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Paper Title & Number

Modeling Behavioral Response to Real Time Traveler Information: An Application of a Continuous-Time Integrated Transport Modeling Framework [ITM # 88]

Abstract

In the transportation arena, technology today has afforded individuals with freely available up to date information about opportunities and network conditions. The prevalence of information has changed how people plan and execute their activity-travel agendas. In particular, the advent of Real-time Traveler Information Systems (RITS) that provide upto-the-minute system wide information about network conditions has altered how people navigate networks and pursue activities. The implementation of any RTIS solution requires a comprehensive modeling analysis for quantifying the impacts of such services. There are however very limited modeling tools that can accurately capture the impacts of such information services on individual activity-travel agendas without compromising on representation of underlying behaviors. The research proposed in this effort is aimed at exploring travel survey data to characterize dimensions of rescheduling behavior and identify schedule adjustment heuristics. Additionally, the observed behaviors will be implemented in a software prototype of a transportation system modeling tool and applied to the Hartford metropolitan region as a case study.

Statement of Financial Interest

There are no financial interests and this is purely a research exercise. All research products will be disseminated under open-source licensing agreements.

Statement of Innovation

The proposed effort will contribute to the state of research and practice in the transportation planning arena. First, the research will add to the literature on travel behavior by attempting to understand activity-travel rescheduling behavior in response to prevailing network conditions. In most implementations of travel demand models, rescheduling behaviors are implemented by imposing consistency constraints (in spatial and temporal representation) and adhering to budget constraints of available resources. For example, rescheduling dynamics are implemented by ensuring that time allocated to activities and trips add up to 1440 minutes in a day. However, such implementations do not consider true rescheduling behaviors and fail to capture the heuristics employed by individuals in making these decisions. In this research effort, travel survey data sets will be explored using data mining principles to understand pre-trip and en-route rescheduling decision heuristics and estimate models of decision processes involved. Second, the research will add to the state of practice on transportation modeling software by enhancing an existing open-source transportation model system to incorporate additional behaviors that accurately mimic rescheduling decision processes exhibited by individuals in real world. The prototype will comprise one of the few implementations of a transportation model system that can comprehensively model the full range of scheduling and rescheduling behaviors exhibited by individuals in response to real-time traveler information. Additionally, the enhanced prototype will be applied to a metropolitan region to demonstrate its applicability for planning and policy analysis.

Modeling Behavioral Response to Real Time Traveler Information: An Application of a Continuous-Time Integrated Transport Modeling Framework

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ABSTRACT

In the transportation arena, technology today has afforded individuals with freely available up to date information about opportunities and network conditions. The prevalence of information has changed how people plan and execute their activity-travel agendas. In particular, the advent of Real-time Traveler Information Systems (RITS) that provide upto-the-minute system wide information about network conditions has altered how people navigate networks and pursue activities. The implementation of any RTIS solution requires a comprehensive modeling analysis for quantifying the impacts of such services. There are however very limited modeling tools that can accurately capture the impacts of such information services on individual activity-travel agendas without compromising on representation of underlying behaviors. The research proposed in this effort is aimed at exploring travel survey data to characterize dimensions of rescheduling behavior and identify schedule adjustment heuristics. Additionally, the observed behaviors will be implemented in a software prototype of a transportation system modeling tool and applied to the Hartford metropolitan region as a case study.

INTRODUCTION

Technology has increasingly permeated all aspects of human life and has significantly changed the way people go about their daily lives. The influence of technology can also be readily seen in the transportation planning arena where individuals have access to more information than ever before about network conditions, allowing them to efficiently plan their activities and travel episodes. All of this information-on-demand has changed the way individuals plan and execute their activities. Operating on a longer time horizon (day-to-day), we have technology in the form of Information and Communication Technologies (ICT) impacting the way individuals plan activities and trips. For example, videoconferencing facilities allow individuals to conduct business meetings without having to travel. Similarly online shopping opportunities have eliminated some shopping trips, at the same time affording individuals the extra time to engage in other types of activities. Additionally, operating on a shorter time horizon (within a day) we have technology influencing the way individuals' modify and execute their planned activity-travel agendas. For example, technology in the form of Advanced Traveler Information Systems (ATIS) provide roadway users with up to date information about travel times along roadway corridors allowing users to make informed decisions about routes to take or avoid, and/or reschedule their activity-travel episodes. ATIS is seen as one of the key solutions for addressing the congestion issues that plague transportation systems today. A specific service in the ATIS realm that is gaining in popularity is the real-time traveler information services (RTIS). RTIS promises the ability to provide upto-the-minute network-wide traffic conditions to people through a variety of technological solutions including smart phones, global positioning systems, and in-vehicle technologies. With RTIS, individuals not only have the ability to access this information but can also consume such information in making efficient choices related to their activity-travel engagement patterns.

