Incorporating Intra-Household Interactions and Joint Travel in an Activity-Based Model

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Background

Many metropolitan areas within the United States have or are in the process of transitioning to activity-based model as their primary regional travel demand modeling system. One of the most promising aspects of recently developed activity-based models (ABM) is its ability to simulate intra-household interactions. Incorporating intra-household interactions is desirable to bring greater behavioral realism to the simulation process. From a practical and implication standpoint, modeling the direct linkages among household members’ travel patterns and joint travel is essential for accurate planning and policy analysis. Examples of planning and congestion management analysis that will benefit from the incorporation of intra-household interactions and joint travel includes HOT lane and pricing analyses, improved transit analysis capable for supporting FTA New Starts requirements, and analysis of travel demand management (TDM) policies such as carpool promotion strategies.

The Houston region is one of the largest and fastest growing metropolitan areas in the U.S. As such, it faces significant challenges in planning for a transportation system to meet the mobility needs of the region’s residents. A variety of policies and strategies has been proposed in the Houston region to help improve and enhance the region’s transportation system. The most relevant ones include the Katy Freeway congestion pricing project, Houston METRO’s (METRO) reversible high-occupancy toll (HOT) lanes, and other managed lanes proposals.

This paper undertakes a descriptive analysis of the prevalence of joint travel in the Houston-Galveston area. It also provides an overview of the activity-based modeling structure adopted for the H-GAC model and focuses on how intra-household interactions are incorporated into the modeling process. The paper will also provide detailed results from model estimation and calibration to observed data. The application of such a model for pricing and HOT lanes analyses will also be described.

Definition of Joint Travel

For the purposes of modeling households, joint travel refers only to travel between members of the same household; carpooling between work colleagues or neighbors will not be classified as joint travel and will not be explicitly modeled, but instead will be captured through the mode choice alternatives shared ride 2 and shared ride 3+ for individual-level tours.

The consideration of time of day choices and overlapping time windows among household members is key to capturing these interactions and estimating joint travel behavior among household members. The 2008/2009 H-GAC household survey indicates a large number of activities, including meals, social/recreational activities, and others, being performed together with other household members. Therefore, the activities of other members of the household can affect the timing of a person’s activities in several ways. These include scheduling activities that are performed with other household members, the need to provide or procure a ride from other members, and the availability of automobiles that may be needed by other members for their activities. The need or desire to perform activities together with others who are not members of the same household is also feasible but this is currently not being modeled as the number of observations from the survey is very low.

Joint travel can be categorized as fully joint travel or partially joint travel. Fully joint travel means that all important aspects of tour-making are shared by two or more household members. Specifically, the location, arrival time, departure time, and purpose of all stops on the tour are identical and the travel mode of all trips is the same. While it is possible that two household members would make a fully joint tour with different purposes at the destination (a trip to the bank for one and a trip to a nearby store for the other), the number of individuals reporting these split purposes is very few, and it will not distort the overall picture greatly to recode one traveler’s purpose in order to make the purposes match.
Partially joint travel means that at least some aspects of the tour are not shared by the household members traveling together. This might mean that the outbound or inbound leg is fully joint but the household members split up after the activity at the destination, or more rarely they begin separately but meet at a destination to share the inbound leg. Partially joint travel may also mean that the outbound or inbound leg is not fully shared and the two members simply depart at the same time (this is particularly the case for drop-off/pick-up activities or other “serve passenger” activities). The most important category of partially joint travel is escorting children to school, both in terms the prevalence in surveys (and thus its reflection on the transportation networks) and in terms of policy impacts because of the concentration of parents driving children to school in a very narrow time window.

Prevalence of joint travel in the Region and Implications for Modeling Intra-household Interactions

A descriptive analysis of the H-GAC 2008 Household Travel Survey was undertaken to analyze the prevalence of joint travel in the Houston-Galveston region. The analysis of the household travel survey indicated that 10 percent of all tours are partially joint and 12 percent are fully joint. This varies by tour purpose and household and person characteristics, as detailed in Table 1.

Work tours are rarely fully joint, and partially joint tours tend to be related to serve passenger-type activities, including school and escorting. While this difference is important to capture, it is clearly less important compared to the 12 percent of shopping/personal business tours that are fully joint and the nearly 15 percent of discretionary travel tours that are fully joint. Essentially half of all school tours are fully or partially joint, and so capturing the joint travel component of school travel is clearly important.

Not surprisingly, individuals living in households with children are more likely to make partial and fully joint tours. Over 30 percent of tours made by these individuals have a joint travel component, compared to less than six percent of tours made by individuals in households without children. These statistics reflect the dependency that children have on their parents to escort them to activities and the high prevalence of joint travel on the school tour, itself. Non-workers are also more likely to make joint tours compared to workers. Working individuals make less than seven percent of travel with other individuals in the household, compared to close to 40 percent of tours made by non-workers.

Given the low percentage of work tours that include joint travel, partially and fully joint mandatory work and university tours will not be modeled directly. However, work tours that include escorting children to school will be captured by modeling partially joint school escorting tours. Due to the high occurrence of joint travel in non-work tours, fully joint nonmandatory travel will also be modeled directly, while partially joint travel will primarily be captured through trip mode choice. With the exception of the school escorting model, the benefits of accurately capturing partially joint travel do not fully offset the increased model complexity required to handle partially joint travel.

