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Capturing the Relationship between Social Interaction and Travel Behavior Using Smart Phones

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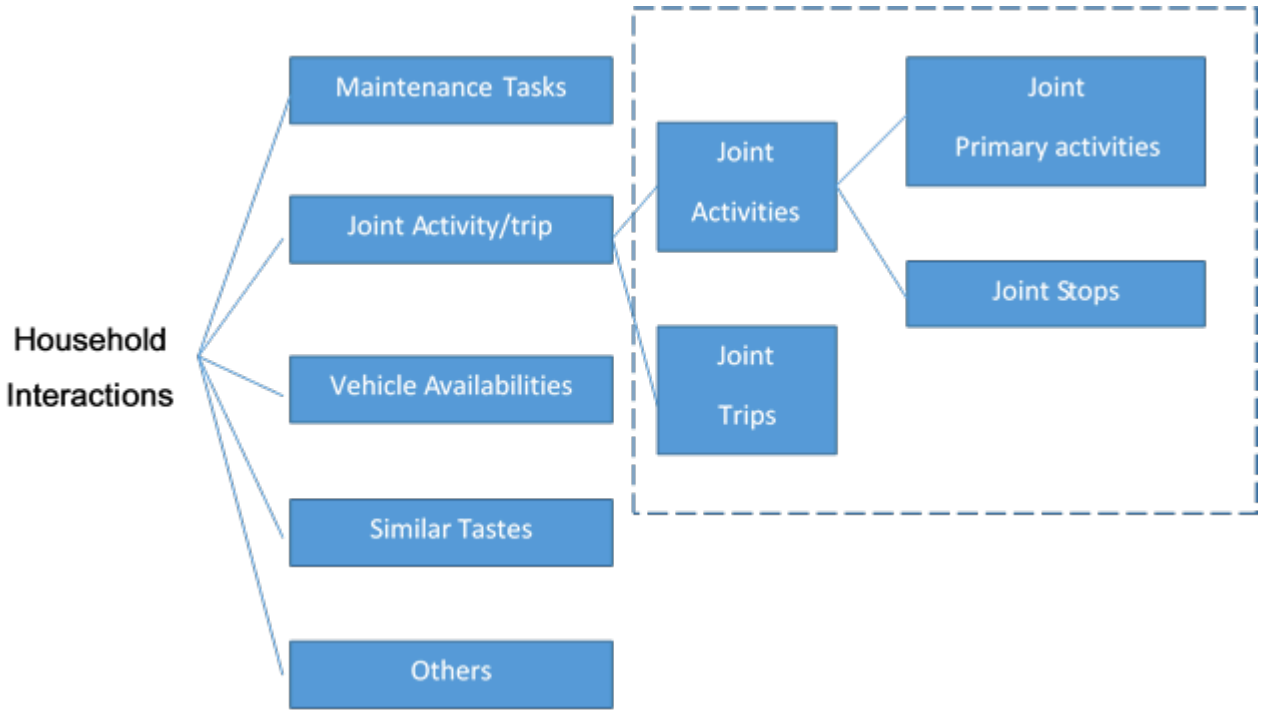
Introduction:
Humans are social beings, and as such their choices are affected by the way they interact with other people. Recent changes to the nature of social interaction have affected travel behavior and have led to an increasing interest in understanding the relationship between the two. Several studies have made efforts to model and quantify this relationship, mainly using pen-and-paper surveys, but very few of them collected data that are rich enough and over a time period long enough. Other studies used electronic devices (such as GPS or smart phones) to collect more precise data, but mostly focused on one behavioral type at a time. We propose a methodology of data collection and modeling that combines recording of location and mode with a smart phone app (using GPS, GSM, WIFI and accelerometer), an egocentric approach for collecting social interaction data (using phone calls, SMS records, Bluetooth scans and Facebook activity), online questionnaires, and modeling of social interactions and travel behavior. This methodology leverages the techniques developed by the Singapore-MIT Alliance for Research and Technology (SMART/MIT) as part of the Future Mobility Sensing (FMS) project and the modeling expertise of the MIT ITS Lab. We anticipate that the results of this research will help policy makers learn how these changes may affect the decisions of individuals and plan accordingly. Social behavior and preferences may also affect people's willingness to travel together, either with friends or with strangers. The results from this study can be used to understand and encourage usage of ride-sharing services, and reduce congestion in the road network.

