Field Deployment to Quantify the Value of Real-time Information by Integrating Driver Routing Decisions and Route Assignment Strategies

By

Dongyoon Song
Ph.D. student, School of Civil Engineering
Purdue University
song50@purdue.edu

Xiaozheng He
Research Associate, Nextrans Center
Purdue University
seanhe@purdue.edu

Srinivas Peeta
Professor of Civil Engineering
Purdue University
peeta@purdue.edu

PURDUE UNIVERSITY
Discovery Park

DISCLAIMER

USDOT Region V Regional University Transportation Center Final Report

TECHNICAL SUMMARY

Title

Field Deployment to Quantify the Value of Real-time Information by Integrating Driver Routing Decisions and Route Assignment Strategies

Introduction

Advanced Traveler Information Systems (ATIS) have been proposed as a mechanism to generate and distribute real-time travel information to drivers for the purpose of improving travel experience represented by experienced travel time and enhancing the performance of the vehicular traffic networks. From the system operator's perspective, it is desired that a driver would fully comply with such information. Traditionally, the prediction of system performance under real-time information provision has been studied using dynamic traffic assignment (DTA) models in which individuals are assigned to time-dependent routes from their origins or en-route locations to their destinations so as to satisfy some system-wide objective and/or individual user level constraints. However, these models primarily focus on prescribing the traffic flow propagation robustly, while the role of driver behavior in the evolution of network dynamics has largely been subsumed by making potentially restrictive a priori assumptions, which include one or more of the following: (i) travel time is the only basis for route choice decision-making, (ii) users are behaviorally homogeneous, and/or (iii) pre-specified behavior classes are available whose fractions are known in the ambient traffic stream. In this context, a comprehensive modeling framework is proposed to understand individual drivers' behavioral responses in route choice under real-time travel information provision based on driving simulator experiment data. An interactive driving simulator experiment is developed to collect various data related to driving and decision-making with real-time travel information. The associated surveys are also precisely designed to measure drivers' perception of the information and evaluation of the travel experience.

Findings

In this study, an integrated route choice model is proposed with the consideration of perceptional and psychological effects of real-time travel information. In the proposed model, the psychological effects are defined based on the distinct characteristics associated with information-related stresses and explicitly captured by the corresponding indicators (responses to survey questions regarding individuals' perception of information) for the latent variables. The perceived benefits of the real-time information is affected by the psychological effects defined as latent variables in addition to the explanatory factors

including individual attributes, route characteristics, and route attribute. To understand the effects of real-time information in decision-making process from the psychological point of view, drivers' real-time behavioral data under various travel contexts with different information characteristics are required.

In this context, advanced driving simulator-based experiments are designed to collect participants' behavior data in the context of decision-making under real-time travel information provision. While drivers' revealed behavior (route choice) data is obtained by the driving trajectory data of the simulator experiment, qualitative data for the real-time perception of information and the evaluation of the travel experience are collected through the multiple surveys associated with the driving simulator experiments. Specifically, a static survey is used to capture the participants' individual demographic and socio-economic attributes and experience with real-time information, and attitude toward real-time travel information. And several intermediate surveys collect real-time perceptional and psychological states data associated with the information provision under the given travel context.

Recommendations

This research illustrates the effectiveness of using the data acquired from the interactive driving simulator experiments in studies involving driver's behavior responses under real-time travel information provision. Using an interactive driving simulator has some practical merits compared to substantially more expensive field experiments on public road networks. First, it is flexible to build a variety of scenarios in terms of network topology (highway geometry and road surface characteristics), information setting (amount, sources, and content), and travel context (demand level, accidents, and weather conditions). In addition, it is safer than the real physical traffic based experiments. Furthermore, based on the incorporated surveys, the qualitative and psychological implications of the information can be easily collected and analyzed.

Contacts
For more information:

Srinivas Peeta
Principal Investigator
Professor of Civil Engineering & Director
NEXTRANS Center, Purdue University
Ph: (765) 496 9726
Fax: (765) 807 3123
peeta@purdue.edu

NEXTRANS Center
Purdue University - Discovery Park
3000 Kent Avenue
West Lafayette, IN 47906

nextrans@purdue.edu
(765) 496-9729
(765) 807-3123 Fax

www.purdue.edu/dp/nextrans

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

1.1   *Background and motivation*

Advanced Traveler Information Systems (ATIS) have been proposed as a mechanism to generate and distribute real-time travel information to drivers for the purpose of improving travel experience represented by experienced travel time and enhancing the performance of the vehicular traffic networks. From the system operator perspective, it is desirable that a driver would fully comply with such information. However, it is also likely that he/she would use it to partly modify the pre-determined route choice or ignore the information based on inherent behavioral tendencies, past experience, situational factors (such as time-of-day, weather conditions, and trip purpose), and the ambient traffic conditions encountered (Peeta and Yu, 2006). Hence, the complexities associated with driver behavior may impact the reliable prediction of traffic network states unfolding over time as well as the potential benefits derived from information provision.

Traditionally, the prediction of system performance under real-time information provision has been studied using dynamic traffic assignment (DTA) models (Ben-Akiva et. al. 1998; Mahmassani et. al. 1998) in which individuals are assigned to time-dependent routes from their origins or en-route locations to their destinations to satisfy a certain system-wide objective and/or individual user level constraints. However, these models primarily focus on modeling the traffic flow propagation robustly, while the role of driver behavior on the evolution of network dynamics has largely been subsumed by making potentially restrictive a priori assumptions on behavior (Peeta and Yu, 2006). Such assumptions include one or more of the following: (i) travel time is the only basis

for route choice decision-making, (ii) users are behaviorally homogeneous, and/or (iii) pre-specified behavior classes are available whose fractions are known in the ambient traffic stream. Further, they do not consider learning that takes place over longer timescales.

As the system performance is evaluated based on such restrictive assumptions on drivers' behavior, the role of real-time information remains unclear for a transportation network with ATIS. There exists a key gap in terms of adequately understanding the value of real-time information in real-world contexts. It motivates us to conduct an integrated driving simulator experiment in which the role of human behavior is analyzed through careful experiment design to understand the potential benefits of real-time information.

1.2   *Study objectives*

The primary objective of this project is to provide a comprehensive modeling framework to understand individual drivers' behavioral responses in route choice under real-time travel information provision based on driving simulator experiment data. With the consideration of qualitative and psychological aspects of information perception, the proposed behavioral model can alleviate the aforementioned behavioral assumptions. An interactive driving simulator experiment is constructed to collect various data related to driving and decision-making with real-time travel information. The associated surveys are also precisely designed to measure drivers' perception of the information and evaluation of the travel experience. The specific study objectives in this project include:

(i)   Review of the current literature regarding the simulation-based models for driver's decision-making behaviors under the real-time travel information provision;

(ii) Development of a decision-making model with considertation of percpetional and psychological effects of real-time travel information;

(iii) Integration of an interactive driving simulator experiment where the virtual environment of the system allows participants to not only drive realistically but also make route choice decisions realistically.

(iv) Design of the dynamic surveys correponding to the experiment which collect the emotional or perceptional states of partcipants depending upon the information provision.

