

EXPERIMENT DESIGN

Phase 1- Socio-demographic characteristics

The first phase of the survey is to collect individuals' socio-demographic data. Respondents are asked to complete a series of multiple-choice questions. Questions are divided into two general subjects; Personal and household information including gender, age, household composition, education, employment status; and transportation including car-ownership, possession of public transport discount card, and travel expenses.

Phase 2- Habitual activity-travel pattern

Activity-participation

In order to identify individuals' habitual activity-travel patterns, the first step is to collect a list of all the activities that is being conducted regularly and at least once per month. In this regard a list of different activities is presented to the respondent and he/she is asked to create his/her activity list by choosing from the represented ones. The activities presented in the list belong to one of the following categories:

- Home (activities conducted at home),
- Paid work,
- Volunteer,
- Study,
- Shopping,
- Service,
- Pick up family members,
- Drop off family members,
- Leisure and Recreation,
- Social,
- Other.

It is important to mention in addition to the activity choice list that is given to the respondent, he/she is able to define and add extra activities if they are not considered in the suggested activity list. Furthermore, respondents will specify the frequency of each activity per month, differentiating between once per month, twice per month, three times per month, every week, every weekend, multiple times per week, every workday, every day and multiple times per day.

> Example of questions; Please select from the activity list below the activities you usually conduct at least once per month. You are able to define and add an activity if it is not in the list. Following please indicate for each activity how frequently you conduct the activity.

As a result of the step one an activity-participation is created for the respondent.

Activity-profiles

The second step is to retrieve all possible profiles for each activity in the respondent's activity-participation. That is to say, respondent is asked to provide different attributes of each given activity and the trip related to the activity including location, start-time, duration, origin of the trip and the transport mode. We represent an activity-profile in terms of different attributes as following:

$A_a = (i, l, t, m, o, c)$

where:

i represents activity type,

l represents location of the activity,

t represents start time of the activity,

m represents transport mode,

o represents the origin location of the trip related to the activity,

c represents company while the activity is being conducted.

In order to be able to capture all activity-profiles and at the same time make the procedure as clear as possible to the respondents we propose the following approach to identify each profile. First, we represent an activity from the activity-participation to the respondent. We ask the respondent where does he/she conduct this activity. The answer to this question would be the name of the location defined by the respondent, which is used to label the activity location in the database and can be adopt in the next steps. It is important to mention in each step the activity attribute that the respondent is being asked about is dependent to the previous attributes that are already given. Therefore we always remind the respondent that which attributes are already given. Next we ask the respondent that at what time does the activity i conducted at the location l usually start. If there is no specific time for the current activity at the current location, respondent can choose the option anytime. Otherwise he/she would give the precise start time of the activity. Then, we ask respondent about the trip would be conducted considering activity i conducted at location l starts at time t. Where is the location that the trip starts from? And what transport mode is used? Regarding to the former question, if there is no specific origin the respondent can choose the optional various locations. Otherwise, the respondent enters the name of the location. As for the latter question, respondents can choose one or a combination of the following options: walking, bicycle, car, tram, train, metro, ferry and slow-mode (scooter, motorbike, etc.).

As a result, the first activity profile of the activity i is created. Furthermore, we represent this profile to the respondent and ask him/her if he/she conduct the activity in any other way than the given activity-profile by modifying one or more attributes. Accordingly we will capture all the changes using a similar approach. Each change defines a new activity-profile that may differ in one or more attributes than the original profile.

The result of step 2 will be a complete list of all the activity-profiles related to the activities in the activity-participation. Table I represents an example of different activity-profiles for one activity.

Table I, an example of different activity-profiles for one activity.

