DEVELOPMENT OF ROUTE CHOICE BEHAVIOR ANALYSIS SIMULATOR UNDER VARIOUS ATIS ENVIRONMENT

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Abstract: This paper is aimed at presenting a new attempt to acquire drivers' route choice behavioral data to evaluate various ATIS in controlled laboratory. Although questionnaire based stated preference surveys have been widely used in this field, they suffer from the difficulty in making respondents fully understand complex scenarios in questionnaires and feel travel time pressure of the scenarios. Therefore, the obtained data can be depreciated.
A simulator is a good alternative to resolve this since it can create more realistic understanding on the traffic situations. A prototype simulator with three modules has been developed. To verify the validity of it, a pilot test was performed for a small real network, and its data was analyzed with a discrete choice model. The result was reasonably acceptable. The simulator can be very effective for developing and evaluating different information strategies, prior to as well as posterior to major investments.

Key Words: Advanced Traveler Information System, Route Choice Behavior, and Mesoscopic Flow Simulation

1. INTRODUCTION

ATIS deployment has started or is being considered in many countries due to the fast development of information and communication technologies. The objective of ATIS is to increase the efficiency, safety and travel comfort of the transportation system by providing travelers with traffic information and/or guiding them to reasonable routes. In other words, providing information is expected to improve network efficiency by improving individual route choices in the interests of an overall network optimum (Bonsall *et al*, 1991).

The predictive information is most useful to drivers because their route choices are mainly influenced by the expected traffic situation. If it is possible to predict the traffic situation exactly and provide drivers with the predictive information efficiently, an ideal traffic information system would be achieved. However, it is too difficult to achieve such a system because of the huge complexity of driver decision-mechanism. Therefore, in the design and evaluation of an ATIS, driver behavior analysis should precede all other ATIS elements.

In assessing the driver behavior to an ATIS implementation, no single solid methodology exists yet. Collecting driver behavioral data directly in the field is almost impossible. Thus, the SP questionnaire survey has been widely used despite of its potential shortcoming. A significant shortcoming of the SP questionnaire method is the difficulty to elicit drivers' true preferences in various traffic situations. In other words, to make respondents fully understand the hypothetical situations and feel travel time pressure of those situations is very difficult. These difficulties may incur biases in the ATIS SP survey and depreciate the survey results.

A computer simulator can be an alternative to provide real-world decision-making environments and to record the behavior of human subjects interacting with this simulated environment. Recently, simulation methods have been used to overcome these limits of SP questionnaire survey and to collect more reliable data. A well-designed simulator represents more realistic traffic situations and helps respondents to understand hypothetical traffic situations. The survey using a simulator in a laboratory repeatedly ask and collect drivers' responses to those traffic situations.

The objective of this study is to develop a prototype ATIS simulator for investigating the relation between traffic information and driver reactions. The prototype simulator is designed to maintain flexibility in representing various operating scenarios and information delivering media. The module based design concept is adopted in implementing the computer code and a pilot test with the developed ATIS simulator was performed to verify its usefulness.

2. METHODOLOGY OF ATIS SIMULATOR

To analyze driver reaction to traffic information, many researcher tries to collect behavioral data. Such data can be classified into two distinct categories, (1) revealed preference (RP) data, and (2) stated preference (SP) data. RP data truly reflects choice behavior because it relies on choices that have actually been made in the marketplace. SP techniques, however, rely on obtaining choice behavior in response to hypothetical situations. As for data validity, RP data is preferable to SP data because RP data is directly connected to actual choice behavior. Despite this fact, in the scope of driver reaction analysis to ATIS, RP data is hardly available to the analysts because of inability of RP methods to address conditions that are not currently existing, and the difficulty to collect drivers' RP data in the field. Therefore, SP approaches have been widely used.

A significant disadvantage of SP methods is that individuals' stated preferences may not be indicative of their true choice behavior. As Wardman (1988) enumerates, systematic bias in SP responses or difficulty in carrying out the SP task may prevent obtaining reliable data. To mitigate this problem, simulation based SP surveys have been used in ATIS driver behavior study as shown in Table 1. This type of simulator helps respondents to understand and differentiate given hypothetical situations. A key to elicit more reliable data to study ATIS behaviors, respondents should feel time pressure of each traffic scenario, which the simulator provides easily than complex text based questionnaire.