1.3 *Organization of the research*

The remainder of the report is organized as follows. Chapter 2 describes the interactive driving simulator experiment design. Chapter 3 presents the step-by-step process of the planned driving simulator experiment with the detailed discussion of corresponding surveys. Chapter 4 summarizes this study and provides potential venues for future research.

.

CHAPTER 2. INTERACTIVE DRIVING SIMULATOR EXPERIMENT DESIGN

2.1   *Main issues in simulation-based studies*

Several simulation-based studies have been conducted over the past two decades to analyze the evolution of the traffic network under real-time information provision to drivers. Some of them assume specific driver behavior models and seek to understand the effect of real-time information on the unfolding network states. Others combine an underlying traffic simulator with laboratory-based interactive experiments where the participants are provided real-time routing information on the traffic conditions related to their origin-destination (O-D) trip. Thereby, their real-time decisions are simulated along with that of the ambient traffic for the test network (Adler et. al., 1993; Pel, 2011; Kwan and Casas, 2006; Adler and McNally, 1994).

However, the various simulation studies are typically limited by one or more of the following: (i) the need to pre-specify behavior models, (ii) the small number of participants in interactive studies, and (iii) the type of network topology considered (such as parallel route corridors). More importantly, and of fundamental relevance to the proposed work, there is a presumption of the type of information available, how and when it can be delivered to the individual drivers, and how it is processed by the drivers. In simulation models, all of these are seamless and the focus is purely on the estimating the potential benefits of real-time information provision.

Unfortunately, there is an underlying disconnect with the real-world, beyond the key issues related to restrictive behavioral assumptions. First, drivers can process only limited information while driving. Hence, it is important to characterize the effects of real-time information based on providing only information that can be realistically

processed by individuals in real-time (as opposed to unstated assumptions in simulation models of the ability to process any information provided). Second, due to safety concerns and the inability of individuals to multitask safely while driving, how the information is provided to them (voice, visual, or text) becomes a key issue. Again, this is presumed as seamless in simulation models. Third, there are technological issues related to when information is provided to drivers. This would imply the continuous tracking of each driver or mechanisms for two-way communication with an automated server. Namely, how would the information system operator ensure the timeliness of the information provided to a driver relative to his/her current location in the network? In simulation models, there is an implicit assumption that a driver can be accessed anywhere or possibly at discrete points, in the network to provide such information. Hence, even if we were to discount issues related to the adequacy of representing driver behavior, the three issues mentioned heretofore would lead to gaps between the benefits predicted by a simulation model and those of well-planned driving simulator experiments.

To provide a better understanding of the potential value of real-time information to drivers, in this study, we propose specifically designed experiments that additionally seek to explicitly capture the behavioral aspects of drivers. That is, we seek to analyze the effect of the actual information provided to a driver on that driver's response after each instance of such information provision. We will then use the collected data to develop more reliable models of driver response behavior by identifying the various factors that affect decision-making under information provision. We further expect to identify additional performance measures beyond the traditionally used benchmark of travel time savings to better understand the potential benefits of a real-time information system to both the user and the operator. An enhanced level of reliability in the understanding of the potential costs and benefits of real-time traffic information systems beyond the insights provided by idealized simulation studies is critical given the expectation of the widespread deployment of these technologies in the near future and the concurrent evolution of the associated information services market (which assumes a significant role for the private sector as well as public-private partnerships).

The advent of modern real-time traffic information dissemination technologies and potential future levels of market penetration make it technologically viable to send personalized information in both pre-trip and en-route contexts (to smart phones through websites like traffic.com, GPS Navigation system through traffic receivers), as well as generic information en-route (through variable message signs (VMS)) and pre-trip (through traffic information websites, apps and radio FM). Further, technologically, it is possible to track the compliance, non-compliance or partial compliance related to the information provided using devices such as GPS (Lawson et. al., 2008), supplemented further manually by drivers' daily trip diaries (Yasuo and Hato, 2004; Shinji and Hato, 2006).

Nevertheless, significant methodological challenges exist beyond privacy concerns in enabling related studies. First, to understand an individual driver's response, there is the need to obtain data on his/her inherent behavioral tendencies (for example, the level of willingness to take risks) as well as attitude towards information provided. Second, the ability to understand whether information provision at any point in time caused the driver to shift from his/her current route requires the knowledge of the current route at each information provision time instance as well as the commonly-used routes by that driver. Third, the decision of the driver is captured immediately after each instance of information provision, as memory retention of the cause of the response may diminish with time, in addition to the response itself, especially if information is provided several times.

2.2 *Advanced driving simulator experiments*

The experiments in this study will make use of an advanced driving simulator to collect participants' route choice data. Using an advanced driving simulator has several practical merits compared to field data from conducting real driving experiment on public road network despite partly losing realism in the behavioral date collected. First of all, it is flexible to create various scenarios in driving simulator experiment, which is essential to controlled experiments. The flexibility is not only for information characteristics such

as amount, sources, and content in the experiment, but also for travel context including traffic demand (ambient traffic situations) and trip purpose. In addition, a driving simulator experiment requires the minimum risk to participate in the experiment as it does not involve any physical vehicles, pedestrians or traffic. As safety is a critical issue in such human-involved experiment, a simulator-based experiment can be an attractive alternative to the field study.
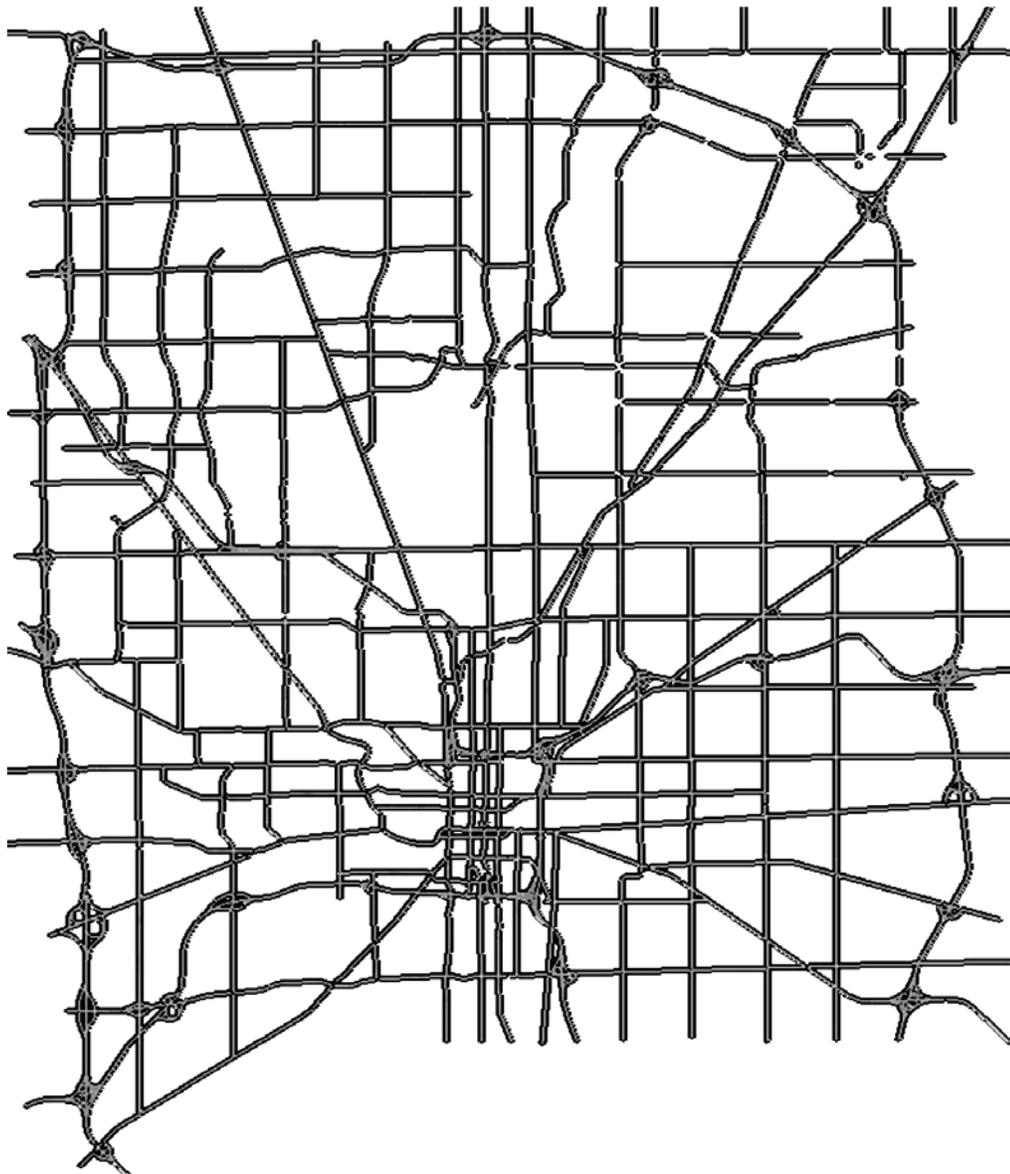