1. Scope of the analysis
Household members affect each other's decisions in significant ways and these interactions exist at different levels. In the long-term, people may select their work and education locations so that they are close to their household members and have a more convenient commute. When people are making decisions about their daily activities, they may consider what their family and friends would do. At the trip level, people may select modes and routes so that they can travel with their family and friends to enjoy the ride and/or save money.

As an extension to the Preday models developed by the ITS lab, our study focuses on the interactions in day level. In the day level, different types of interactions exist, and they may affect household members' activities in varying ways. For example, if one household member wants to go to a movie, he may invite or persuade other members of the household to join him which increases other members' chances of making a movie tour. On the other hand, if one household member decides to go grocery shopping for the house, then this occurrence will likely decrease the chances of another household member going to the grocery store on the same day. Due to the distinct nature of different types of interactions, the interactions must be identified and addressed in different ways.

Different types of household interactions in day level travel decisions are listed below. Based on the current structure of the Preday framework and the importance of different types of interactions, we decided to first include the joint activities and joint trips performed by different household members in our model as circled in dashed lines. At this point, we include only joint household tours with joint primary activities in our model.



Activities in the Preday model are divided into 6 types: work, education, personal, recreational, shopping and escort. Based on the fact that education and work activities are usually performed at fixed locations and at fixed frequencies, we did not include the joint activities with purposes of work or education, even though the MTS survey data indicated such activities existed. We deem the interactions of these two types of activities mainly on long-term decisions, which means that household members influence others' decisions of work and education when they accept job offers or enroll in school, but this is not occurring much at the day level. The people who actually go to work or school together could be considered as shared trips and modeled in the trip level.

Joint household primary activities are defined as at least two household members performing the same primary activity at a same location. The interactions between two people exist so long as they are doing a single activity together for a period, but not necessarily from the beginning of the activity to the end of it. Based on these observations, different types of joint primary activities exist. In our analysis, based on the empirical appearance frequencies, two types of joint primary activities were included. The first type of joint primary activities is defined to be the activities where all the household members who have joined start and end the activity at the same time, which accounts for 94% of the joint primary activities in the MTS data. The second type of joint primary activities is defined to be the activities where at least all members of the party start or end their activities around the same time, which accounts for another 5% of the joint primary activities in the MTS data.

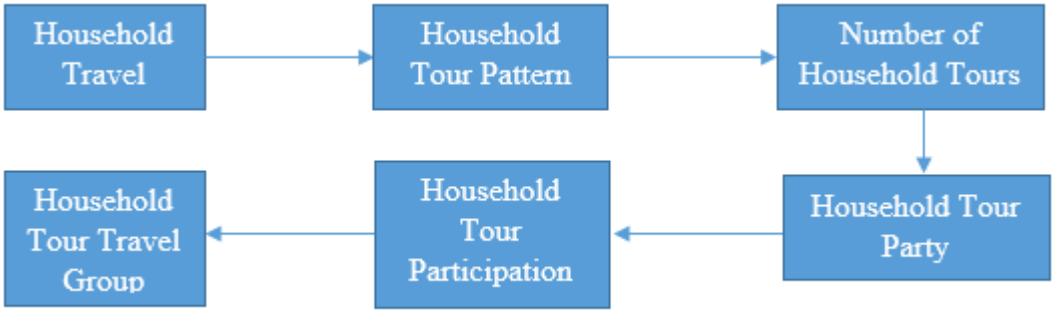
Other work on this topic has defined household joint tours to be fully joint, which means all the travel party leaves their home together, performs the same sequence of activities and trips along the way and returns home together. The flexible structure of the Preday models allows us to only constrain the primary activities of the household joint tours to be the same, which enables the models to capture more realistic cases that exist in our daily life.