Table 1. Simulator Developments for Driver's Route Choice Behavior Analysis

Developer	Year	Summary
Bonsall, Parry University of Leeds	1991	● Developing IGOR (Interactive Guidance On Routes). ● If respondents select next direction, they can see a next traffic situation screen. ● Respondents can hear sound effect like engine on passing an intersection. ● It is successful to collect data, but there are several problems; the insufficiency of reliability in user interfaces, the limitation of modeling various traffic-operating situation and information supply strategies.
Bonsall, Firmin University of Leeds	1993	● Developing three simulators as the following of IGOR. ● Investigating the influence on user behavior concerned with simulator designs (TRAVSIM) ● Investigating user response to various ATIS strategies (VLADIMIR) ● Integrating advanced computer image technology with real vehicle environment.
Chen, Mahmassani University of Texas at Austin	1993	● Collecting driver behavioral data about day-to-day dynamic. ● Describing more realistic traffic situation using DYNASMART. ● Analyzing the interaction between a user decision-making and network states.
Koutsopoulos, Lotan, Yang MIT	1994	● Describing en-route driving situation ● Developing a flexible simulator to model various traffic operation scenarios

The well-fusioned traffic information is delivered to drivers through various media such as VMS, Internet, ARS/FAX, radio, etc. These media can be embodied in the simulator and presented to respondents. This study designed an ATIS simulator and implemented a prototype one with VMS mode. The pilot survey was performed to verify the usefulness of it. The new prototype ATIS simulator was designed to hold flexibility, expendability and theoretical foundation in traffic dynamics. It consists of three sub-modules: *Traffic Simulation Module, Database Module, User Interface Module*. Traffic Simulation Module is mesoscopically designed for future large-scale network applications without losing microscopic flow model's advantage in ATIS evaluation. Database Module manages input/output data, and User Interface Module controls graphic displays to show respondents hypothetical traffic situations. The application procedure is shown in Figure 1

Database Module receives network typology data, dynamic OD, and traffic scenarios in text. Traffic Simulation Module computes network-wide traffic pattern and sends it back to Database Module. Database module delivers network traffic flow pattern for each scenario to User Interface Module. User Interface Module displays network traffic pattern and traffic information to respondents, and collects individual attributes and respondents' choices on each scenario. Database Module keeps the results and the external analysis proceeds.