Figure 2.1 Indianapolis road network for driving simulator experiment

2.2.1 *Network building*

The interactive driving simulator experiment in this study is conducted on a realistic road network as of the participants' daily commute based on a Google map overlay. Specifically, the Indianapolis road network is used to construct a virtual network environment for travel. Multiple O-D pairs with distinct characteristics such as average driving distance, availability of freeway option, and number of alternatives, are built for the use of different scenarios. Figure 2.1 shows the network topology used in the driving simulator experiment. For a realistic representation, various 3D objects (buildings, and trees) are inserted according to the area characteristics, in addition to the road signs along the roads and traffic signals at intersections. Figure 2.2 illustrates a bird's view of the 3D driving environment. The driving environment from driver's perspective is presented in Figure 2.3.

Figure 2.2 Example of experiment network

Figure 2.3 Example of driving environment in driving simulator

2.2.2   Information provision

The simulator has the ability to provide Variable Message Sign (VMS) messages to participants at distinct points while en-route. Through triggers, different text messages can be displayed for different information scenarios. In addition, with the integration of a personal device (iPod Touch in this study) and relevant software packages with the driving simulator, we can create a situation with multiple information sources. Each information source (VMS or personal device) provides different travel information in terms of level of details, customization, or temporal effectiveness. For example, as illustrated in Figure 2.4, the personalized information that is tailored for a particular driver's need may be more convincing because of the content fitted to the need than the generic information distributed to anonymous drivers (non-personalized information). The presence of multiple sources of information is important since it allows establishing different information scenarios with respect to the number of information sources and potential issues with inconsistency between the messages from different sources.

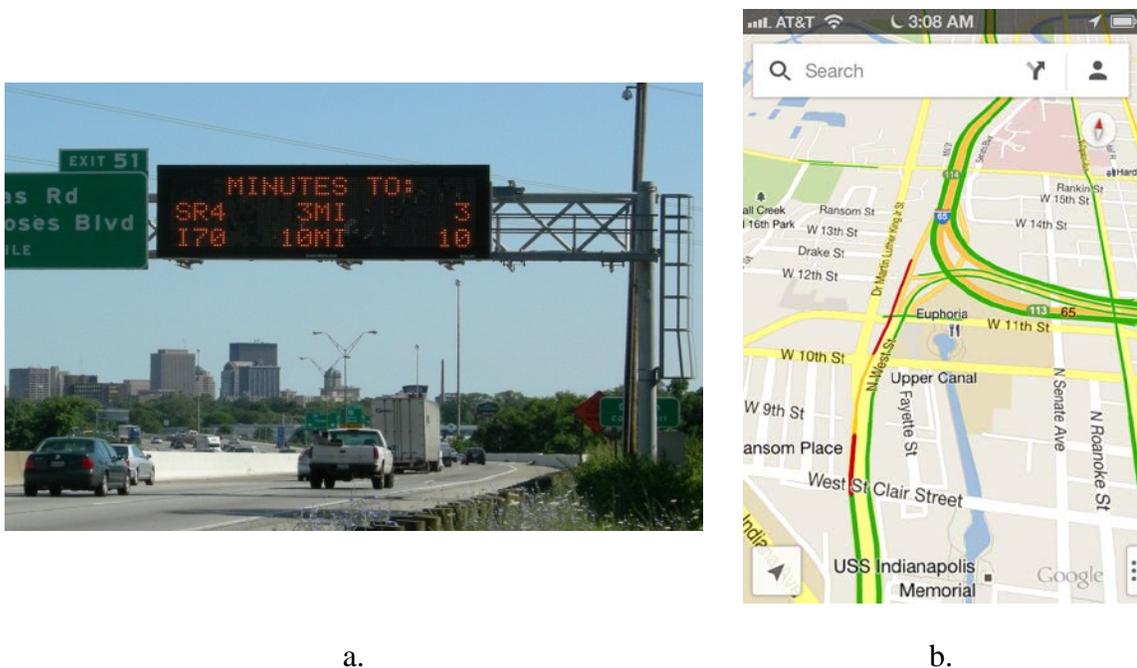a.   b.

Figure 2.4 Examples of real-time travel information from different sources

a. Example of generic real-time travel information (VMS); b. Example of personalized real-time travel information (Google map)

2.2.3   *Traffic demand*

As the levels of traffic congestion are not supposed to be the same in a major freeway and a minor local road, the simulator interfaces with microscopic traffic simulation software, AIMSUN, so as to create dynamic traffic conditions in accordance with the type or hierarchy of road which reflects the asymmetric traffic demand in reality (That and Casas, 2011; Punzo and Ciuffo, 2011). The driving simulator helps to create various scenarios in controlled conditions that cannot be attempted in the field for safety reasons.

2.3   *Survey design*

In order to collect data of participants' stated preference and evaluation of travel experience, driving simulator experiment is integrated with several surveys for different purposes. The surveys planned in the experiment are two types: (i) A one-time static survey that captures socio-economic characteristics and inherent preferences of the driver, and (ii) dynamic surveys that capture the real-time psychological states or evaluations of the travel experience during and after each simulation run in the driving simulator experiment.