Activity (Type)	Start time	From (Origin of the trip)	With (Mode)	To (Location of the activity)
Grocery shopping	17:00	Work	Car	AH Supermarket
Grocery shopping	19:00	Work	Car	AH Supermarket
Grocery shopping	11:00	Home	Walking	AH in the city centre

Considerable effort is devoted to design the interactive web-based questionnaire. It should be emphasized that the order questions are being asked from the respondent is important. That defines the complexity of the system and also the amount of time the respondent should spend to complete the questionnaire, which might be one of the most significant reasons that a respondent abandon the questionnaire and decides to drop out. In order to specify an optimal sequence we conducted a series of face-to-face interviews among colleagues. We asked them about their habitual activity-travel pattern. With this regard we explain what is the definition of a habitual activity-travel pattern and then asked them to report us their pattern related to a few selected activities. No table or guidance has given to respondent regarding activity's attributes. They would specify the attributes in any order. Results of these interviews let to current questionnaire design, which in our belief is the closest approach as if someone would have asked a respondent in an interview.

Activity-location

Third step is to identify the geographical location of each activity. As it is mentioned before, in step 2 the respondent labeled each activity's location. At this step, we represent each label to the respondent and ask him/her to give us the precise location. We use the Google map structure. Therefore, respondent would enter the address in a search box and the location will be shown in a map. Then the respondent would confirm that if the suggested location on the map is correct or not. Figure II shows the interface designed in order to record activity-locations.

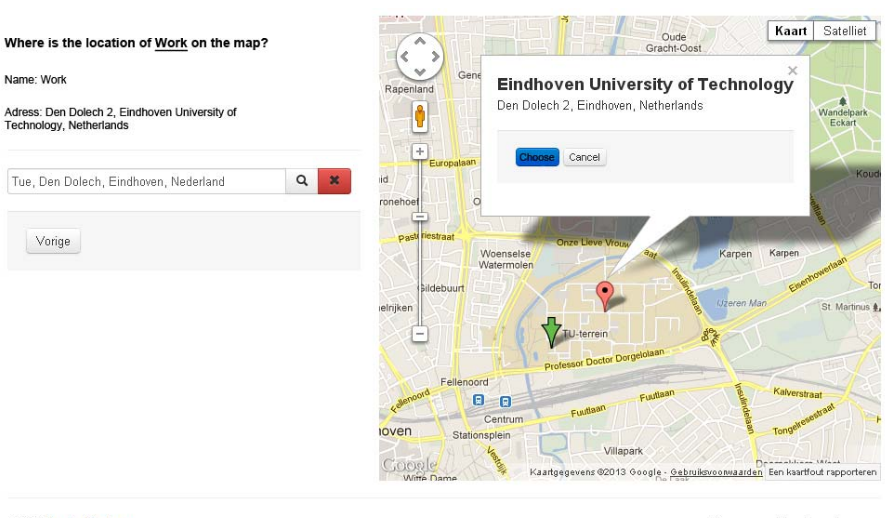

Figure II, the interface designed in order to record activity-locations.

Trip

Step 4 is looking at the respondent habitual travel pattern related to the given habitual travel activity. Respondents are asked to report details of the trip that is made. We designed the web-based questionnaire in a way that the respondent is able to enter details of his/her trip whether it is a single mode trip or it is multimodal. In the case that the transport mode is car, we ask the respondent to locate the parking spots at the origin and destination using drag and drop system on the map. Then, the system will suggest a route between these two parking spots using Google map structure that finds the shortest path. Respondents can change the route on the map by moving each point in the route. Then, they can confirm that this is the habitual route for this particular trip and activity-profile. As a result, we would have the latitude and longitude information regarding to the origin and destination and as well as the parking spots. Also we would record the route trajectory, which can be identified as one of the strength points of our interactive web-based questionnaire.
In addition we ask the respondent to report the travel time, parking cost, travel company, and if there is an alternative route or not. If there is one or more alternative routes, respondents are asked to enter their trajectory. It is important to highlight that the alternative route is also a route that is taken usually and are assumed to be respondent preferred routes. Moreover adding an alternative route would result in creating a new activity-profile. Figure III represents the interface design for a car trip.

