HYBRID CHOICE FRAMEWORK FOR TIME-OF-DAY CHOICE IN TRIP-BASE MODELS

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INTRODUCTION

An adequate transportation model is expected to have a time-of-day component. Policies such as the increasingly popular variable road pricing (and other pricing mechanisms), which stimulates an effective use of the existing network, are often aimed at changing the temporal distribution of traffic. Therefore, any model aiming to work with such policy measures should be able to produce a temporal distribution of demand and be sensitive to travel behavior changes.

One major weakness of traditional trip-based models is that they usually suffer from elementary time-of-day components, such as hourly factors or link-based and trip-based adjustments. Discrete choice models for time-of-day are usually utilized in tour-based or activity-based models. Data on schedules or preferred times are usually unavailable for trip-based models, and these models are limited to using post-processing techniques. In addition, many trip-based models are combined with static traffic assignment that does not have a time component.

This paper introduces a framework that can be used with a typical trip-based model to add a time-of-day component using hybrid choice models. Hybrid choice models are the combination of discrete choice models and latent variable models. In terms of data requirement, the proposed framework matches with trip-based models. It requires a travel survey, trip-based model outputs (skim matrices and trip tables), and traffic count data. Travel surveys are the main dataset used in estimating trip-based models, therefore they are usually available in areas with a trip-based model. Traffic count data is also becoming increasingly available. An estimation framework is combined with an iterative prediction framework to predict demand's temporal distribution for a given scenario. This paper proposes a hybrid choice model using "preferred departure time" as the latent variable to account for unknown scheduling preferences. The hybrid choice framework estimates a model for unobserved preferred departure time and a model for time-of-day choices, simultaneously using maximum likelihood estimation.

The literature review suggests that a temporal component is usually modeled with one of the following methods (1): [1] post-processing technique that applies hourly factors; [2] link-based or trip-based adjustments, which address the problem of projected demand-exceeding capacity; [3] equilibrium scheduling theory; [4] discrete or continuous choice models; and [5] rule-based models. Hourly factors are the most basic approach of estimating volumes for hourly analysis. The Maryland Statewide Transportation Model (MSTM) version 1.0 , similar to many other trip-based models, uses this method with four time periods, namely morning peak, midday, afternoon peak, and night (2). The state of Maryland is now developing an activity-based model for the state.

Link-based and trip-based methods are other ways of time-of-day modeling. They use the capacity of the links and do not allow demand to exceed capacity during peak hour by shifting demand to the shoulders of the peak. Equilibrium scheduling theory (EST) (3) uses direct equilibration of simple models of supply and demand. These models are based on Vickrey's bottleneck model (4). In EST, Vickrey's model is extended in a number of aspects, such as consideration of heterogeneous users. Discrete choice models for the time-of-day follow the work of Small (5), which is based on random utility theory. Some of the more recent works consider time as a continuous variable. (6-11)

Most of the aforementioned choice models were based on rational behavior, assuming travelers are able to identify all their feasible alternatives, measure all their attributes and choose accordingly to maximize their utility. Rule-based models avoid this assumption of rationality, and try to model how travelers actually make decisions through learning, knowledge, and searching. One good example is the positive model (12) of departure time choice by Xiong and Zhang (13).

After reviewing the aforementioned types of models, discrete choice model was found to be a good choice to incorporate with trip-based models in terms of compatibility and data requirement. One important aspect in modeling time-of-day using discrete choice models is scheduling preferences. This paper implements hybrid choice modeling framework to estimate the unknown scheduling preferences model and the time-of-day choice model simultaneously. Hybrid choice model treats the unknown variable as a latent variable and combine latent variable model with discrete choice model. Usage of hybrid choice model can be traced back to McFadden (14).

METHODOLOGY

This paper proposes a hybrid choice framework for time-of-day modeling. The framework includes simultaneous estimation of a discrete choice model for departure-time choice, and a latent class model for preferred departure-time and prediction of demand's temporal distribution for a given scenario.

Hybrid Choice Framework for Model Estimation

Hybrid choice models are formed from a combination of discrete choice models and latent variable models. Effects of latent variables, such as perception, knowledge, and preference, can be added to discrete choice models using hybrid choice framework. Hybrid choice model used in this paper can be summarized as follows:

- Utility is modeled as a function of observed explanatory variables and unobserved latent variable.
- Unobserved latent variables are modeled as a function of observed explanatory variable.
- The choice can be obtained knowing the utility of alternatives.
- The indicators can be obtained knowing the value of latent variables.