2. Model Framework

2.1 Model Overview

In the individual Preday models developed, the framework was divided into 3 sections: the day pattern level, the tour level and the intermediate stop level. The household joint activities (the extension) are modeled in the day pattern level, prior to all the individual Preday models.

The framework of the household joint activity models is composed of 6 models: Household Travel model, Household Tour Pattern model, Number of Household Tours model, Household Tour Party model, Household Tour Participation model and Household Tour Travel Groups model. How these models are linked is shown below:



At the end of the framework, we have output formed from different travel groups who performs fully joint household tours. The different travel groups could actually have a joint primary activity, such as when people have the joint primary activity but do different stops. In such a case, each group can be served as an agent to enter the tour level of the individual Preday models with group parameters.

If personal characteristics of household members, such as occupation, education status, gender and age, are included in any model, they are modeled as a whether-there-is kind of dummy variable due to the small sample size. Generally, we found household characteristics such as whether there is an infant or disabled person to be significant in many of the levels.

In most of the models, household utilities are modeled directly under the random utility framework instead of combining household members' individual utilities. In the Household Tour Participation model, individual choice and individual utilities are modeled based on the nature of the choice setting. In the last model Household Tour Travel Group model, group utilities are considered.

The models were estimated for the Greater Boston Area using the 2010 Massachusetts Travel Survey (MTS) by Pythonbiogeme.

2.2 Model Components

1. Household Travel

The Household Travel model determines if the household makes any joint tour (primary activity) in a given day. If the household only has 1 member, then it directly enters the individual level. The model takes the form of a Binary Logit (BL), where the choice is whether or not to have a joint household tour during the given day. It takes household size, number of household workers, date (a dummy variable indicating whether the date is a Friday) and other personal characteristics of the household members as inputs. A decision to travel will lead to the second model Household Tour Pattern, otherwise all household members will directly enter the individual Preday model.

2. Household Tour Pattern

If a household determines to have joint tours in the day, the Household Tour Pattern model determines which activity purpose(s) the household will pursue as their primary purpose(s) of the tour(s). The model is a mixed nested logit (MNL) where the choice set includes a combination of each of the available activity purposes. The limit on the number of activity purposes in the combination is empirically determined to be maximum 2. Based on that we have 4 types of primary activities considered for the household joint activities, we have 10 choices here. Each choice's utility includes household size, number of household workers, household income, Friday dummy and personal characteristics of the household members. The resulting pattern enters the next model.

3. Number of Household Tours

For each purpose inside the household pattern, this model determines how many tours of this purpose will be performed. The model is BL where the choice set is 1 tour or 2 tours, which was determined empirically. Inputs include personal characteristics of the household members. However, for numbers of household tours of different primary activity types, different characteristics appear to be significant. For example, the presence of a disabled member in the household is very significant in decreasing the frequency of joint shopping tours, while the presence of two retired member is very significant in increasing the frequency of joint recreational tours. Moreover, household income seems to only play a role in the number of joint shopping tours, which can be comprehended as a general effect of income of the number of all shopping tours. After running this model, we know how many household joint tours (primary activities) there will be.

4. Household Tour Party

For each household tour, the Household Tour Party model determines the composition of the travel party. The types of travel parties are divided into adult parties, where all travel participants are adults, children parties, where all travel participants are children, and mixed parties, where there are at least 1 adult and 1 child. People ages 18 and above are classified as adults, and people under 18 are classified as children. The different party types are determined based on the number of adults and children in the household. The inputs for this model are the number of adults inside the household, the number of children inside the household, primary activity type and personal characteristics of the household members.