The survey in this study has been designed by considering standard practices in the literature (NCHRP, 2008 and TSM, 2012). There are multiple challenges associated with designing the survey for the proposed study which are discussed hereafter in the paper. First, the questions related to the knowledge of real-time traffic information, past experiences with en-route or pre-trip real-time traffic information, and experiences with information on personalized devices need to be separated. Further, the experience with generic real-time traffic information and personalized information can be different. Second, people with high familiarity with a network may treat real-time travel information less significantly in many instances. In a simulator, such experience needs to be replicated and understood through targeted survey questions. Third, information complexity of a suggested alternative route and the capability for mentally processing the complex information while driving may play a critical role in the context of the benefits

derived from real-time traffic information. This needs to be captured through the variables/indicators identified in survey questions that feed into the proposed model. Fourth, various indicators related to information accuracy, adequateness, and unfavorableness may impact driver perception of real-time traffic information. These variables and indicators need to be captured, while ensuring that the survey meets some space constraints.

2.4   *Latent variable model*

Based on the revealed behavioral data from driving session and the stated data from the associated surveys, in this study, we propose a latent variable model to address the unobservable latent variables and its relationships. In the measurement relationships of latent variable model, each latent variable (ellipses in Figure 2.5) are defined by multiple indicators (rectangles in Figure 2.5) which can be regarded as the responses of survey with psychological representation implied.

$$I = \Lambda P + \delta$$

where *I* is a vector ($q \times 1$) of exogenous indicators, *P* is a vector ($a \times 1$) of latent exogenous variables, Λ is a matrix ($q \times a$) of coefficients for *P* to *I*, and δ ($q \times 1$) is measurement error terms for *I*, that are independently distributed.

On the other hand, structural relationships of our model include not only the relationship among latent variables but also the relationships with observable explanatory variables representing situational factors and driver, route and information characteristics. These structural relationships can be mathematically represents as:

$$P = \mathrm{B}P + \Gamma X + \zeta$$

where, B is a matrix ($b \times b$) containing direct effect coefficients between *P*'s, Γ is a matrix ($a \times b$) of regression coefficients for *X*, and ζ is a structural error term ($b \times 1$).
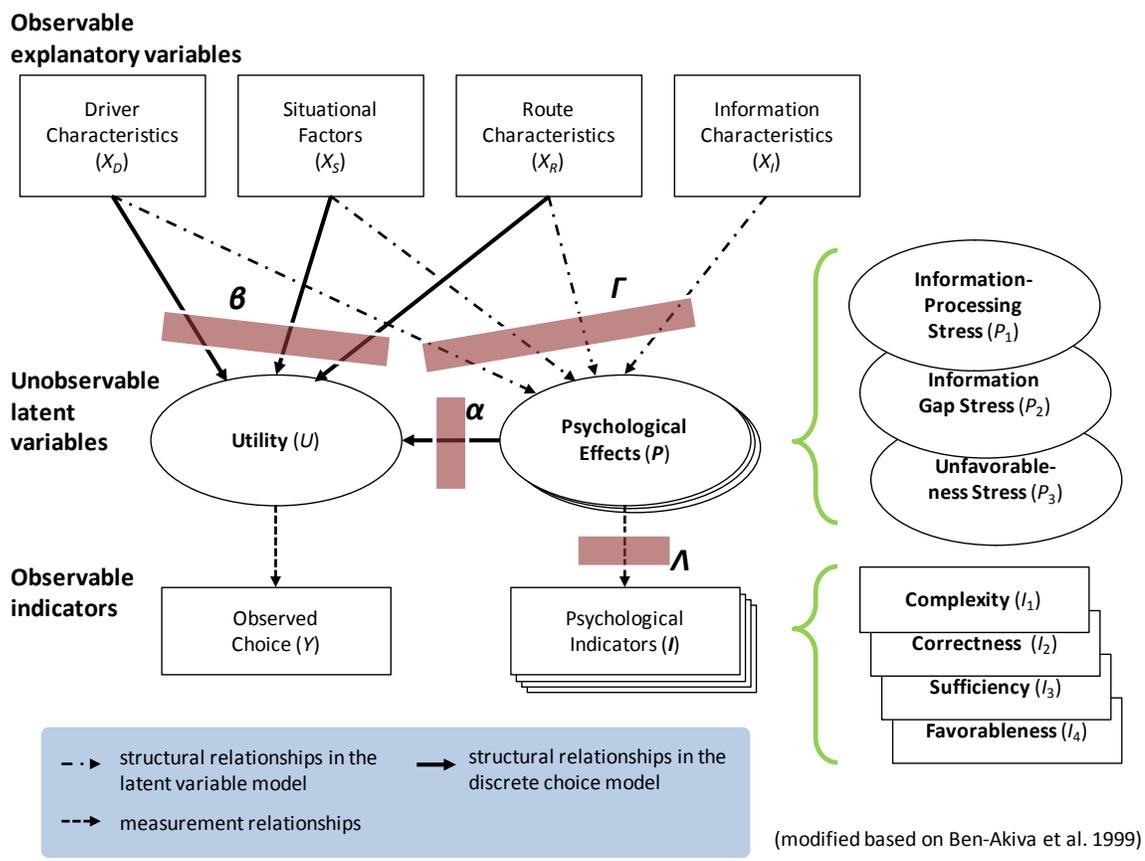
Figure 2.5 Proposed integrated choice model

A list of explanatory variables that may impact the choice model and will be captured in the survey is given in Table 2.1. The explanatory variables have been divided in four categories: driver attributes, situational factors, route characteristics, and information characteristics. Further, psychometric data such as responses to attitudinal and perceptual survey questions, can be used as indicators of the latent psychological factors (Ben-Akiva et. al., 1997). In the proposed model the psychological factors are explicitly captured by including indicators of psychological factors (such as responses to survey questions regarding individuals' attitudes, perceptions, etc.) for the latent variables that are directly fed in the utility function as illustrated in Figure 2.5. The dotted lines show the relationship between indicators and latent variables.

Table 2.1 List of representative explanatory variables

Category	Variable	Acquisition
Driver Attributes	- Demographic attributes (age, gender, etc.) - Socio-economic attributes (Household income, etc.) - Driving experience -Familiarity with real-time travel information - Propensity of using real-time travel information system - Driver familiarity with network*	Online static survey * Controlled in experiment by individuals
Route Characteristics	- Estimated travel time to destination - Type of the route (freeway) - Route preference - Route recommendation	Controlled in experiment by selection of O-D
Situational Factors	- Trip purpose - Ambient traffic demand - Expected travel time left at the location of information provision	Controlled in experiment by different scenarios
Information Characteristics	- Amount of information - Source of information - Content of information	Controlled in experiment by different scenarios

CHAPTER 3. INTERACTIVE DRIVING SIMULATOR EXPERIMENT PROCESS

The proposed study seeks to determine the value of real-time information for drivers through specifically designed experiments in a driving simulator that circumvent the limitations of behavioral assumptions as well as the methodological challenges. The detailed investigative approach is shown in the conceptual plan in Figure 3.1. The flowchart shows a step-by-step approach for the planned study. The first step of the experiment process is to create a diverse pool of volunteer participants for the experiment. The participants will be chosen so as to represent the general driving population. The purpose of the experiment will be explained to the participant when he/she is first contacted for the experiment, as well before starting the practice session on the driving simulator. The participants will be specifically requested to imitate their normal response behavior in the real world rather than some expectation of an idealized behavior. This can be an issue for the experiment as it is possible that participants may artificially tend to be more compliant than is representative of real response behavior. Once the survey procedure is understood by the participants, they will be required to complete a one-time survey. In this survey, the participants will provide information on their socio-economic characteristics and attitude towards information.