Formulating a hybrid choice model requires specifying the following:

- The alternatives
- The decision rule
- The relationship between the utility of each alternative and attributes (observed and latent variables)
- The relationship between the latent variables and the explanatory variables
- The relationship between the indicators and latent variables

The proposed hybrid choice framework models how individuals choose departure-time. For this type of time-of-day modeling, alternatives are different times of the day. The decision rule is utility maximization. It is assumed that the decision makers choose the alternative that has the highest utility.

Model Prediction Framework

Once the hybrid choice model is estimated, it can be incorporated into a trip-based travel demand model to predict the temporal distribution of demand. Figure 1 shows the prediction framework. After estimating the hybrid choice model, the model is used to predict the distribution of travel demand for a given scenario.

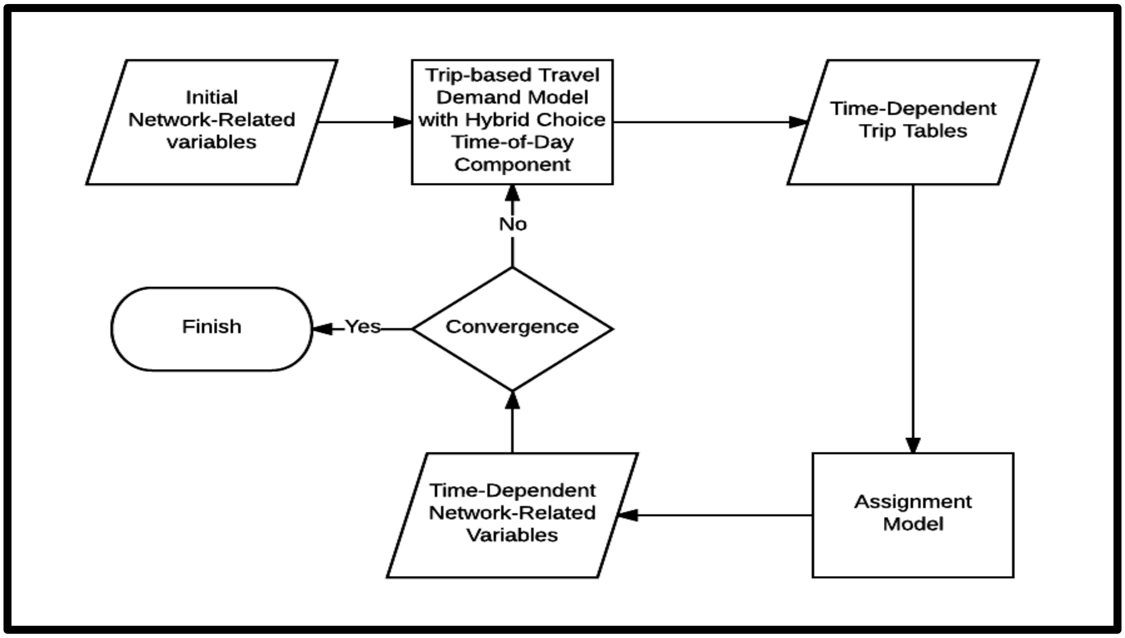

Figure 1. Model prediction framework

EMPIRICAL APPLICATION

In this section, the proposed methodology is applied to the Maryland Statewide Transportation Model (MSTM) to obtain the temporal distribution of demand for two given scenarios. MSTM is a trip-based travel demand model that currently uses four hourly factors to divide daily trips between four time periods: morning peak, midday, afternoon peak, night. The study area for this application is Montgomery County, Maryland.

Data

2007-2008 TPB-BMC Household Travel Survey: This survey was used to estimate the hybrid choice model. The Transportation Planning Board (TPB) from February 2007 to April 2008 conducted this survey in order to gather information about demographics, socioeconomics and trip-making characteristics of residents in the Washington and Baltimore metropolitan areas.

Maryland State Highway Administration (SHA) traffic count data: Information on attributes of all alternatives need to be available for model estimation. In this application, travel time of each alternative needs to be available for the estimation year (2007).

Prediction Results

In this section, demand profiles for two different scenarios were compared:

- The first scenario is for base year 2007. The scenario used 2007 population, 2007 network, and 2007 land-use data.
- The second scenario is for future year 2030. Predicted 2030 population and land-use was used in this scenario.

Demand's temporal distribution was compared for these scenarios to assess how demand shifts occur. Figure 2 shows the change in demand's temporal distribution between the base-year (2007) and future-year (2030). The Y axis represents the change in percent share from total number of trips. A positive value for a time-period means that demand will shift to that alternative, and a negative value means that demand will shift from that alternative.