5. Household Tour Participation

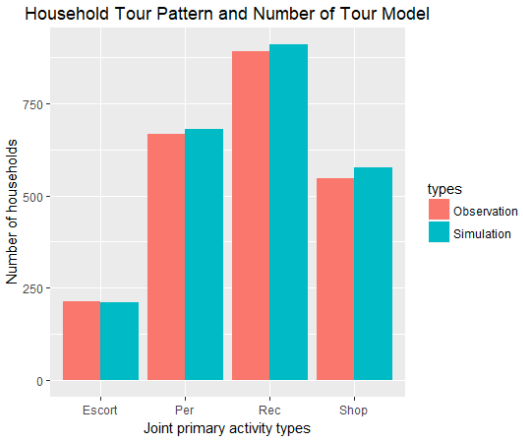
For each household tour, a sequential model is used to determine which person inside the household will join the tour. The model is BL where the choice set includes the options of to join and not to join. The decision order is pre-defined based on the party type and personal characteristics. The model includes personal characteristics, number of household joint activities the decision maker already decided to participate, the number of adults already on the tour (not applicable if the party type is children) and the number of children already on the tour (not applicable if the party type is adults). The determined party type serves as an input and its interactions with other inputs are widely considered. If the output from the sequential BL models doesn't fit the determined party-type, the model will be re-run until it fits.

6. Household Tour Travel Groups

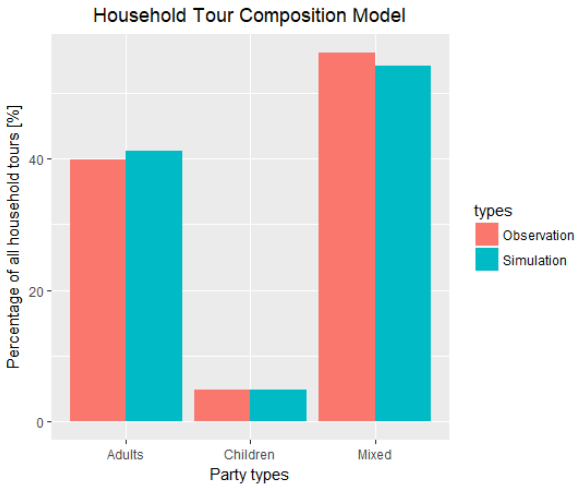
For each household tour, Household Tour Travel Groups model determines the people who joined the tour will perform their tours in how many groups. A group could be formed by only 1 person, so every household joint tour (activity) could potentially split into two groups. As a result, the model is BL where the choice set includes splitting to 1 group or 2 groups. More than 2 travel groups also empirically appear in MTS but it seldom happens so that the sample size isn't large enough to estimate. The model inputs are the number of people who joines the activity and the party types.