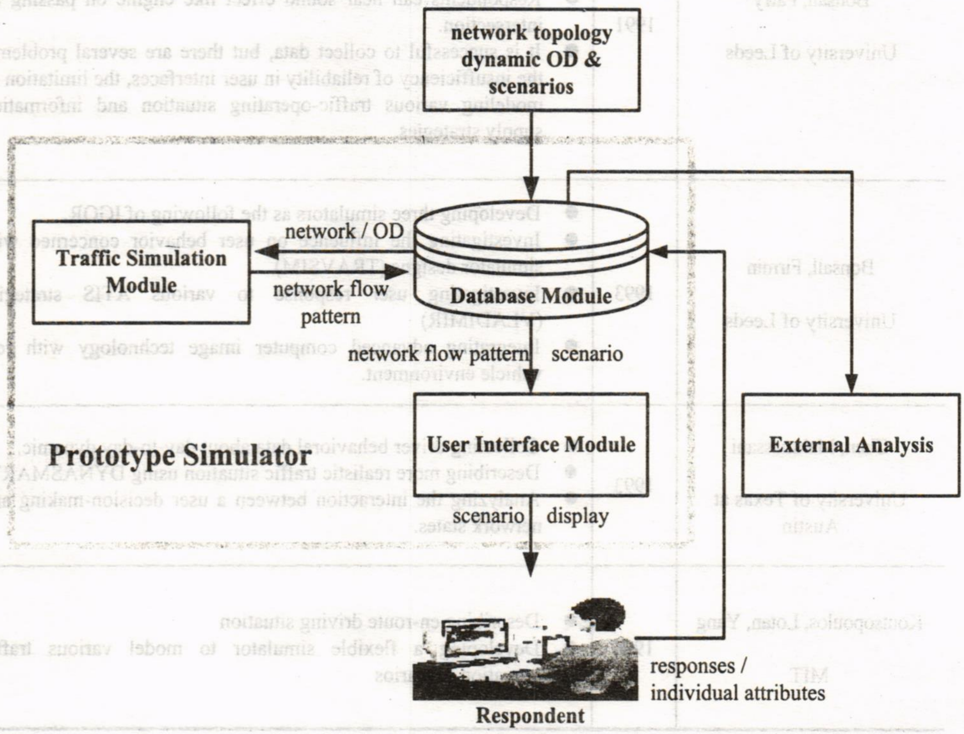

Figure 1. Prototype ATIS Simulator and Application

3. IMPLEMENTATION OF THE PROTOTYPE ATIS SIMULATOR

This section explains detailed implementation of the prototype ATIS simulator. As mentioned section 2, it consists of three modules: traffic simulation module, database module, and user interface module. The most important feature of our simulator is its flexibility and expandability to deal with traffic scenarios and networks. Once networks and hypothetical scenarios to investigate are decided, the three modules evaluate and present network traffic flow pattern without major source code change. Another feature of the simulator is its mesoscopic flow modeling is theoretically sound in large-scale applications.

3.1 Traffic Simulation Module

Traffic simulation module was designed in mesoscopic traffic flow theory after reviewing various flow model including DynaMIT of MIT and DynaSMART of the University of Texas at Austin. It creates the network flow pattern using network typology data, dynamic OD and traffic scenarios including incidents. It is theoretically structured with deterministic queuing theory and computes time dependent events.

This module was developed with the object-oriented programming. Each object contains its particular characteristics and functions, and interacts with other objects. The included objects are site, environment, network, node, link, segment and vehicle object:

Site Object executes the followings:
- To control traffic simulation module overall;
- To create other objects such as environment, network, link, segment, node and vehicle needed to perform simulation;
- To operate objects according to simulation algorithm.

Environment Object executes the followings:
- To manage global data needed to simulation operation.

Network Object executes the followings:
- To control link, segment, node and vehicle.

Link Object
- Divided into several segments and vehicle moves on the segment.
- Properties: ID, length, the number of segments, the length of moving part, saturation flow rate, start node, end node, queue length, vehicle ID on link etc.

Segment Object
- Vehicle travels in accordance with segment speed, density, inflow and outflow constraints.
- Properties: ID, length, speed, saturation flow rate, free flow speed, jam density, initial volume, acceptance capacity, output capacity, input counter, output counter, queue length, vehicle lists on segment, queuing vehicle lists on segment etc.

Node Object executes the followings:
- To control vehicle movements at an intersection;
- To connect the vehicle movement of a link with another link;
- To operate a virtual link unless vehicles are accepted to a next link;
- Properties: Intersection capacity, cycle, effective green time, dummy variable of virtual link etc.

Vehicle Object executes the followings:
- To control vehicle to be interacted simultaneously with link, segment or node objects and move on the route set previously.
- Properties: ID, start link, arrival link, start time, arrival time, vehicle length, travel speed, route data, position on the segment, travel time, current using link, current using segment etc.

3.2 Database Module

Database Module manages all input and output data, and produces text or DB files for the external analysis. It delivers other modules with input data and receives user responses, individual characteristics and module outputs. This modules contains two elements: data related to Traffic Simulation Module, and data related to User Interface Module.

Data related to Traffic Simulation Module are as follows:

- Node: node ID, x coordination, y coordination.
- Link: link ID, from node, to node, segment index, free flow speed, length.
- Vehicle: vehicle ID, departure time, path.
- Incident: time ID, modification indicator, modification degree.

The format of input data fields is designed as the general data structure in network analysis. To describe incident situations, the incident data includes three fields: time ID, modification indicator and modification degree. The prototype simulator provides respondents with screen-displays to animate vehicle and network representation. Thus, the output data of Traffic Simulation Module is arranged to make scenario data using time step and link segment speed.

