Abstract

This paper presents an econometric modelling technique for a joint trivariate discrete-continuous-continuous decision structure. The model formulation exploits successive variable transformation technique (Lee’s transformation) to derive likelihood function based on a general error structure. The derived likelihood function is of closed form and estimable by the conventional maximum likelihood estimation technique. For empirical investigation, the model is applied for commuting mode choice, work start time and work duration using a data set collected in Greater Toronto Area (GTA) in 2001. The empirical investigation proves that the work duration is endogenous to joint mode choice and start time decisions. Compared to only mode choice model or joint mode choice and start time model; the joint mode choice, start time and duration model improves the overall model significantly by improving value of travel time calculation. It is also very clear that it is not the mode choice and start time, rather the mode specific start time and duration that are highly correlated. In terms of application, the modelling technique has the potential to enhance predicting capacity of activity-based travel demand model. At the same time, independent application of the model for independent applications for travel demand management policy evaluations is promising.

Key Words: Trivariate discrete-continuous-continuous model; Peak period travel demand; commuting mode choice; work start time and duration; activity-based model; travel demand management policy evaluation.
Extended Abstract

Work trips in any urban area are always at the centre of focus in urban transportation planning and policy analyses. Work trips in aggregation define peak versus off-peak period traffic flow in the urban transportation network. Although, activity-based modelling practice is to focus beyond just peak period travel, commuting activities are always at the centre of all modelling approaches. The concept of skeletal activities in activity-based travel demand modelling framework is to recognize the importance of work activities in defining urban transportation system performance (Habib and Miller, 2006). Now, it is becoming increasingly evident that the common picture of having very sharp peak period urban traffic flow within a narrow time window due to the collective work trips is getting flatter over longer time windows (Schwanan and Dijst, 2003). Such phenomenon is widely known as peak spreading (Mayer and Miller, 2001). Peak spreading phenomenon is a direct result of workers’ mode and trip timing choice decisions. Basic reason of moving away from peak-period only modelling approach to 24-hour travel demand modelling is to capture the peak versus off-peak period tradeoffs in travellers’ travel related decisions. However, even 24-hour activity-based travel demand models cannot capture peak spreading phenomenon properly (Roorda et al, 2008). Unlike all other activities, work activity related decisions are more important in our daily life. For this reason, work activities and work trips received considerable attentions in literature (Bhat and Singh, 2000; Bhat 2001). Individually work mode choice, departure time and numbers of stops etc. are investigated using advanced econometric techniques (Bhat, 1996; Bhat, 2000). However, dealing with work mode choice, start time and duration comprehensively within unified econometric modelling framework is rare in literature. In case of commuting activities, when to start work, how long to work, what mode to use to reach the work place, etc. all are intricately related to each other (Jara-Diaz, 2003a, 2003b). From methodological point of view, most of the advanced techniques available in literature require discretization of time in some way (Bhat, 2001; Bhat and Steed, 2002). In such cases, developing modelling structure always remains at the discretion of the researcher based on how to discretize the time. Comprehensive methodological approach is necessary to address interrelationships between commuting mode choice, work start time and work duration. It is necessary to develop modelling framework that allows the modellers avoiding any arbitrary discretization of time for trip timing decisions. Such an approach can address realistically the peak spreading phenomenon in urban transportation network and at the same time allows evaluating a wide range of alternative policy options to reduce peak period traffic congestion.

Unlike a conventional four-stage model, the activity-based travel demand models consider interrelationships of different activity decisions (mode, start time, duration etc.) at the disaggregate level. Typical ways to introduce such interrelationships are to use joint probability distributions of the decisions. Still many operational activity-based models have difficulties with introducing policy sensitivity to the distributions of such decisions that serve as key inputs to the activity schedulers. In TASHA, FAMOS, and ALBATROS for example, base year distributions cross-classified by activity type, person, household, and schedule attributes are used in a decision tree approach or are randomly drawn from observed distributions to simulate activity frequencies, start times, and durations for the population (Roorda et al, 2008; Pendyala et al, 2005 ; Arentze and Timmermans, 2005). Such approaches are 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. CEMDEP, the econometric modelling system for activity-travel demand uses econometric models for almost all decisions of activity-travel demand. Even in this case the individual econometric models for mode choice, start time, durations etc. are univariate in nature that do not address interrelationships of these decisions at the estimation stage (Bhat et al, 2004). Activity-based models by Vovsha and Bradley (2004), 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 or individual univariate econometric models, limitations remain with the representation of time as a discrete value. Efforts are taken to incorporate interrelationship between mode choices and start time of work activity using joint discrete-continuous modelling approach, but still work duration is considered as exogenous input to the model (Nick et al, 2008b). On the other hand Munizaga et al (2006) modelled mode choice and duration of work activity jointly, but without considering the start time. Endogeneity of work duration in travel demand is well argued in literature (Jara-Diaz, 2002, 2003a, 2003b). It is still not clear whether mode choice is correlated with start time or mode choice is correlated with duration or start time is correlated with duration for given mode choice. According to our knowledge, no econometric modelling approach is available in transportation literature that can allow investigating this without assuming arbitrary discretization of time. No remarkable attempt has been taken to model econometrically these three decisions: commuting mode choice and work start time and work duration jointly. So, any efforts in this regard will have implication to improvement to activity-based travel demand modelling framework as well as independent application to travel demand management policy evaluation.

In this paper, a new modelling approach for joint commuting mode choice, work starts time and work duration is developed. The econometric formulation of the presented model ensures correlations among these three decisions and allows continuous time modelling approach for start time and duration. So, this modelling structure can be applied for any discrete-continuous-continuous decision situation. The desirable property of the model is that the likelihood function is of closed form and can be estimated using the conventional maximum likelihood estimation technique. For policy application, the modelling framework has the potential to test a wide range of travel demand management policies, where policy responses can be expected to affect the tradeoffs between commuting mode choice, work start time and work duration. From activity-based travel demand modelling point of view, this econometric modelling approach addresses the correlations of three key decisions of work activities in the parameter estimation stage. Hence, this can potentially ensure capturing the peak spreading phenomenon of urban travel patterns. For empirical investigation, the model is estimated using a data set collected in Greater Toronto Area (GTA).

From methodological point of view the model exploits successive Lee’s transformation technique to derive closed form likelihood function for joint trivariate decisions. The model can be estimated by using maximum likelihood estimation technique. The advantage of the modelling structure is that it does not need to assume any sequences of the individual decisions under investigation. The formulation presented in this paper is of homogeneous population.
However, heterogeneity across the population as well as correlation among the discrete alternatives of discrete decision would be easier. In that case maximum simulated likelihood estimation would be as simple as that of mixed logit model estimation process. This extension is the future scope of works of this present investigation.

In conclusion it should be noted that the modelling structure developed in this paper has far wider applicability than to work activity only. In particular, the formulation corresponds to a joint discrete-continuous-continuous choice model in discrete choice literature. It is possible to use this model for many other travel related decisions, (e.g. modelling vehicle type choice and usage: when to change vehicle and how much to use; shopping location choice and timing of shopping activity etc.), for land use related decisions (e.g. home type choice, amount of investment and duration of stay), for marketing context (e.g. product brand choice, quantity to buy and usage etc.), etc.

References