3. Validation

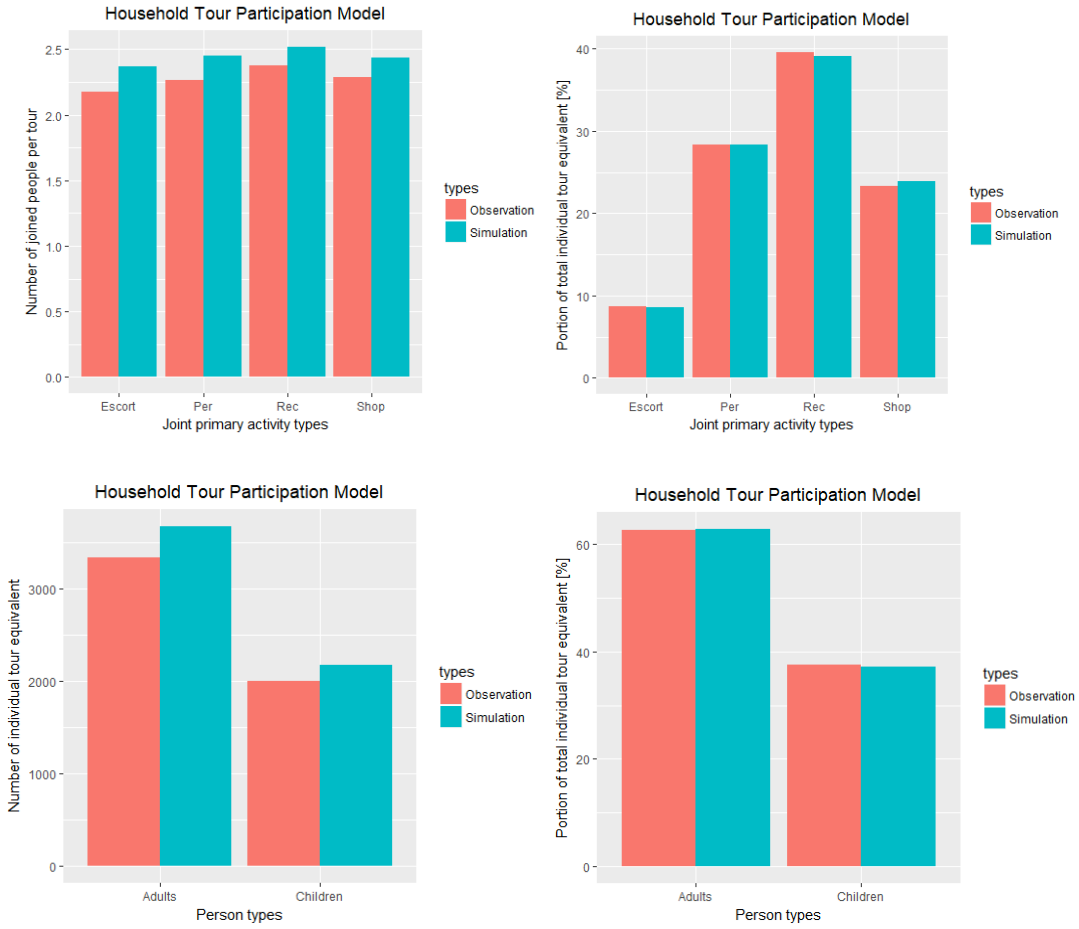
The framework was implemented in R and tested on the MTS data. As shown below, the framework performs nearly perfect in determining whether a household will have joint primary activities, while in the pattern and number of tour estimation the framework seems to slightly overestimate the personal joint tours, recreational joint tours and shopping joint tours.



For the tour composition model, small discrepancies exist in the portion of adult party tours and the portion of mixed party tours.



From the household tour participation model, we see that the framework tends to overestimate the number of people joining the household joint activity, although it manages to keep the portion of people attending different activities and the portion of children and adults correct. There are two possible explanations for this phenomenon. The first one is the limitation of the sequential model, where only the number of previously joined people is considered while the complex interactions of the identity of the decision maker and the identities of the people who already made their decisions are ignored. The second reason is that the framework hasn't been connected to the individual Preday models yet. We have not included the values from the individual level. This could be influential because all the work and education tours are in the individual level.



For the final travel group split, we see that the split itself was quite accurate while the total number of resulted travel groups is biased by the results from previous day pattern and number of tour models.

References

1- Atlanta Regional Commission (2012) "Activity-Based Travel Model Specifications:Coordinated Travel – Regional Activity Based Modeling Platform (CT-RAMP) for the Atlanta Region"

2- Vinayak, Pragun, Felipe F. Dias, Sebastian Astroza, Chandra R. Bhat, Ram M. Pendyala, and Venu M. Garikapati. "Accounting For Multi-dimensional Dependencies Among Decision-makers Within a Generalized Model Framework: An Application to Understanding Shared Mobility Service Usage Levels."

3- Bhat, C. R., & Pendyala, R. M. (2005). Modeling intra-household interactions and group decision-making. Transportation, 32(5), 443-448.

4- Ferdous, N., Eluru, N., Bhat, C. R., & Meloni, I. (2010). A multivariate ordered-response model system for adults' weekday activity episode generation by activity purpose and social context. Transportation research part B: methodological, 44(8), 922-943.

5- Fu, X., Lam, W. H., & Xiong, Y. (2016). Modelling intra-household interactions in household's activity-travel scheduling behaviour. Transportmetrica A: Transport Science, 12(7), 612-628.

6- Ho, C., & Mulley, C. (2015). Intra-household Interactions in tour-based mode choice: The role of social, temporal, spatial and resource constraints. Transport Policy, 38, 52-63.