Data related to User Interface Module are as follows:

- Node: node ID, x coordination, y coordination
- Link: link ID, from node, to node, segment index, free flow speed, length
- Scenario file
- Options: background image, text information, icon

The scenario file is used to describe traffic situations changing at each time step until respondent's vehicle arrives at its destination. Input data are integrated into a single file to remove the effort of reading data.

Respondents are endowed with user ID and should make out a simple questionnaire about individual attributes before prototype simulator starts. Respondents select their routes responding to network situation and traffic information displayed on computer screens. Output data of User Interface Module are as follows:

- User responses: User ID, scenario number, travel path, travel time etc.
- Individual attributes: User ID, age, gender, income, job etc.

3.3 User Interface Module

User Interface Module provides graphical displays with respondents depending on scenarios, traffic situations and traffic information with VMS mode at each time step. Respondents are asked to choose their preferred route and those responses are sent back to Database Module. When the survey starts, the respondent is asked several questions to collect his/her socioeconomic attributes. Then flow pattern and traffic information are displayed as like as Figure 2.

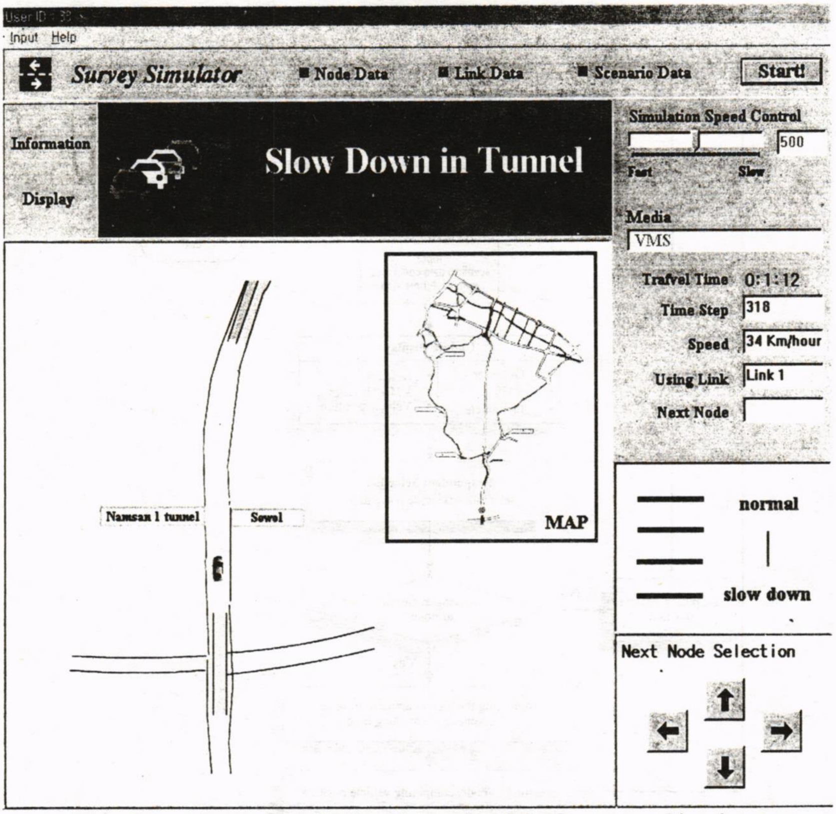

Figure 2. Executing Display Example of the Prototype Simulator

The executing display consists of three components:

- Vehicle and Network Display Part: left of Figure 2;
- Route Selection Part: right of Figure 2;
- VMS part: top of Figure 2.

Now, Figure 3 represents the procedure of User Interface Module, which makes vehicles move and respondents feel time pressure proportional to travel speed.