3.1   *Online static survey*

The first step to participate in the interactive driving simulator experiment is to answer an online static survey where the participants' individual characteristics, experience with real-time travel information and preferences in travel context are collected. Table 3.1 summarized representative explanatory variables to be captured through the static survey.
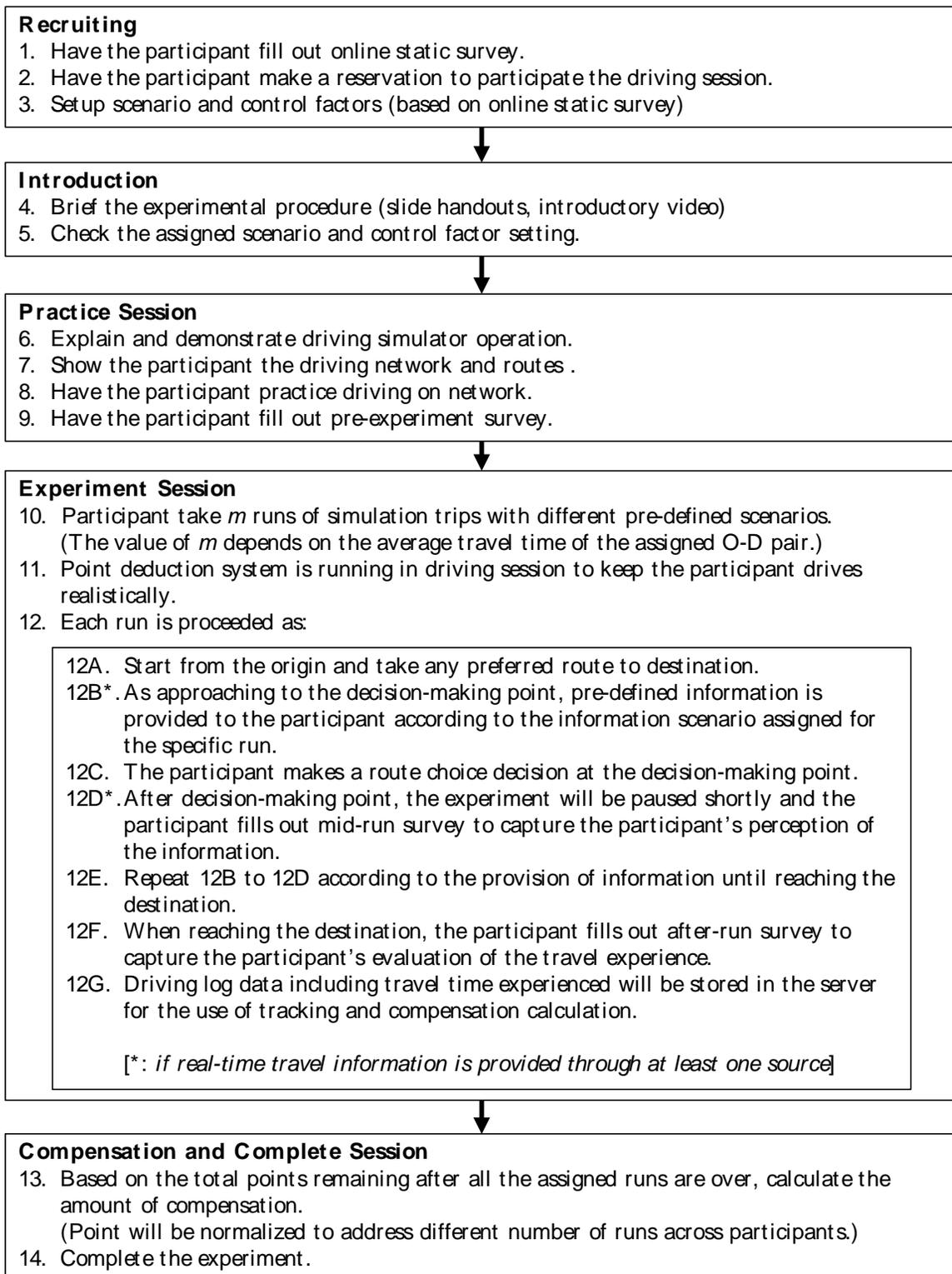
Recruiting
1. Have the participant fill out online static survey.
2. Have the participant make a reservation to participate the driving session.
3. Setup scenario and control factors (based on online static survey)

Introduction
4. Brief the experimental procedure (slide handouts, introductory video)
5. Check the assigned scenario and control factor setting.

Practice Session
6. Explain and demonstrate driving simulator operation.
7. Show the participant the driving network and routes .
8. Have the participant practice driving on network.
9. Have the participant fill out pre-experiment survey.

Experiment Session
10. Participant take *m* runs of simulation trips with different pre-defined scenarios.
    (The value of *m* depends on the average travel time of the assigned O-D pair.)
11. Point deduction system is running in driving session to keep the participant drives
    realistically.
12. Each run is proceeded as:

> 12A. Start from the origin and take any preferred route to destination.
> 12B*. As approaching to the decision-making point, pre-defined information is
>   provided to the participant according to the information scenario assigned for
>   the specific run.
> 12C. The participant makes a route choice decision at the decision-making point.
> 12D*. After decision-making point, the experiment will be paused shortly and the
>   participant fills out mid-run survey to capture the participant's perception of
>   the information.
> 12E. Repeat 12B to 12D according to the provision of information until reaching the
>   destination.
> 12F. When reaching the destination, the participant fills out after-run survey to
>   capture the participant's evaluation of the travel experience.
> 12G. Driving log data including travel time experienced will be stored in the server
>   for the use of tracking and compensation calculation.
>
> [*: *if real-time travel information is provided through at least one source*]

Compensation and Complete Session
13. Based on the total points remaining after all the assigned runs are over, calculate the
    amount of compensation.
    (Point will be normalized to address different number of runs across participants.)
14. Complete the experiment.

Figure 3.1 Steps in driving simulator experiment

3.1.1   Individual attributes

Demographic and socio-economic attributes including gender, age, education level, household income level, and so on, are known to influence driving behavior and information compliance, and route choice decisions (Khattak et al., 1993; Ullman et al., 1994). The variables related to driving experience with real-time travel information are presented separately based on the source and property of the information, i.e., generic information from VMS and personalized information from personal device such as a smart phone, for the purpose of factorizing participants' familiarity with the information and trust in the information. As the perception of the information also depends on participants' familiarity with the information and the level of trust in the information, the variables can serve to understand the participants' perception.