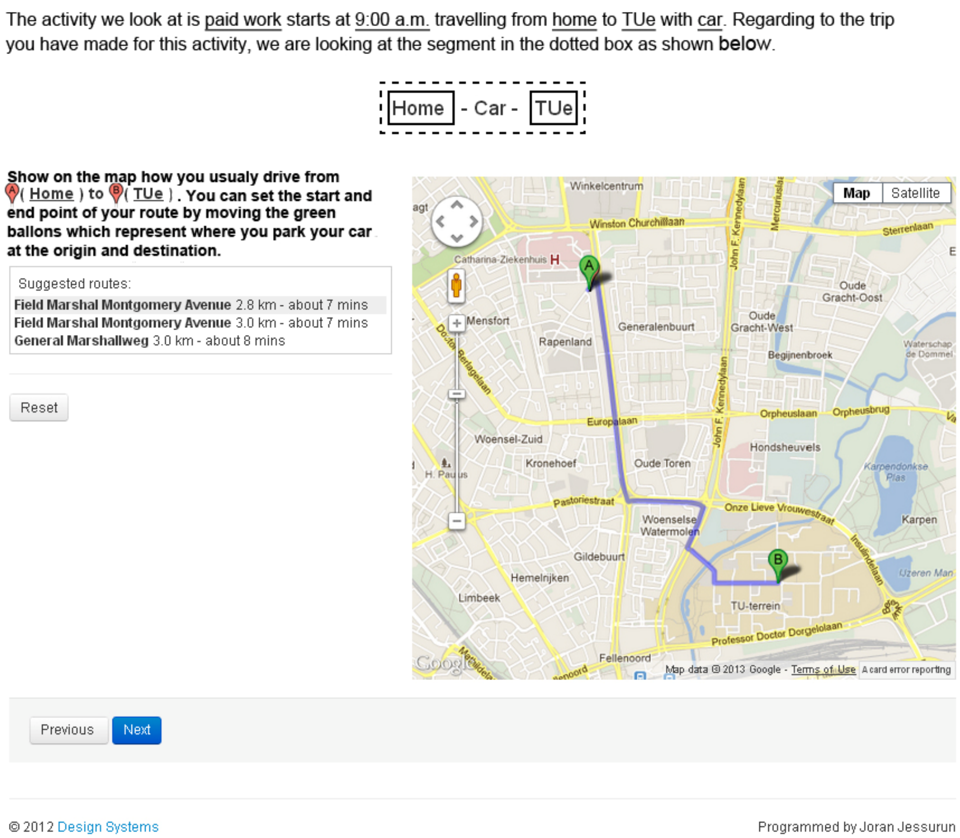

Figure III, the interface design for a car trip.

In the case of public transport, if it is bus, tram, metro or ferry respondents should enter the related line then the line would be represented on the map and the respondent can identify at which stop she/he would get in and get out. We also ask respondents about the travel time and the travel cost. In case of the train the only difference would be that we just ask about the origin and destination stations. Figure IV represents the interface that is designed for a bus trip.