The potential of RTIS for improving the efficiency of different aspects of the activity and travel choices is undisputed. The use of smartphone navigation apps providing real-time network conditions helps an individual in making efficient route choice. Individual gains in efficiencies are associated with cascading and downstream impacts on the activity and travel decisions in a later time period. The net impact of a RTIS strategy on the transportation system as a whole is complicated to assess. Therefore, there is a need for a comprehensive system modeling tool that can be utilized to systematically assess the direct and cascading impacts of real-time services such as RTIS. Subsequently results from the modeling tool can be used to evaluate the effectiveness of different RTIS strategies for addressing specific transportation issues. Additionally, the system modeling tool can also be used to examine different implementation options for a selected RTIS strategy and select an option that best meets the agency objectives given the constraints of resources and time.

The focus of this research effort is threefold and aims to address the potential limitations of existing transport model systems for accurately modeling the influence of real-time traveler information services (RTIS) on activity-travel engagement patterns. First, in this paper, literature will be explored to better understand the pre-trip, and en-route rescheduling dynamics exhibited by individuals in response to RTIS. Further, a conceptual modeling framework for the activity-travel generation will be formulated based on the literature synthesis that can accurately represent the influence of real-time traveler information on the activities that individuals pursue and the trips that people undertake in a behaviorally consistent fashion. Second, the conceptual framework will be implemented in an existing microsimulation-based transportation software by extending the software to model the impacts of different RTIS strategies. Lastly, the extended microsimulation-based transportation model will be demonstrated by applying the model to Hartford metropolitan area in the state of Connecticut. The model will be applied to study the impacts of a range of real-time traveler information strategies including radio, variable message signs, real-time GPS navigation systems, and smartphone applications, among others. This presentation will offer details of the modeling framework and initial prototype results from the case study.

MODELING IMPACTS OF RTIS ON TRAVELER BEHAVIOR

There are a number of system modeling tools that have been used to model RTIS strategies (Venkatraman 2013, Gao 2012). The system modeling tools to evaluate RTIS often comprise a transport model based on microsimulation approaches. The transport model system typically includes two component model systems namely, the travel demand model and the traffic assignment model. The travel demand model attempts to replicate the activity-travel decisions of individuals (including choices of when, where, how, with whom, and mode for trips) while the traffic assignment models attempts to simulate the routing decisions and the network conditions given the activity-travel decisions. Most of the work in the evaluation of RTIS strategies has been limited to capturing the impact of RTIS on routing decisions and network conditions (through the use of traffic assignment models) with no treatment of the influence of RTIS on the activity-travel decisions. In the few studies where the impact of RTIS on the activity-travel decisions is considered, the treatment is simplistic with no deployment of a microsimulation model to capture travel demand. The treatment in such efforts is often fraught with inconsistencies in the representation of underlying behaviors, thus affecting the validity of the results. The limitations of the traditional transport model tools for evaluating RTIS can be categorized into two main types as described below.

- First, there are number of activity-travel dimensions that are influenced by RTIS and the specific dimensions of activity-travel engagement which are impacted depends on when, where, and how the information provided by RTIS was accessed and utilized. For example, when provided with information pre-trip, individuals may alter their destination, mode, or completely forego the activity based on network conditions. On the other hand, individuals that are en-route to an activity destination may change their route, destination, or skip activities. Therefore, it can be seen that RTIS can not only alter the route for a trip but it can also influence other activity-travel dimensions. Therefore there is a need for a system modeling tool which can comprehensively capture the range of pre-trip and en-route decision processes related to the planning and execution of activity-travel choices.