Table 3.1 Online static survey variables and their description

Variable	Description
Demographic, socio-economic characteristics	- Gender, age, education level - Household size - Number of children - Household income - Number of household vehicles - Years of holding driver's license - Annual driving mileage - Familiarity with Indianapolis road network (experiment network) and familiar area(s)
Experience with real-time travel information	- Experience of using generic real-time information - Familiarity of using generic real-time information - Trust in generic real-time information - Reasons for not using generic real-time information - Experience of using personalized real-time information - Familiarity of using personalized real-time information - Trust in personalized real-time information - Reasons for not using personalized real-time information
Situational questions	- Stated willingness to pay (sacrifice) for avoiding risk from uncertainty under diverse situations - Stated willingness to pay for avoiding effort to switch route under diverse situations
Screening question	Potential health issue with simulation sickness

3.1.2   Situational questions

Participants' preferences and attitudes toward real-time travel information are captured by the situational questions in the online survey as well to be used in information scenario assignment. Under diverse travel situations, participants' stated willingness to pay (or sacrifice) in time to avoid risk from uncertainty is measured in an indirect way by asking the minimum expected travel time presented in the information that makes them switch the route. Trip purpose and familiarity with alternative route is the selected situational dimensions to represent the existence of restricted arrival time and uncertainty in the alternative route, respectively. By the combination of the two factors we have four situations: (i) business trip and unfamiliar alternative route, (ii) non-business trip and unfamiliar alternative route, (iii) business trip and familiar alternative route, and (iv) non-business trip and familiar alternative route, as shown in Table 3.2.

Table 3.2 Dimensions of travel context for situational questions

		Familiarity with alternative route	
		Unfamiliar	Familiar
Arrival time restriction	With restriction (Business trip from home to work)	Situation 1	Situation 3
	Without restriction (Non-business trip from work to home)	Situation 2	Situation 4

For each situation, two questions are asked to identify the participants' minimum expected travel time on the current route that makes them switch the route with different information content: (i) when only the expected travel time for the current route is provided and (ii) when both the expected travel times for the current and uncongested alternative routes are presented. Based on the difference between the answers, we can infer the participant's behavioral implications of being aware of the real-time travel information of the alternative route under the specific travel context defined by trip purpose and familiarity with alternative route. This implication can be later used in information scenario assignment in the experiment in terms of the content of information (including alternative route information or not). Examples of the situational questions for the Situations 1 and 4 are presented in Figure 3.2 and Figure 3.3.

Please read through and understand the given situation below.

At 8:00 AM, you are driving alone to your office to attend an important business meeting. You need to arrive at the office by 8:30 AM. You know there are two route options – A St. and B St. **You are familiar with A St. but have never taken B St.** Since you are not using a GPS, you decide to take familiar A St.

Based on your experience, you know it usually takes **20 minutes via A St.** to the office. However, you have no idea about how long it would take via B St. unless real-time travel information tells you.
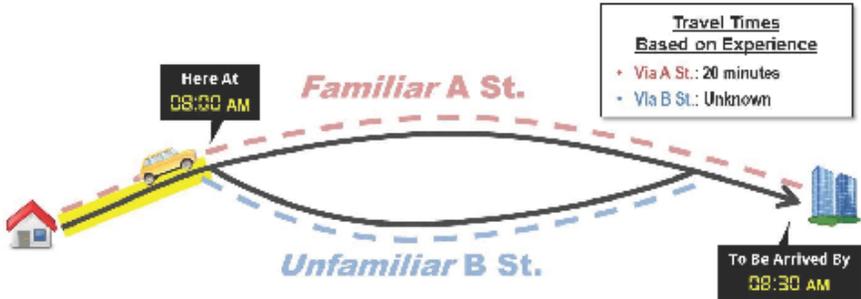
1. What is the usual travel time from "Here" to the office via the A St. route?

○ 20 minutes   ○ 30 minutes   ○ Unknown

2. At "Here", you receive real-time travel information about the expected travel time on your current route.

A ST: ☐ MINS TO DESTINATION

What would be the minimum expected travel time on A St. that makes you change your route from A St. to B St.?

[▼]

3. At "Here", you receive real-time travel information about the expected travel times on your current and the alternative routes.

A ST: ☐ MINS TO DESTINATION
B ST: 20 MINS TO DESTINATION

What would be the minimum expected travel time on A St. that makes you change your route from A St. to B St.?

[▼]

Figure 3.2 Example of situational questions in online static survey (Situation 1)

Please read through and understand the given situation below.

At 6:00 PM, you are driving back to home from the office with <u>no specific time limitation</u>. You know there are two route options – A St. and B St. **You are equally familiar with both routes**, but you decide to take the preferred A St.

Based on your experience, you know it usually takes **20 minutes via both A St. and B St.** to the office.
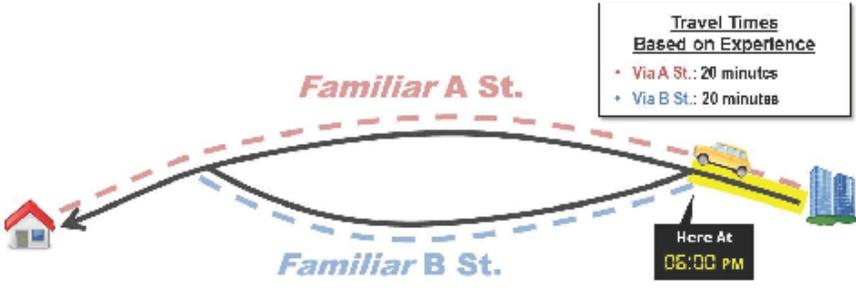
4. By what time do you have to arrive home?

○ 6:20 PM   ○ 6:40 PM   ○ No specific time limitation

5. At "Here", you receive real-time travel information about the expected travel time on your current route.

A ST: [   ] MINS TO DESTINATION

What would be the minimum expected travel time on A St. that makes you change your route from A St. to B St.?

[▼]

6. At HERE, you receive real-time travel information about the expected travel times on your current and the alternative routes.

A ST: [   ] MINS TO DESTINATION
B ST: 20 MINS TO DESTINATION

What would be the minimum expected travel time on A St. that makes you change your route from A St. to B St.?

[▼]

Figure 3.3 Example of situational questions in online static survey (Situation 4)

3.1.3   Driving simulator experiment website

A secure website has been developed to facilitate the study participants better understand and participate in the experiment. The website provides participants a brief description about the objectives of the driving simulator experiment. A video on the front page shows the experiment environment. Detailed experiment steps are presented on the website, with a hyperlink to the online static survey to allow study participants to complete it before they come to the experiment site.

A participant screening process is performed through the online static survey. As the driving simulator experiment involves many 3D objects (such as buildings and trees), which may cause sickness or dizziness (known as simulator sickness) during the experiment for some participants. For the purposes of avoiding such participants in the early stage of the experiment, we have an optional question about any known medical issues related to simulator sickness. Thereby, sufficient acknowledge can be presented before conducting driving simulator sessions and the possibility that participants feel simulator sickness may be reduced.

At the end of the online static survey, a direct link to the experiment scheduling website provided to select the most convenient time to come and complete driving simulator sessions, as shown in Figure 3.4.

3.2   Introduction and practice session

Upon their visit, an introductory session will provide the participants a short briefing about the tasks and the operation of the driving simulator. At the same time, the maps with highlighted alternative routes in the study network will be explained to participants before practice session. Then, the participants will be allowed to sit on the cockpit of the simulator and try to operate it to be familiar with the driving on a simulator as well as the route.