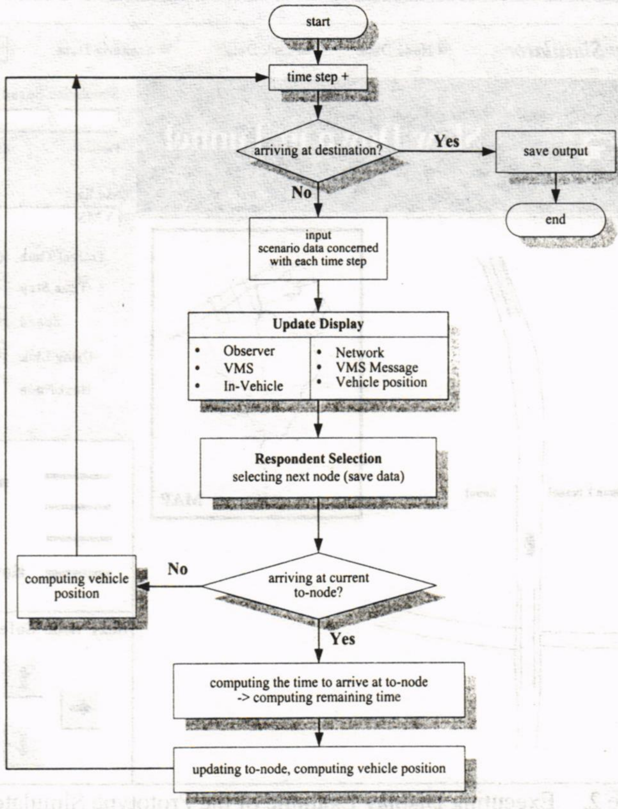

Figure 3. User Interface Module

Detailed file list of the integrated scenario file contains the following:

- Network file
- Graphic file (Background)
- Traffic states file
- Traffic information file

User Interface Module in Figure 3 performs as follows;

- Start
- Arriving at destination?: One survey scenario ends, if respondent's vehicle arrives at the destination node;
- Input scenario data relevant to each time step: The simulator reads all link attributes of current time step in the scenario file calculated by traffic simulation module;
- Update Display: Screen is updated depending on information mode.
- Respondent selection: Respondents should select next direction to progress until their vehicle arrives at the destination continuously;
- Arriving at current to-node?: The simulator judges whether vehicle can arrive at to-node by comparing coordinates of current vehicle position to to-node coordinates. If respondent's vehicle does not arrive at to-node in interval time, simulator updates location of vehicles and returns to next time step after displaying the vehicle on screen. If possible to arrive, updates from-node and to-node, calculates remaining time to updates vehicle position and returns to next time step.

The above procedures are implemented, resulting in a prototype ATIS simulator. To verify its usefulness, a web-based pilot test was performed in section 4.

4. PILOT TEST AND RESULTS

The implemented prototype ATIS simulator needs to be verified if it works reasonably. The pilot test was performed. The test was designed to analyze the VMS impacts on a small but real network with two paths. One is a short tunnel path charged by a fixed congestion toll and another is Sowol Street, a long free path. The respondents were asked about their socioeconomic characteristics such as age, gender and education level, then they were encountered a series of network traffic scenarios and selected the preferred path between two. This test measures attitudes towards traffic information on VMS and their propensity to divert under certain situations. The collected diversion behavioral data are analyzed with a logit model.

Summary of pilot test is as follows:

- Traffic network: two paths, Namsan 1 tunnel and Sowol Street. Drivers pay about \$2.00 for using Namsan 1 tunnel. Sowol Street takes 7 minutes more in normal traffic conditions;
- 50 respondents were participated in the test. Nine scenarios for each respondent were tested;
- Respondents should choose either Namsan 1 tunnel with paying \$2 or Sowol Street in three traffic conditions: normal (VMS1), slow down (VMS2) and incident (VMS3);
- Three trip purposes were tested: commute, business, and other;
- Thus, for the nine different cases depending on traffic conditions and trip purposes. Furthermore, respondents were given by hypothetical early or late band travel times to their destination when they see VMS messages.