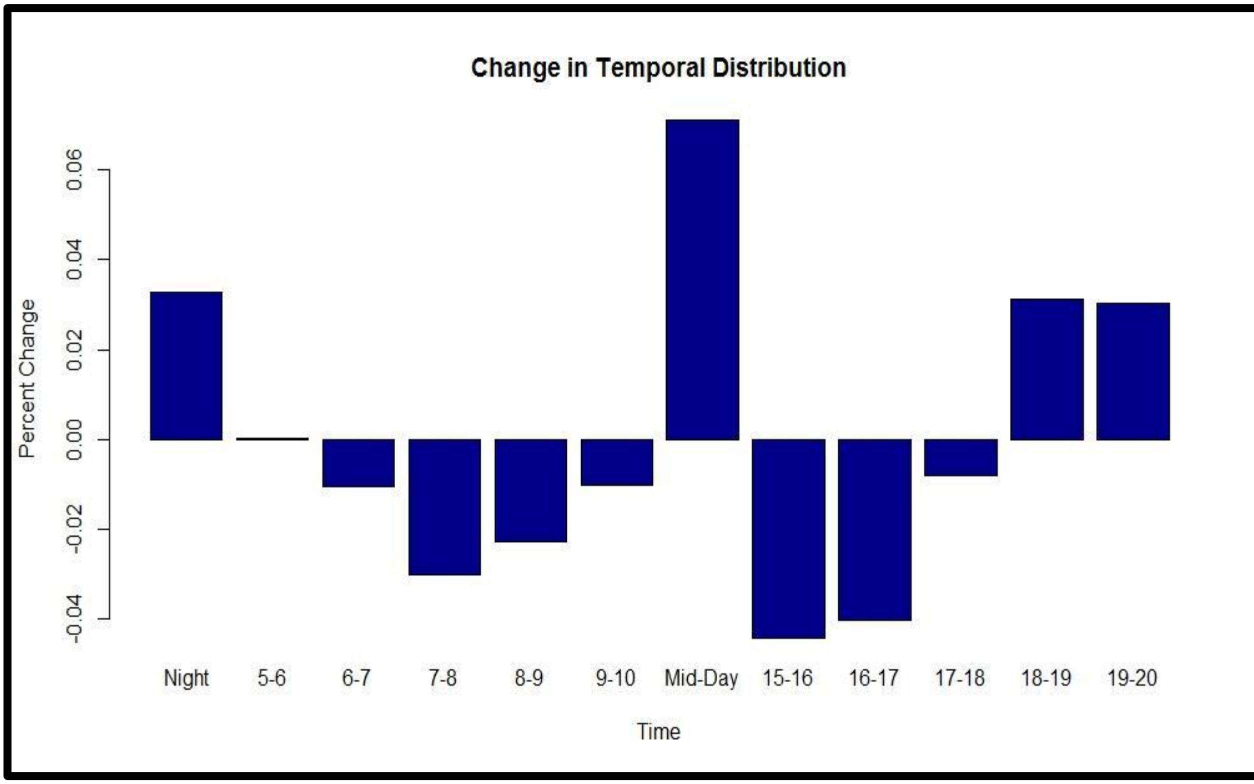

Figure 2. Comparison of demand's temporal distribution between base and future year

It can be seen that the demand is being shifted from peak periods to off-peak and night periods. The phenomenon is known as peak-spreading. Figure 5 shows the daily variation of travel time for both scenarios.

The prediction results show how adding a time-of-day component to a trip-based model can convert its static results to dynamic results sensitive to network, socio-economics, and land use changes, and highlight the importance of time-of-day modeling in having a sufficient understanding of travel demand.

SUMMARY AND CONCLUSIONS

This paper proposed a framework that can be employed in trip-based models to account for time-of-day component. The framework utilized hybrid choice method to model departure-time choice and unobserved preferred departure-time simultaneously using observed explanatory variables, such as socio-economic and network-related variables. Scheduling preferences are important factors in time-of-day modeling, but preferred schedules data is usually unavailable. In the proposed hybrid choice framework, preferred schedules were the latent variables of hybrid choice model. Using latent variables in hybrid choice model not only improves efficiency, but also adds behavioral realism to the model. Furthermore, hybrid choice models can capture unobserved heterogeneity through the distribution of preferred departure time. The proposed methodology was applied to Maryland statewide trip-based model to obtain temporal distribution of the demand. The temporal distributions were compared for two scenarios (year 2007 and year 2030) to analyze demand shifts and peak spreading. The comparison between the predicted demand distributions showed how changes in demand distribution occur. It also showed the importance of time-of-day modeling for capturing temporal changes and having proper prediction for future demand.

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