Figure 3.4 Website for scheduling driving simulator experiment

Initial levels of familiarity with the network and the traffic conditions are constructed in these stages by multiple ways. Table 3.3 summarizes the methodology to help participants get familiar with the network and the traffic conditions. As the familiarity is one of the critical factors in route switching behavior, different levels of initial network familiarity, especially with the alternative route, is implemented to reflect different threshold values in route switching behavior in the experiment. The familiarity with traffic conditions, on the other hand, is also significant in evaluating expected travel time provided in the real-time information as it provides a reference to be compared with

the information. In the experiment, the average travel times of each route in major sections (from one decision-making point to next decision making-point) are going to be learned only for the participants who are assigned as familiar drivers representing their knowledge about the usual traffic conditions.

Table 3.3 Plan for building initial familiarity for participants

Familiarity	Step	For familiar drivers	For unfamiliar drivers
Network	Introduction	Demo video of the preferred route (notification of connection road)	Demo video of the preferred route (notification of connection road)
	Practice session	On a non-preferred route	On an irrelevant route
	Experiment	GPS with all routes highlighted	GPS with all routes highlighted
Traffic conditions	Introduction	Travel time map provided	No travel time map provided

3.3   *Pre-experiment survey*

Once the participants become familiar with handling the driving simulator and the network in different levels, they will be required to complete a pre-experiment survey. This iPad-based pre-experiment survey captures the participant's initial perception of familiarity with each route and likelihood to choose each route for the trip. Figure 3.6 and Table 3.3 illustrate the variables to be captured by the survey when two route options – freeway option and arterial option – are available in the experiment scenario. The collected data will be used in decision-making model as the variables to represent route characteristics in terms of its familiarity and preference to the participant. As the experiment proceeds, the participants' familiarity and preference will evolve over runs in the experiment and the changes will be captured by another set of these questions after each trip (run).

Figure 3.5 Example of pre-experiment survey

Table 3.4 Pre-experiment survey variables and their description

Variable	Description
Initial familiarity with routes	▪ Familiarity with freeway option ▪ Familiarity with arterial option
Initial likelihood to choose of routes	▪ Likelihood to choose of freeway option ▪ Likelihood to choose of arterial option

3.4 _Experiment session and mid-run surveys_

After the pre-experiment survey, the participants take the first run in simulator driving session with the specific scenarios that have been assigned to the participants based on their responses to the static survey. The experiments will be repeated multiple times (or runs) with different scenarios in terms of travel context and information settings, as allowed by limited time. The traffic conditions will be modified in real time based on the dynamic results of a microscopic traffic simulation. Throughout the multiple runs, traffic demand level (high or normal) and trip purpose (business or non-business) are

controlled for a single participant in the experiment to isolate the effects of the different settings of information. In this context, information settings in terms of amount, source, and content of information vary across the randomly-ordered runs, so that possible biases from the specific order of runs with different information settings can be eliminated in aggregate level.

To create travel contexts with and without arrival time restriction (represented by business trip and non-business trip, respectively), a point deduction system is implemented that shows the deducting points on the screen with different speed (faster for business trip and slower for non-business trip) to generate differently perceived time values. The point matters to the participants as it will be used to calculate the final monetary compensation.

Right after a participant makes a decision based on the information provided, the experiment will be paused, and the participant conducts a mid-run survey about the perception of the information. This instant survey using 7-point Likert scale allows the collected data to avoid any possible biases or distortions because of the reminder of the travel experience after the decision-making associated with the provided information. The responses to mid-run survey will be used as indicators for latent variables representing the psychological effects of the real-time information to build a latent variable model that affect decision-making process, as shown in Figure 3.6. Table 3.5 lists the indicator variables for the mid-run surveys that can be collected as many times as the information-assisted decisions have made in a trip.

Table 3.5 Mid-run survey variables (indicators)

Latent variable	Indicator
Complexity (ease of comprehension) of information	▪ Easiness from amount of information ▪ Easiness from content of information ▪ Easiness from multiple source of information
Consistency of information	▪ Consistency with expectations ▪ Consistency with content of information from multiple sources
Sufficiency of information	▪ Sufficiency from content of information
Favorableness of information	▪ Favorableness from content of information

Figure 3.6 Example of the mid-run survey

The indicators related to the complexity (ease of comprehension) of information explain latent information-processing stress as it is caused by excessive cognitive burden from the perception of the information. The indicators representing the consistency and sufficiency of information are present to identify information gap stress that is defined by the cognitive gaps between the level of information that a driver desires to know and the level of information that the driver actually received and comprehended. Consistent

information in relation to the prior experience and information from multiple sources enhances the awareness of the traffic situations and reduces the information gap as well as the sufficient information does. The indicators for favorableness of information are used to specify a latent variable, unfavorableness stress, reflecting the emotional spectrum in terms of reassurance and anxiety. As the unfavorableness stress is caused by the unfavorable traffic situations projected in the information under the given individual attributes and travel context such as sensitivity to delay or trip purpose, it is also possible to have positive effects based on the favorably anticipated travel experience with the provided information.

3.5   *Post-run surveys*

After each run in experiment, participant will be asked to complete the post-run survey that captures participants' level of satisfaction from travel experience as well as their attitude and preference changes in route choice for next experiment run. The answers regarding satisfaction level are also interpreted as indicators for latent variables for psychological benefits (i.e., satisfaction). Table 3.6 lists the variables to be captured in the post-run surveys. The Likert scale-based questions are asked as the indicators for satisfaction with travel experience and psychological effects (cognitive burden, cognitive decisiveness, and emotional burden) of the information. Note that the latent satisfaction inferred by the indicators from post-run survey is not included in the integrated decision-making model presented in Chapter 2. Rather, the indicators will be used to illustrate the comprehensive psychological process of real-time travel information provision that includes satisfaction from psychological effects of the information as well as travel experience (experienced travel time).

In addition to the questions about satisfaction, another set of questions about the updated perception of familiarity with each route and likelihood to choose each route for the trip for the use of prerequisite information for the next run.

Table 3.6 Post-run survey variables and indicators

Latent variable	Indicator
Satisfaction	▪ Satisfaction from travel time ▪ Satisfaction from route choice decisions ▪ Satisfaction from accuracy of information ▪ Satisfaction from cognitive burden ▪ Satisfaction from cognitive decisiveness ▪ Satisfaction from emotional burden
Familiarity with routes	▪ Familiarity with freeway option ▪ Familiarity with arterial option
Likelihood to choose of routes	▪ Likelihood to choose of freeway option ▪ Likelihood to choose of arterial option

3.6   *Compensation*

One of the major disadvantages of behavioral data collected under simulator environment is that the acquired data may not fully represent the real world since: (i) the simulator-based experiment does not involve any considerable real risks to the participant, and (ii) real travel context can never be fully implemented in the experiment. The risk-free environment may result in reckless driving behavior (excessive speeding, ignorance of signals, aggressiveness, etc.). Creating travel context, especially trip purpose that is related to the value of time, and making the participant feel and think that way context is another issue in simulator-based experiments. Even though a participant drives a simulator in a very realistic manner, if any of his or her behavioral decision is not made under the pressure that the business trip would have compared to non-business trip, the collected data is not sufficient from the behavioral point of view.

