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Response to paper call "Linking Demand and Dynamic Network Models"

TITLE: "Dynamic Choices in Coordinated Household Activity-Travel Systems"

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INTRODUCTION

State-of-the-art activity-based travel forecasting models and dynamic traffic assignment models have been developed essentially independently from one another. Sophisticated activity-based demand models have been developed using simplistic, static travel cost skims. Meanwhile, sophisticated dynamic traffic assignment models have been developed using simplistic fixed trip tables. Consequently, the decision structures found in most activity-based travel forecasting model systems are not sensitive to temporal variation in travel costs. When subject to the litmus test of time-dependent travel time/cost information, these models will fail to produce activity-travel patterns with reasonable and feasible tours. This problem is particularly acute where transit is concerned, subject as it is to time-varying availability.

The Portland, Oregon region of the U.S. has had a wealth of experience in advanced model research and is now developing a practical activity-based model system designed for eventual integration with dynamic highway assignment and schedule-based transit assignment modules. The model system is based on dynamic choice concepts, specifically to be responsive to price signals by time of day and to the notion of system reliability. The activity-based demand components includes coordination between household members and, at the same time, features time-dependent activity type choice, time-dependent activity location choice, time-dependent mode choice, and time-dependent activity durations. Time-dependency extends to both time-of-day, accumulated activity and tour time, and time-varying travel costs. Coordination between household members embeds the notions of coincident and communicative opportunistic activities as well as planned synchronicity of events. This paper and presentation will explore the model design and specifications and will present preliminary estimation and calibration results.

BACKGROUND

The questions being asked of travel demand modelers increasingly require explicit consideration of the timing of travel (1). Congestion-based or time-of-day based pricing schemes are rapidly becoming a standard alternative to be considered in infrastructure investment studies. The system-wide effects of intelligent transportation systems (ITS) can be understood at a regional level only through dynamic representation of both supply and demand. A greater sensitivity to the timing of travel is also required to properly understand and predict the effects of traveler responses to variability in transit and freeway levels of service. Finally, a more accurate portrayal of speeds and volumes by time of day is essential for air quality analysis. These issues, and potentially many others, suggest that planning-level dynamic assignment models are important and that their integration with activity-based travel demand modeling systems is a need that must be met.

Unfortunately, the development of state-of-the-art travel forecasting tools has proceeded along two essentially independent paths corresponding to supply and demand. Representation of transport system supply through network models has advanced in large part through the development of dynamic traffic assignment (DTA) approaches, motivated more so by the desire to provide real-time traffic control capabilities than by purposes of regional planning. In a similar vein, public transit system operational planners have driven the development of schedule-based transit assignment methods. Meanwhile, development of demand-side modeling tools, developed to satisfy the needs of regional planning and policy, has coalesced around the unifying notion of travel demand derived from the activity participation choices of individual decision-making agents.

Despite these parallel advances in supply and demand models, there has been little progress to date in making these sophisticated systems work together at a regional level. Activity- or tour-based models have been presented in many forms, all attempting to model time of day and activity duration choices in various ways. Examples of relatively sophisticated activity- or tour-based modeling systems now being used by agencies in the United States include the models developed for the San Francisco County Transit Authority (SFCTA), New York Metropolitan Transportation Commission (NYMTC), and Mid-Ohio Regional Planning Commission (MORPC) (1). Models with similar demand structures are also now under development in the Atlanta, Denver, Sacramento, St. Louis, and San Francisco-Oakland Bay regions. At the end of the demand process, however, each of these models produces aggregate trip tables for static assignment within aggregated time periods; hence, the daily activity patterns produced by these models are never subject to the litmus test of time-dependent travel times and costs.

An important step forward in integrating supply and demand in a dynamic context was provided by the METROPOLIS project, which features a meso-scopic DTA combined with explicit random-utility-based travel departure time choice decisions based on preferred arrival times (2). METROPOLIS, however, remains essentially a trip-based approach to modeling demand, focusing on vehicle movements.

The first large-scale attempt to incorporate dynamic traffic assignment and schedule-based transit assignment into a regional planning model was the TRANSIMS project, which also offered a relatively simple activity-pattern generation module, using a classification and regression tree method, combined with tour-based location choice components (3). The application of TRANSIMS in the Portland, Oregon region attempted to integrate microsimulation-based assignment processes with a daily activity pattern generator and tour-based location choice model through feedback mechanisms, but fell short of producing a working model. When held to the standard of internal consistency between activity episode durations, locations, travel times and times of day, the TRANSIMS approach used in Portland, however well calibrated at an aggregate level, was unable to consistently produce reasonable and feasible tours when subject to time-dependent travel path information. The study team concluded that additional research in algorithm development was needed.

Other modeling systems may be viewed as partial successes in integrating activity-based demand with dynamic network supply models. MATSIM was developed as a toolkit of packages in which a simple activity-based demand modeling package, similar to that employed by TRANSIMS was developed, along with a simpler dynamic traffic assignment module (4). One part of the toolkit is a module known as "planomat," which enforces consistency across daily activity patterns of individuals through schedule modification. A separate module for the location choices of "secondary" stops on tours (work and school being primary) provides flexibility in the spatial dimensions of multi-stop tours. Like the original TRANSIMS activity generator, however, the top-down generation of activity patterns and method of schedule enforcement offered in MATSIM lacks a behavioral foundation.

