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Final Report

Project Title:

Characterizing Traffic under Uncertain Disruptions: An Experimental Approach

Project Number:	Project End Date:	Submission Date:
UMAR22-14	April 30, 2013	March 31, 2013

Problem Addressed

The objective of the research is to study long-term traffic patterns under uncertain disruptions using data collected from human subjects who simultaneously make route choices in controlled PC-based laboratory experiments. Uncertain disruptions to a traffic system usually include incidents, bad weather and work zones which result in uncertain travel times. Meanwhile, real-time information is and will be available to travelers so they can adapt to actual traffic conditions and reduce the negative effects of uncertainties. In conventional traffic prediction models, these disruptions are excluded and travelers are assumed to face a deterministic network. However, as uncertain disruptions account for a significant portion of the total traffic delays on the road, it is imperative to incorporate them in a traffic prediction model. In a New England UTC Year 21 project, we developed an individual behavioral model of route choice in an uncertain network with real-time traveler information. This project builds on the behavioral model and considers the collective congestion effects of many individual drivers' route choices. Two central research questions are to be answered: 1) Is there a steady traffic pattern in terms of probability distributions of traffic variables under uncertain disruptions, with and without real-time traveler information? 2) Can we build a model to characterize traffic patterns under such situations?

Approach and Methodology

Laboratory Experiment
Recruited subjects were students at the University of Massachusetts Amherst. Each session had sixteen participants. We asked subjects to make work-to-home trip on a "day-to-day" basis. Participants were expected to have preferences among a highway, an arterial, and a local road. The risky route (highway) has a one out of four chance of having an incident. We notified the subjects of the incident odds and its potential consequence. We randomly generated the position of an incident in each 4-day block. All subjects' route choices collectively determined the travel time, and they were made aware of the actual travel time of the chosen route after the trip. We presented the information of the route traveled on the previous day for all sessions. Subjects made route selections for a total of 120 days. There were eight sessions in total, with four using real-time information (information scenario) and four that did not (incident scenario). In the information scenario, a variable message sign (VMS) just before the second bifurcation informed drivers whether there was an incident on the highway or not. This piece of information was only available for those choosing the branch that contains the highway.

Statistical Analysis
Data visualization and non-parametric statistical analyses were carried out to compare route flows, route switches, average trip times and trip time standard deviations between the incident and information scenarios.

Model Development
A reinforcement learning model with two scale factors, a discounting rate of previous experience, and a constant term is estimated by minimizing the deviation between predicted and observed daily flows. The estimation combines brute force enumeration and a subsequent stochastic approximation method.

Conclusions and Recommendations

Comparing the traffic patterns with and without real-time information, we found that real-time

information significantly reduces network travel time and its variability. However, we did not observe equilibrium in any of the experiment sessions. Participants switch more often in the information scenario at the branch than in the incident scenario. However, this trend is reversed at the origin. It is plausible that route switching may permit information gathering when real-time information is unavailable. The significant difference in route flows on the safe branch between scenarios verifies the need to consider travelers' long-range planning behaviors in a traffic assignment model.

These results have particular relevance for the future development of smart traveler information systems. Over 90% of participants chose Routing Policy 4, which suggests a route switch at the branch in response to an incident alert. We also performed simulations based on an exponential probabilistic reinforcement learning model and compared to daily and overall prediction flows with the observed experiment data in the information scenario. Despite its relative simplicity, the simulation model performed well when compared to observed experiment data.

Outcomes

Journal Publications

Lu, X., Gao, S., Ben-Elia, E. and Pothering, R. (Forthcoming). Travelers' Day-to-Day Route Choice Behavior with Real-Time Information in a Congested Risky Network. Mathematical Population Studies. Accepted Aug. 27, 2012.

Lu, X., Gao, S. and Ben-Elia, E. (2011). Information Impacts on Route Choice and Learning Behavior in a Congested Network: An Experimental Approach. Transportation Research Record 2243:89-98. doi:10.3141/2243-11

Conference Proceedings

Lu, X., Gao, S., Ben-Elia, E. and Pothering, R. Information Impacts on Travelers' Route Choice Behavior in a Risky, Congested Network. The 91st Annual Meeting of Transportation Research Board Compendium of Papers. Paper #12-2956. Washington, DC, Jan. 22-26, 2012.

Conference Presentations

Lu, X., Gao, S. and Ben-Elia, E. Comparison of Basic Assumptions of a Learning-Based Route Choice Model in a Congested, Uncertain Environment. The 13th International Conference on Travel Behavior Research, Toronto, Canada, Jul. 15-20, 2012.

Lu, X., Gao, S., Ben-Elia, E. and Pothering, R. Information Impacts on Travelers' Route Choice Behavior in a Risky, Congested Network. The 91st Annual Meeting of Transportation Research Board. Washington, DC, Jan. 22-26, 2012.

Lu, X., Gao, S. and Ben-Elia, E. Information Impacts on Route Choice and Learning in a Congested Network: An Experimental Approach. The 19th Triennial Conference of the International Federation of Operational Research Societies. Melbourne, Australia, July 10-15, 2011.