  There are some implementations of transportation models which accommodate the influence of RTIS on activity-travel choices. However, in these models, the influence of RTIS on the activity-travel choices is captured by imposing consistency constraints (in spatial and temporal representation) and by adhering to budget constraints of available resources. For example, rescheduling dynamics are implemented by ensuring that time allocated to activities and trips add up to 1440 minutes in a day (Konduri et al. 2012). It can be argued that such implementations do not consider true underlying behaviors and fail to capture the individual activity-travel decision-making dynamics. Therefore, in addition to considering the full set of activity-travel dimensions, the model system should also incorporate the scheduling and rescheduling dynamics.
- Second, in most traditional transport model applications for simulating the impacts of RTIS, trips are considered in isolation. However, it has long been acknowledged in the transportation planning arena that trips result from an individual's need to engage in

activities subject to their spatial, temporal, and resource constraints and the interactions they experience (Jones 1979). Further, information about the prevailing network conditions (or lack thereof) affects activity-travel engagement decisions in the later part of the day. For example, if an individual is oblivious to an incident along a planned route, then he or she may experience congestion. Subsequently, the delay experienced will affect the activity-travel engagement patterns for the person in the later part of the day. The person may arrive later to the activity destination and adjust the duration of destination activity or keep the duration of the destination activity as is but alter subsequent activity-travel schedule. The same individual, in the presence of information about network conditions as afforded by RTIS, may skip the planned activity or choose a different destination to pursue the same activity which will also affect subsequent activity-travel engagement decisions. By considering trips in isolation, all of the above underlying activity-travel decision making processes are ignored and this in turn affects the validity of the results. Therefore, any system modeling tool needs to accurately represent the processes underlying trip making by accounting for the individual decision maker, the activities they wish to pursue and the different constraints and interactions to which they are subjected.

The intent of this paper is to offer a modeling framework that overcomes the drawbacks noted above. The modeling methodology and behavioral framework offer the ability to simulate adjustments in route choice *and* activity-travel demand choices in response to real-time information about network conditions.

METHODOLOGY

In the following subsection, the methodology to analyze rescheduling behaviors exhibited by individuals in the presence of RTIS is presented. This is followed by a subsection describing the transportation model system that is capable of modeling RTIS. In the third subsection the transportation software prototype that will be developed is presented, followed by a description of the case study application in the last subsection.

Activity-Travel Scheduling and Rescheduling Behavior

A key component of the proposed research is to explore existing literature and readily available survey datasets to better understand the scheduling and rescheduling behaviors exhibited by individuals in response to information about prevailing network conditions provided by RTIS. First, existing literature on the responses exhibited by individuals in response to RTIS will be explored to characterize dimensions of activity-travel scheduling and rescheduling behaviors. Existing survey datasets that collect information about activity-travel agenda plans and how they are executed (Doherty and Miller 2000, Auld et al. 2009) will be explored to identify candidate datasets that can be utilized to estimate models. The decision dimensions will be modeled using appropriate statistical formulations, and decision heuristics will be identified using data mining principles (Walczak and Gregg 2003).

A Continuous-Time Integrated Transport Modeling Framework

There are two main components of any model of the transportation system, namely, travel demand model and traffic assignment model. In an activity-based travel demand microsimulation model, individual activity-travel patterns are generated for every individual while recognizing the constraints and interactions they experience. The traffic assignment model identifies routes for each trip pursued and simulates the movement of vehicles on the network. Research in the development of these component model systems has happened largely independently. However, there are important linkages across these components. Network conditions are directly influenced by the activity-travel patterns that are generated, i.e. the demand for travel. Activity-travel patterns in turn are influenced by the network conditions, which govern individual opportunity spaces given spatio-temporal constraints they experience, i.e., how far and what places can one access given network conditions. Therefore there is a need for an integrated model system that accurately represents the interdependencies between travel demand and network supply.

An approach that is often proposed to integrate the two components is to apply the model systems sequentially and interface the component systems through input-output data flows and feedback loops. The sequential application works well for most planning and policy applications. However, recent work suggests that the sequential approach compromises the representation of underlying behaviors and leads to inaccurate policy inferences (Konduri et al. 2013). This is particularly true when modeling the impact of network dynamics (non-recurrent congestion, say due to accidents, roadway construction) on the formation and evolution of activity-travel patterns. Recognizing the limitations of the sequential approach, researchers have since called for tighter integration paradigms so that consistency and continuity in the representation of behavioral units, spatial entities and temporal scales is ensured. More recently researchers have proposed integrated modeling frameworks that comprise a tighter coupling between the travel demand and traffic assignment with constant communication between the two components along the continuous time axis (Pendyala et al 2012, Javanmardi et al. 2012). The tighter coupling framework referred to here as the dynamic approach builds on an event-based paradigm proposed previously by Kitamura et al. (2008). In this integration approach, at the end of every minute, the demand model passes information about vehicle trips that need to be routed and simulated through the network to the traffic assignment model. The traffic assignment model routes and simulates the trips and returns information about vehicle trips when they have reached their destination. In the next minute, the demand model makes activity-travel choices for those that have reached a decision point including those that have arrived at their destination in the previous time interval. It can be seen that in this minute-by-minute interfacing, the travel demand and traffic assignment model operate in unison and ensure that behavioral consistency is ensured. As a result, the activity-travel patterns generated are behaviorally consistent. For example, if a person arrives late, then the activity at the destination and all subsequent activities may be adjusted. The representation of such network-responsive adjustments is extremely difficult (if not impossible) in the sequential approach.