Total 450 observations were collected from the 50 respondents. After data cleaning, 419 observation data were used to develop a logit model for drivers' diversion decision. Binomial logit model was estimated with the following utility function:

$$V=(V_{1n}-V_{2n})=CONST+\beta_1 EB+\beta_2 LB+\beta_3 CMMT+\beta_4 BSN+\alpha_1 VMS2+\alpha_2 VMS3 \quad (1)$$

where,
1 = alternative representing Namsan 1 tunnel,
2 = alternative representing Sowol Street,

Table 2. Explanatory Variables in the Driver Diversion Model

Explanatory Variable	Mnemonics
Namsan 1 Tunnel constant	CONST
Early band time (min.)	EB
Late band time (min.)	LB
Commute trip dummy = 1, if commute trip to work place = 0, otherwise	CMMT
Business trip dummy = 1, if business trip = 0, otherwise	BSN
VMS dummy variable corresponding to delay message on Namsan 1 tunnel = 1, if traffic slowing down on Namsan 1 tunnel = 0, otherwise	VMS2
VMS dummy variable corresponding to incident message on Namsan 1 tunnel = 1, if incident situation on Namsan 1 tunnel = 0, otherwise	VMS3

Table 3 shows the estimated binary logit model. The variable CONST is the alternative specific constant for the Namsan 1 tunnel path. The negative sign (-0.841) implies a natural aversion to use the tunnel path because the disutility due to the toll overshadows travel time saving of the tunnel path. This tendency was maintained when respondents are exposed in early arrivals (notice EB, β_1 = -0.017).

Here, early band (EB) means respondents might be able to arrive at their destinations earlier than the usual day by this amount, and late band (LB) means vice versa. The amount of the band is randomly given to the respondents during the survey. When respondents are exposed in late arrivals, drivers tend to select the Namsan 1 tunnel path (notice LB, β_2 = 0.082). The coefficient of LB is generally believed larger than EB (β_1 = -0.017) and our results confirmed this.

Dummy variables corresponding to trip purposes (business, commute and other) were included in this logit model (other trip is the base case). Business trip(β_4 = 0.891) shows more time saving tendency indifferent of a toll than commute trip(β_3 = 0.45), and the same relation are observed between commute trip and other trip.

Dummy variables corresponding to VMS messages (normal, slowdown and incident) were included in this model (VMS1-normal is the base case). The VMS variables are very significant and provide the largest increases in log-likelihood. Slow down information (VMS2) and incident information (VMS3) in the Namsan 1 tunnel path drive respondents to the Sowol street path in spite of no information on the Sowol street. The impact of incident message (VMS3, β_6= -2.77) is much stronger than that of slow down message (VMS2, β_5= -1.377).

Table 3. Logit Model for Driver Response Under VMS

Variable	Model	
	Coefficient (β)	t-ratio
CONST	-0.841	-2.1
EB	-0.017	-0.8
LB	0.082	2.9
CMMT	0.45	1.3
BSN	0.891	2.6
VMS2	-1.377	-3.3
VMS3	-2.77	-5.1
Number of observations	419	
L(0)	-290.43	
$L(\hat{\beta})$	-166.68	
ρ^2	0.4261	

The above results are limited but surprisingly reasonable. Our ATIS prototype simulator is able to make respondents understand different traffic situations without intensive education to perform the survey. This pilot test suggests that the simulator be powerful to investigate driver reactions to traffic information. This promising result need to be verified with more intensive survey and is being prepared for a lager network.

5. CONCLUSIONS

Ever improving information technologies are realizing a long-cherished advanced traffic information systems. However, driver reaction to the information systems is somewhat unclear. Thus, the usefulness of the information system needs to be confirmed before major investments. Recently, a simulation based driver reaction study has been spotlighted because of its relative superiority to a questionnaire based SP survey.

The prototype ATIS simulator was developed to collect more reliable user behavioral data to investigate the relation between driver reactions and traffic information. It is developed in object oriented way to maintain flexibility and expandability. The simulator was tested using a pilot survey. The data was analyzed with a binomial logit model. Through the pilot test, the simulator showed its usefulness to overcome a shortcoming of a questionnaire based SP survey in ATIS evaluation. Our simulator will help to evaluate the new developed traffic information systems and/or information providing strategies prior to a massive investment. The experiences of the code development will be revitalized in our next version of the ATIS simulator for large-scale applications.

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