A very behaviorally rich model system, the comprehensive econometric model of daily activity patterns (CEMDAP) has been developed by Bhat and colleagues at the University of Texas at Austin and has been applied in a Dallas-Ft. Worth test case.(5) CEMDAP is now being tested in combination with a meso-scopic DTA system, VISTA (6), originally developed at Northwestern University. CEMDAP's design based on continuous-time would seem to hold promise, although it is unclear at this point what mechanism will be used to ensure internal consistency between activity episode generation, duration, spatial location and travel mode when subject to the time-dependent travel costs.

Perhaps the most forward thinking model to combine ideas of activity-demand with dynamic network supply is the prism-constrained activity travel simulator (PCATS), developed by Kitamura et al. (7), and incorporated into later versions of the activity mobility simulator (AMOS) and its application in the state of Florida (FAMOS) (8). PCATS explicitly recognized the spatio-temporal limits of activity patterns by generating time-space prisms within which tours are generated and scheduled, each activity stop in sequence, and individual tours sequentially concatenated into daily activity patterns. This model system has recently been enhanced with the addition of a dynamic event-based traffic simulator (DEBNETS) and is likely to be the first truly integrated model of activity-based demand and dynamic-network supply. One weakness in the AMOS-DEBNETS model system is the focus on individual activity patterns, with intra-household interactions represented through statistical correlation rather than an explicit joint decision structure. Explicit, behaviorally-based representation of household interactions may be found in the MORPC and CEMDAP model systems mentioned above.

The approach advocated in our research also follows a sequential approach to activity-episode generation and scheduling, but uses a set of dynamic discrete choice models to step through each household's day at five-minute time intervals. This is a semi-Markovian approach in which time of day, activity duration, tour duration, and pattern duration are explicit considerations in the utilities of whether to continue a current activity, whether to engage in a new activity, the location of new activities, and the choice of travel mode. We do this simultaneously for an entire household of individual decision makers, accounting for joint activity participation and shared rides. Our confidence in this method was motivated by the successful application of a similar, albeit simpler approach by Gliebe et al. (9) in the context of commercial vehicle and person travel. Our objective for the Portland region is to extend and refine this approach for the household context.

MODEL SYSTEM DESIGN OVERVIEW

The proposed modeling system includes a population synthesizer, and household decision making modules at long-term, daily, and quasi-dynamic time scales. The population synthesizer will create synthetic households and persons including home locations, and household and person attributes. Long-term decision making includes workplace and school location choice models as well as auto ownership.

Daily decisions include the assignment of roles to individual household members. For example, typical household member roles might include: "adult worker," "adult worker with childcare," "adult non-worker," "pre-school-age child," "college student," etc. Conditional upon this role assignment, each synthetic individual will draw an initial activity starting time.

The definitions of daily role alternatives are subject to empirical findings and model development. This step in the model system process establishes the initial conditions for the dynamic simulation to follow. It is purposely left general to allow activity patterns to emerge from the dynamic choice process; however, these roles can be used to force certain overarching patterns to occur. For example, we could enforce pre-planned joint activity patterns to occur by preconditioning the dynamic choice process through the assignment of "joint excursion activity" or "child escorting" roles.

The alternative is for interpersonal interactions to emerge through the dynamic choice process, which may be viewed as "opportunistic choice." The dynamic choice process begins for each household with the assigned starting times and roles for each person. We then step through each person's day in five-minute intervals, with household members taking turns. At each time step, we evaluate for each household member the utility of remaining at the current activity relative to making a change to a new activity. When a new activity is chosen that does not involve a trip to a known location such as home, work or school, a tour-based activity location choice model is used to select the activity site. Next, a starting travel mode is chosen to begin the tour, which then conditions subsequent choices along the tour.

Activity duration is determined by decisions to change from one activity state to the next and is thus dependent upon competing demands on one's time. Household members are assumed to be aware of what other household members are doing and their location (spatial separation) through an activity event tracking module. With this information, an individual in the household may "signal" through his choice the desire to engage in an activity with another household member or to obtain a ride, in which case the utility of the other household member to provide the ride or engage in the joint activity will subsequently increase, subject to potential, compensating (dis)utility due to spatial separation, auto availability, and temporal factors.

Time dependency enters the picture by tracking cumulative time spent in the current activity, the current tour, and the time since an individual first began her day. Thus, the propensity to engage in additional activities will decrease as time accumulates. Activities begun later in the day and towards the end of a tour will be shorter in duration. Locations for discretionary activities will tend to be made closer to home as time accumulates. Mode choices will also depend on availability by time of day, one challenge being to specify utility functions for transit mode alternatives that account for schedule awareness at an appropriate level of specificity. For example, a person may choose to engage in fewer activities or to shorten duration based on the expectation of transit service provision decreasing after a certain hour. The actual time of day will also affect the utility of starting new activities and the type of activity chosen, corresponding to typical hours of operations for work, schools, shopping and mealtimes.

All individuals and households are simulated in this manner until their simulated daily activity patterns are complete. The resulting activity patterns can then be assigned to either a dynamic network or regional microsimulation in the form of trip lists, or aggregated into trip tables for classical static assignment. Since a dynamic highway assignment and schedule-based transit assignment approaches are envisioned as the eventual future form of this tool, time-dependent path costs will be integrated into the system through a feedback loop. Initial development using a static assignment will also incorporate feedback.

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