Modeling Joint Travel in the H-GAC Activity-Based Model

In order to model joint travel, schedules between at least two people in a household must coordinate to the extent that both individuals have available time to travel together. This complication in the coordination of schedules is the driving factor in determining at what point in the modeling process joint travel should be predicted. Depending on whether an individual undertakes mandatory travel, mandatory tours or joint tours serve as the “anchor”, which is modeled first, and then the remaining tours are fit into the remaining time windows. Rules will be developed to ensure that joint travel occurs only when two or more household members have available time windows that overlap. In the household context, this means that after mandatory travel (work, school or university tours) has been scheduled, the remaining time for each individual is compared to the remaining time for each other household member. At least two individuals must have enough “free time” in their schedules, occurring at the same time, for
joint travel to be considered. If joint travel is the “anchor,” joint travel is scheduled first, and other activities are fit into individual schedules. The H-GAC model is designed using this modeling approach.

The proposed modeling system for the new H-GAC model is shown in Figure 1. The H-GAC Activity-Based Model includes a population synthesizer, a usual work location model, a school location model, and a vehicle availability model which are grouped into the “Households generated” box in Figure 1. Modeling of individual’s daily travel begins with determining the high level daily activity patterns. The day pattern model will be a nested logit model that takes as its alternatives all combinations of mandatory activities (0, 1, 2 work tours in conjunction with 0, 1, 2 school/university tours) with and without the presence of stops (0/1 indicator for each work and university tour if a stop is made), along with three other alternatives: 1) the individual engaged in 0 mandatory tours but did engage in nonmandatory travel; 2) the individual stayed at home and had no travel activity at all; and 3) the individual was out-of-area all day.

It has been found that an individual’s day pattern can be influenced greatly by the day pattern choices of other household members. The sequencing of individuals in the household matters, and experience has shown that children (starting with the youngest) should be modeled first, since children’s mobility is more limited (often requiring an adult escort) and effects the choices of other household members in the most direct ways. For instance, if an infant is home sick all day, presumably an adult in the household must remain in at home as well. Thus, children’s day patterns can be extremely consequential for the day patterns of other household members, particularly adults. Presumably the impact of a child staying home on adults’ travel behavior lessens as the child’s age increases. It is proposed to model nonworking adults next in sequence, specifically because if a nonworking adult stays home to take care of a child, then the statistical impact on the full-time worker staying home should drop considerably. On the other hand, if the model indicates that the nonworker does not stay home, then the impact is not reduced.

Once it is determined the type of tours individuals are scheduled to participate in, the destination choice and time-of-day components of mandatory travel (i.e. work, university, and school tours) will be determined. This means that the model simulates mandatory travel before joint travel. It is possible that people, in fact, schedule mandatory activities around planned joint activities. Unfortunately, identifying causality in this case is not simple, and it likely differs across different people and households. Some individuals likely schedule joint activities around their other, more important, mandatory activities, while others likely rearrange mandatory schedules in order to accommodate planned joint activities. Without convincing evidence either way, the choice to model mandatory travel before joint travel is based on the notion that joint travel is more often scheduled around mandatory activities, rather than the reverse.

Determining the location and time-of-day of mandatory activities allows for available time-windows to be determined so that school escorting and joint travel can be scheduled. Since a worker may drop a child off at school on the way to work, mode of travel and stop-making characteristics of the mandatory tours are not modeled until later in the modeling sequence.

Whether a child is escorted to school and who escorts the child is sequenced before fully joint nonmandatory tours are scheduled. For both theoretical and practical reasons, fully joint nonmandatory tours are modeled before non-joint nonmandatory tours. From a theoretical perspective, it is theorized that an individual will schedule non-joint tours around planned joint tours. From a practical perspective, modeling joint tours first gives more opportunities for time windows to overlap between household members so that joint tour-making can be scheduled.

The first step in modeling joint travel will be determining the number and type of joint tours that are made within each household. The household-level joint travel model will be a nested logit model with up to fifteen alternatives, one for each combination of purpose (meal, shopping, personal business, or social/recreation) and number of tours (0, 1, or 2). The number and length of available time windows between household members will be the driving factor in determining the number and time-of-day of joint tours. Once joint tours are generated at the household level, the destination and time-of-day of each joint tour will be modeled. Individual participation in each joint tour is the final step, using a binary participation choice model at the individual-level. Individuals with overlapping mandatory activities will be automatically removed.

The number and purpose of nonmandatory tours are scheduled after the number, destination, and time-of-day of each joint tour is determined for each individual. This model is followed by the destination and time-of-day of nonmandatory tours. Finally, all other tour characteristics are modeled including, tour mode choice, number of stops, and all stop-making features.

The Cambridge Systematics team is currently beginning estimation of each model component. Software design and coding is occurring simultaneously with model estimation. Consideration was given during model design to develop a modeling system that ensures logical and proper simulation of activity-travel patterns. A detailed model validation plan has been created and will be implemented following the completion of model estimation and coding.
### Table 1. Joint Travel in H-GAC Household Survey by Overall Tour Purpose

<table>
<thead>
<tr>
<th>Tours</th>
<th>Tour Purpose</th>
<th>Household/Person Characteristic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Work</td>
<td>School</td>
<td>Shop/ Pers. Bus.</td>
</tr>
<tr>
<td>Not Joint</td>
<td>94.4%</td>
<td>50.5%</td>
<td>80.7%</td>
</tr>
<tr>
<td>Partially Joint</td>
<td>5.3%</td>
<td>21.2%</td>
<td>7.6%</td>
</tr>
<tr>
<td>Fully Joint</td>
<td>0.3%</td>
<td>28.3%</td>
<td>11.7%</td>
</tr>
</tbody>
</table>
Figure 1. Overview of Joint Travel Approach

Households Generated

Daily Activity Pattern in Sequence, with children first

Primary destination and TOD scheduling of mandatory tours

Calculation of time window overlaps (derived indices)

School escorting model

Joint HH Tour Generation/Allocation to HH members

Individual maintenance/discretionary tour generation

Primary destination and TOD scheduling of nonmandatory tours

Mode choices and stop-generation for all tours