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An investigation of commuting trip timing and mode choice in the Greater Toronto Area: Application of a joint discrete-continuous model

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A B S T R A C T

The trip timing and mode choice are two critical decisions of individual commuters mostly define peak period traffic congestion in urban areas. Due to the increasing evidence in many North American cities that the duration of the congested peak travelling periods is expanding (peak spreading), it becomes necessary and natural to investigate these two commuting decisions jointly. In addition to being considered jointly with mode choice decisions, trip timing must also be modelled as a continuous variable in order to precisely capture peak spreading trends in a policy sensitive transportation demand model. However, in the literature to date, these two fundamental decisions have largely been treated separately or in some cases as integrated discrete decisions for joint investigation. In this paper, a discrete-continuous econometric model is used to investigate the joint decisions of trip timing and mode choice for commuting trips in the Greater Toronto Area (GTA). The joint model, with a multinomial logit model for mode choice and a continuous time hazard model for trip timing, allows for unrestricted correlation between the unobserved factors influencing these two decisions. Models are estimated by occupation groups using 2001 travel survey data for the GTA. Across all occupation groups, strong correlations between unobserved factors influencing mode choice and trip timing are found. Furthermore, the estimated model proves that it sufficiently captures the peak spreading phenomenon and is capable of being applied within the activity-based travel demand model framework.

1. Introduction

The trip timing and mode choice decisions of commuters are critical considerations for transportation demand modellers. These two decisions along with route choice directly determine the temporal distribution of demand experienced on any given piece of transportation infrastructure in an urban area (Susilo and Kitamura, 2007). Certainly, increasing congestion and transportation demand management policies in modelled future year scenarios can be expected to influence both temporal and modal decision making. Despite the importance of the impacts of trip timing decisions on the distribution of transportation demand, in practice most transportation demand models used at the regional planning level do not explicitly model the temporal dimension of travel. For example, the latest version of the Southern California Association of Governments (SCAG)

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four stage regional transportation model (SCAG, 2003) for the Greater Los Angeles Area and the Greater Toronto Area's GTA model (Miller, 2007) use peaking factors derived from observed origin-destination survey data to subdivide generated trips/journeys into discrete time periods for trip assignment. These fixed peaking factors calculated from base year data are inherently insensitive to the changing temporal conditions and policies of future years.

Activity-based models, on the other hand, handle trip timing decisions more comprehensively by considering the detailed impacts of scheduling constraints on trip timing and mode choice at the disaggregate level (Davidson et al., 2007). However, even such activity-based models have difficulties with introducing policy sensitivity to the distributions of the activity frequencies and start times that serve as key inputs to their activity schedulers. Activity-based models such as TASHA, FAMOS, and ALBATROS, use base year distributions cross-classified by different variables to simulate activity-travel demand (generation) (Roorda et al., 2008; Pendyala et al., 2005; Arentze and Timmermans, 2004). This approach is insufficient when considering policies and scenarios that have the potential to significantly shift travel trends away from the base year distribution of activity start times. Activity-based models by Vovsha and Bradley (2004) and Bowman and Ben-Akiva (2000), on the other hand, are examples of models that include explicit tour-based time-of-day discrete choice models to schedule the travel tours of individuals. Although this approach represents a significant improvement over the use of base year distributions, as will be discussed in the next section, limitations remain with the representation of time as a discrete variable. Overall, a better understanding and representation of the distribution of activity start times/trip departure times is required.

In reality, it is reasonable to expect significant differences in observed home–work departure time distributions by mode of travel. Each mode offers very different levels of service throughout the day. For example, transit modes are considerably less attractive during off-peak periods due to lower service levels, while the auto mode is more attractive during off-peak periods due to lower traffic congestion. In the extreme, some transit modes (e.g. commuter rail) may be completely un-available during certain time periods due to limited periods of operation. As a result, an integrated treatment of mode and time of day choice that explicitly considers their interdependence or endogeneity is important. In this paper, 24 h joint models of home–work (H–W) trip timing and mode choice are estimated using revealed preference survey data from the Greater Toronto Area (GTA). A joint discrete-continuous model specification, with a continuous time hazard model for home–work (H–W) trip timing and a multinomial logit model for mode choice, is used to capture the interconnected nature of mode choice and trip timing decisions.

The paper is arranged as follows: first a review of pertinent literature on trip timing models is presented; this is followed by a description of the theory behind the joint model structure used, a discussion of the detailed model estimation, model sensitivity analysis and model application. The paper concludes with a summary of the investigation and recommendations for future studies.

2. Modelling trip timing

2.1. Discrete choice models

The vast majority of trip timing models in the literature employ a discrete choice utility maximization framework, which requires the definition of finitely many contiguous time period choices. Small (1982) constructs a multinomial logit (MNL) time allocation model for home–work morning departure time choice that incorporates scheduling considerations. In Small's model, each commuter is presented with the choice between twelve discrete work arrival times periods grouped into 5-min arrival intervals. Small argues that during work trip scheduling, individuals consider their expected travel time and make a trade-off between arriving early, which involves some time wasted, and arriving late, which can have more severe consequences that depend on one's level of work hour flexibility.

A significant issue encountered when applying discrete choice models to time of day choice is that neighbouring time period choices are likely to be correlated, especially if the discrete time periods are short. The appropriate discretization of time in travel demand modelling is always a significant challenge because of the natural correlations that exist among different time periods (Russo et al., 2009). However, this correlation is a violation of the Independence of Irrelevant Alternatives (IIA) property of the multinomial logit (MNL) model, which requires that the unobserved components of the utility of each alternative be uncorrelated. As such, a significant proportion of more recent time of day choice research has focused on applying more complicated discrete choice models with less restrictive assumptions on correlation. For example, Small (1987) and others have derived models belonging to the Generalized Extreme Value (GEV) family to allow for the accommodation of correlation among time period alternatives. Small derived the Ordered Generalized Extreme Value (OGEV) model specifically for problems with ordered alternatives, such as the naturally ordered time period choices in a time of day choice model. Logically, one would expect the highest degrees of correlation between adjacent time period choices, with correlation decreasing as the distance between alternatives increases. The OGEV model recognizes this fact by introducing a correlation parameter for each pair of alternatives that is a function of the distance between them. When applying the more theoretically robust OGEV framework to the work departure time survey dataset previously used in Small (1982), likelihood ratio tests revealed that the OGEV model did not perform well in comparison to a NL model and the original MNL framework. Furthermore, the OGEV model's correlation parameters were only found to be marginally significantly different from a value of one. A study by Bhat (1998), on the other hand, is an example of a considerably more successful application of the OGEV model to trip timing decisions. Bhat jointly models urban shopping trip departure time and mode choice using a nested