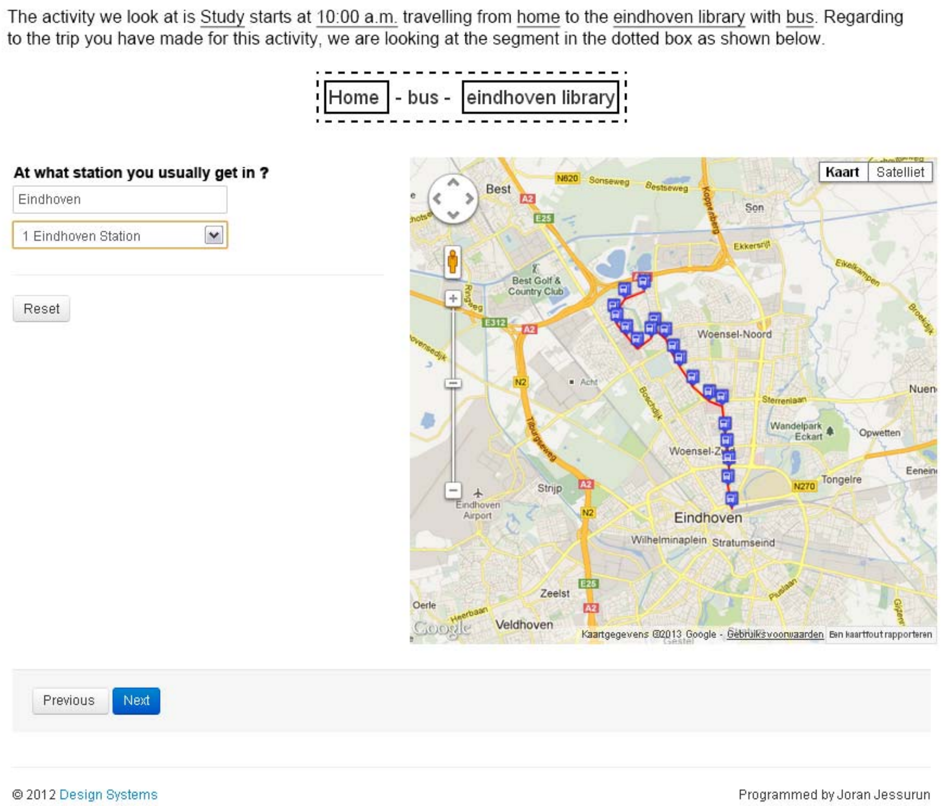

Figure IV, represents the interface that is designed for a bus trip.

In the case of the multimodal transport a combination of both systems of car and public transport is used. Accordingly using this system gives us the ability to capture respondents habitual travel pattern including all the important details. As a result considering the advanced travel information, we can provide more realistic information and also we would be able to identify even the small changes in their travel pattern.

Frequency

The final step to collect data regarding to respondent habitual activity-travel pattern is to identify the frequency of each activity-travel profile. We represent a list of detailed activity-profiles to the respondent and ask him/her how often would he/she repeat each activity profile over time.

Phase 3- Provision of advanced travel information and the adaptation

As a result of phase 1 and 2 a detailed data is collected including respondent characteristics and activity-travel behavior. The goal of phase 3 is to identify how respondent would change his/her habitual activity-travel pattern in presence of advanced travel information.

Scenarios

We employ respondents' habitual activity-travel pattern to generate realistic travel information, which will be represented to them in the form of scenarios. As noted before travel information can be pre-route or en-route, public or personal and prescriptive or descriptive. There is a difference in decision-making process when the information is descriptive or prescriptive. Descriptive information gives more and updated information about the state of the network, e.g. real travel time of a particular route. As a result, the individual will process the received information, and then update his/her beliefs about the network state. In other words, information directly impacts the individual's beliefs, which may lead to changing his/her activity-travel schedule.

However, prescriptive information does not give quantitative information and may introduce new choice alternatives to the individual. As a result, the individual will evaluate the choice alternatives and compare them with known ones, and then choose among the choice alternatives. We consider descriptive and prescriptive information to investigate these differences and assess how respondents adapt their activity-travel behavior. Personalized travel information will be provided to the respondent. The information is generated adopting respondent's habitual activity-travel pattern. As a result the respondent will be familiar with the presented situation in the scenario and can make his/her choice easier. Moreover the scenario's consistency with the reality will be much higher comparing to the hypothetical situation.

To investigate the short-term effect of providing personalized travel information a sample from activity-profiles will be drawn randomly. As for descriptive information, travel time of possible routes to the location of the activity will be provided to the respondents. The provided information will be related to the habitual routes that respondents use and one or more additional routes chosen by a path-finder algorithm. The scenario will be such that, according to the travel information provided, the travel time of respondents' habitual routes is more than the others. Therefore we ask respondents if they would change any attribute of the current profile or not.