While the dynamic approach with its event-based paradigm has the basic framework for evaluating real-time information type strategies, it needs to be extended to address several considerations discussed earlier. The activity-travel decisions in the dynamic approach are typically based on expected network conditions. Therefore, the dynamic approach cannot be directly applied for modeling RTIS. There is one study that attempted to extend the dynamic approach to model activity-travel decisions based on prevailing network conditions (Konduri et al. 2013). However, the model framework did not allow for en-route decision making. Therefore, the event-based paradigm needs to be extended to accurately represent the scheduling and rescheduling behaviors exhibited by individuals in response to RTIS. A conceptual modeling framework of activity-travel adjustments in response to RTIS will be formulated based on evidence from prior research.

Simulator of Transport, Routes, Activities, Vehicles, Emissions, and Land (SimTRAVEL)

SimTRAVEL is a software prototype of an integrated model system that aims to couple land use, travel demand, and network operations under a single unifying framework ensuring consistency in the behavioral representation (Pendyala et al 2012). The SimTRAVEL prototype will be extended in this study to implement the proposed conceptual framework for modeling RTIS. There are a number of implementations of microsimulation-based models of transportation, however SimTRAVEL was chosen for this research effort because SimTRAVEL achieves integration between the travel demand and traffic assignment model in a dynamic way (as noted in the previous subsection). The dynamic integration approach is critical to the modeling of dynamics associated with RTIS and to accurately mimic impacts on activity-travel engagement patterns. Additionally, SimTRAVEL software is available under open-source licensing agreements and thus can be adopted and enhanced to successfully implement the proposed framework for representing the en-route decision heuristics and real-time information provision.

Case Study

The extended SimTRAVEL prototype will be applied to evaluate four common RTIS strategies including radio, variable message signs, real-time GPS navigation systems and a smartphone application under non-recurrent congestion scenarios. In particular the focus will be on evaluating the effectiveness of RTIS strategies for addressing the congestion issues that result from non-recurrent traffic accidents on roadways in the Hartford metropolitan area. Further, for each RTIS strategy, different scenarios will be run to mimic varying levels of RTIS technology penetration and usage. Results from the scenario analyses will provide important insights into the effectiveness of different RTIS strategies. The analyses will also help characterize the efficacy of RTIS strategies based on the levels of participation.

RESEARCH CONTRIBUTION

The proposed effort will contribute to the state of research and practice in the transportation planning arena. First, the research will add to the literature on travel behavior by attempting to understand activity-travel rescheduling behavior in response to prevailing network conditions. In most implementations of travel demand models, rescheduling behaviors are implemented by imposing consistency constraints (in spatial and temporal representation) and adhering to budget constraints of available resources. For example, rescheduling dynamics are implemented by ensuring that time allocated to activities and trips add up to 1440 minutes in a day. However, such implementations do not consider true rescheduling behaviors and fail to capture the heuristics employed by individuals in making these decisions. In this research effort, travel survey data sets will be explored using data mining principles to understand pre-trip and en-route rescheduling decision heuristics and estimate models of decision processes involved. Second, the research will add to the state of practice on transportation modeling software by enhancing an existing open-source transportation model system to incorporate additional behaviors that accurately mimic rescheduling decision processes exhibited by individuals in real world. The prototype will comprise one of the few implementations of a transportation model system that can comprehensively model the full range of scheduling and rescheduling behaviors exhibited by individuals in response to real-time traveler information. Additionally, the enhanced prototype will be applied to a metropolitan region to demonstrate its applicability for planning and policy analysis.

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