In order to address these problems, a compensation system is introduced in this experiment. In a point-based mechanism, we will deduct some points per unrealistic driving behavior including excessive speeding, collision, signal ignorance, and so on, to prevent unrealistic driving behaviors. Also, by setting different targeted arrival times for different trip purposes and deducting the point at different speeds (faster in business trip representing the higher pressure to be on time), travel context can be enforced to the participants. And the points will be computed based on the following scheme:

Figure 3.7 Example of the post-run survey

- Initial points of 65 for all participants.

- Uncompleted simulation runs will lead to deduction of points: 15 points will be deducted for each uncompleted simulation run. For example, if a participant withdraws from the experiments after completing three of five assigned driving simulator runs, then 30 points will be deducted from the participant's total points.

- Late arrival of the experimental trip beyond a scale of time (3 minutes) will lead to deduction of points: 5 points will be deducted if we are simulating a business trip; 3 points will be deducted if we are simulating a non-business trip. Unnecessary speeding, traffic violations may lead to deduction at random (to represent the reality no details will be provided except for points that will be deduced): 5 points will be deducted for each violation.

- Incidents or accidents with other vehicles in the driving simulator will lead to point deductions: 10 points will be deducted for each incident.

The participants will be specifically told that there is no point deduction for following or not following the information provided in the driving simulator. They are free to make choices between different routes based on their preferences and attitudes. After a participant completes (or withdraws from) the driving simulator experiments, his/her compensation will be calculated based on the table shown below:

Table 3.7 Reward in point-based compensation system

Final Points	Reward
Below 20	$10 gift card
20 to 29	$20 gift card
30 to 39	$30 gift card
40 to 49	$40 gift card
50 to 59	$50 gift card and chance to win an iPad Mini (lottery)
60 to 65	$60 gift card and chance to win an iPad Mini (lottery)

CHAPTER 4. CONCLUSION

4.1 *Summary*

In this study, we construct an interactive driving simulator experiment to acquire the real-time data of driver behavior as well as their perceptional and psychological states. In order to overcome the common limitations of driving simulator experiments, the proposed interactive driving simulator experiment is: (1) using a realistic network of Indianapolis, Indiana, so that the participants configure the attraction of the routes based on not only the information but also the route attributes (e.g., freeway, toll, or safety); (2) considering dynamic background traffic demands which are enabled by integration by driving simulator software and online traffic assignment in microscopic traffic simulation package; (3) providing diverse information scenarios with multiple sources to understand participants' perceptional and psychological states depending on different information characteristics (e.g., amount, source, or content) and; (4) conducting intermediate surveys, so that we can obtain during-the-trip perceptional and psychological data which are not biased because of travel experience (e.g., travel time experienced).

In this study, we discussed the need for explicitly capturing psychological factors in an integrated choice model framework. The planned experiments in the driving simulator have been explained in a step-by-step mechanism. Identification of explanatory variables and indicators for latent variables and challenges associated with capturing each of these variables and indicators are discussed. The expected results from survey completion and the developed models are a better understanding of the psychological benefits to users from real-time traffic information beyond just the travel time savings.

4.2   Future research directions

Using an interactive driving simulator allows to collect a variety of behavioral data regarding driver's decision-making under different travel situations and various information scenarios. Based on the data collected, the proposed model addresses the decision-making behavior of individual driver assuming homogeneity of driver in terms of the attitude toward real-time travel information. In further research, the approach should be extended to consider heterogeneity of drivers in decision-making process from the behavioral perspective.

REFERENCES

Adler, Jeffrey L., Wilfred W. Recker, Michael G. McNally (1993). A conflict model and interactive simulator (FASTCARS) for predicting enroute driver behavior in response to real-time traffic condition information. Transportation, 20 (2), 83 – 106.

Asakura, Yasuo and Eiji Hato (2004). Tracking survey for individual travel behaviour using mobile communication instruments. Transportation Research Part C, 12, 273–291.

Ben-Akiva, M. Bierlaire, H.N.M. Koutsopoulos and R. Mishalani (1998). DynaMIT: A Simulation based System for Traffic Prediction and Guidance Generation. Proceeding of the 3rd Triennial Symposium on Transportation Systems, San Juan, Puerto Rico.

Ben-Akiva, M., J. Walker, A. T. Bernardino, D. A. Gopinath, T. Morikawa and A. Polydoropoulou (1997), Integration of Choice and Latent Variable Models. Paper presented at the 1997 IATBR, University of Texas at Austin.

Dudek, C.L. (2006) Dynamic Message Sign Message Design and Display Manual. Product 0-4023-P3. Texas Department of Transportation, Austin, TX. (URL:http://tti.tamu.edu/documents/0-4023-P3.pdf)

Itsubo, Shinji and Eiji Hato (2006). A study of the effectiveness of a household travel survey using GPS-equipped cell phones and a WEB diary through a comparative study with a paper based travel survey In CD Proceedings Transportation Research Board 85th Annual Meeting.

Jeffrey L. Adler and Michael G. McNally (1994). In-laboratory experiments to investigate driver behavior under advanced traveler information systems. Transportation Research Part C: Emerging Technologies, 2 (3), 149-164.

Khattak, A. J., Schofer, J. L., and Koppelman, F. S. (1993), Commuters' Enroute Diversion and Return Decisions: Analysis and Implications for Advanced Traveler Information Systems, Transportation Research Part A, 27 (2), 101-111.

Kwan, Mei-Po and Irene Casas (2006). GABRIEL: Gis Activity-Based tRavel sImuLator. Activity Scheduling in the Presence of Real-Time Information GeoInformatica, 10 (4), 469-493

Lawson, Catherine T., Cynthia Chen, Hongmian Gong, Sowmya Karthikeyan, 2008. GPS Pilot Project Phase Three: Mixed Mode Data Collection And Identification Of Special Population Segment (URL :www.nymtc.org/project/surveys/GPS/061508GPS_PILOT_PIII.pdf)

Mahmassani, H.S., Y.-C. Chiu, G.L. Chang, S Peeta and A Ziliaskopoulous (1998). Off-line Laboratory Test Results for the Dynasmart-X Real-Time Dynamic Traffic Assignment System. Technical Report ST067-85-TASK-G, Center for Transportation Research, The University of Texas at Austin.

NCHRP (2008) Report 571: Standardized Procedures for Personal Travel Surveys.

Peeta, S, and J-W Yu (2006). Behavior-based consistency-seeking models as deployment alternatives to dynamic traffic assignment models. Transportation Research Part C, 14, 114–138.

Pel, Adam J. (2011) A review on travel behaviour modelling in dynamic traffic simulation models for evacuations. Transportation, 39, 97–123.

Punzo, V. and B. Ciuffo (2011) Integration of Driving and Traffic Simulation: Issues and First Solutions. IEEE Transactions on Intelligent Transportation Systems, 12(2), 354-363.TSM (2012) Travel Survey Manual (URL: http://www.travelsurveymanual.org/)

That, T. N. and J. Casas. (2011) An integrated framework combining a traffic simulator and a driving simulator. Procedia Social and Behavioral Sciences, 20, 648-655.

Ullman, G. L., Dudek, C. L., and Balke, K. N. (1994), Effect of Freeway Corridor Attributes on Motorist Diversion Responses to Travel Time Information, Transportation Research Record 1464, TRB, National Research Council, Washington, D.C., 19-27.