As for prescriptive information, the received travel information may recommend the respondents to take another route than their habitual route, or to go to another location, or to change the transport mode. This information is not quantitative at all. As a result we ask respondents if they would follow the recommendation and change any attribute of the presented profile.

Adaptation

After introducing the scenario to the respondent, he/she will be able to choose from a list the attribute that he/she wants to change in the activity-travel profile. The respondent might:

- Change start time of the activity,
- Change duration of the activity,
- Change the activity location,
- Change the travel mode,
- Change the route of the trip,
- Skip the activity to another time or delete the activity,
- Change a combination of above attributes.

A similar interactive web-based system as phase 2 is used to record respondent's adaptation behavior. After that the respondent chooses which adaptation she/he would want to make, the system will represent to the respondent the relevant question how the change will be implemented related to the chosen attribute. For example if the respondent would choose to change the route, a map will be represented to him/her in order to specify the new route.

STRENGTHS AND WEAKNESSES

As for any innovative design our proposed approach has its own strengths and weaknesses. We are going to discuss some of them in this section.

Strengths

The interactive design of the questionnaire provides the kind of interactivity that someone would experience during a face-to-face interview. The design is highly flexible and by any change in the choice of the respondent the interface would change accordingly.
In addition, the interactive design provides the ability to assess complex situations. For example if someone uses three different modes in his/her multimodal travel pattern and in the adaptation phase the pattern would change in just one section including one of the modes, the system allows the respondent to select and modify just that section.
Moreover the system is designed to be smart and to help respondents by giving them recommendation and suggestions based on the data that they have already reported.
In contrast to SP or Choice experiment, using SA gives the respondents the freedom to adapt their activity-travel pattern in the way they want to. And implementing it in an interactive smart structure provides the possibility to modify one or more attributes at the same time. This will result in an increase in range of observed changes.
Someone could argue why asking about habitual activity-travel pattern not asking about the activities that has been conducted one week ago or one month ago as it is being done collecting an activity diary. There are three reasons. First, the activities that are mostly affected by the imposed changes are the activities that are being conducted on a habitual basis. Second, following the proposed approach the focus won't be on the day of the week or

date of the month the activity is conducted on, which makes the activity independent of time. Finally, the design structure and the face that the scenarios are based on respondents' habitual activity-travel pattern increase the realism and validity of the responses in the real world.

Weaknesses

Collecting activity-travel data in details results in long questionnaire, which probably take more than half an hour to complete. This is one of the issues that we have been struggling with during the design. We had to find a balance in the amount of data we want to collect and the amount of time in average a respondent would have to spend to complete the questionnaire. Nevertheless it was not possible to decrease the length to less than half an hour. Therefore we decided to divide the experiment into two sections, which will be conducted in two different days. Section once includes collecting socio-demographic and habitual activity-travel pattern data. Section two includes introducing the scenarios and collecting adaptation data.

Since the experiment based on hypothetical scenarios, despite all the effort to design is as close as possible to the real world, some sort of bias can be expected in the result. However controlling the sample and experiment process and generating the scenarios based on respondents' activity-travel pattern can increase that effect.

In the proposed approach we are not observing individuals' strategic decision-making behavior towards the presence of travel information and if the provided information is public or personal. These can be investigated in the future studies, by introducing different scenarios to the respondents.

CONCLUSIONS

This paper has introduced an innovative stated adaptation experiment, which can be used to assess individuals' activity-travel behavior under travel information provision. It takes into account individuals' preferences, and their habitual activity-travel pattern introducing the scenarios. It is implemented in an interactive smart web-based questionnaire design, which increases the realism and range of the responses. The proposed approach can be implemented in different studies evaluating different type of scenarios.

Our plans for future research will be to employ the system in practice. Results of SP experiment will be analyzed to evaluate effects of advanced travel information provision on activity-travel behavior. Results provide insights into the differential effects of descriptive and prescriptive travel information on activity-travel patterns. In turn, any induced change will provide keys to the effectiveness of travel information for transport demand management.

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