Transportation Research Part A 50 (2013) 15–32

Contents lists available at SciVerse ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

# Modelling departure time choices by a Heteroskedastic Generalized Logit (Het-GenL) model: An investigation on home-based commuting trips in the Greater Toronto and Hamilton Area (GTHA)

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ARTICLE INFO

*Article history:*
Received 7 June 2012
Received in revised form 19 October 2012
Accepted 3 January 2013

*Keywords:*
Departure time choice
Discrete choice model
GEV model
Heteroskedasticity
Dynamic pricing policy
Commuting trips

ABSTRACT

The paper presents an econometric model for departure time choice modelling. The proposed model is a discrete choice model with latent choice sets. As per the formulation of the mode, the model falls in the general category of Generalized Extreme Value (GEV) models with choice set formation, which is also known as a Generalized Logit (GenL) model. However, the proposed modelling framework uses a scale parameterization approach to capture heteroskedasticity in departure time choices. Hence, the model presented in the paper is a Heteroskedastic Generalized Logit (Het-GenL) model in general or specifically a heteroskedastic Paired Combinatorial Logit Model (Het-PCL). Empirical models are developed for the departure time choices for home-based commuting trips in the Greater Toronto and Hamilton Area (GTHA). The datasets from the Transportation Tomorrow Survey, a 5 percent household based trip diary survey conducted in 2006 is used for empirical model estimation. Separate models are estimated for private car and transit users' departure time choices. It becomes evident that transportation level-of-service attributes enter into the systematic utility function as well as the scale parameter function with significant coefficients. The proposed econometric approach captures the normalization effect of different variables in terms of simultaneously influencing systematic utility as well as the scale parameter and thereby correctly explains the elasticity of corresponding variables.



## 1. Introduction and motivation

Increasing peak period traffic congestion makes transportation policies such as dynamic public transit pricing and road pricing more feasible than ever before as these are intended to influence the distribution of travel demand throughout the day. However, designing such policies requires proper understanding of the nature of travel demand with respect to time-of-day choices. For any specific urban forms and land use conditions, elasticities of commuting departure time choices with respect to transportation level-of-service attributes are major factors that can define the success or failure of any demand management policies. So, this research is focused on improving our understanding of patterns and factors influencing commuting departure time choices.

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0965-8564/$ - see front matter 
http://dx.doi.org/10.1016/j.tra.2013.01.028

For proper and systematic investigation, it is important to use models that can capture the behavioural tradeoffs involved in commuters' departure time decisions as this decision determines the distribution of demand on road and transit networks. Proper modelling techniques that enable the testing of a wide variety of policy initiatives are required. This research aims to develop models of departure time in order to evaluate the effectiveness of various dynamic policies in managing peak period travel demand for the Greater Toronto and Hamilton Area (GTHA).

To capture tradeoffs involved in commuting trip departure time choices, we need to ensure that the time representation maintains a cumulative time-of-day sequence (for example 7:00–7:29 is just adjacent to 7:30–7:59 am and so on) and also that alternative time intervals that are not adjacent to each other are comparable (for example, the choice between travelling before or after the peak period). So, in this research, we discretize the 24-h time period into alternative departure time choice segments and apply advanced discrete choice models that can accommodate the correlations between adjacent time slots as well as allows comparing alternative slots that are not adjacent. Addressing correlation between adjacent time slots is necessary to address the issues related to boundary conditions due to time discretization. For example, a commuter departing at 7:55 am may be put in a different time slot than a commuter departing at 8:05 am. However, 7:55 am and 8:05 am are very close and may not be perceived as different time slots by the individual commuters. In our modelling approach, such artificial time boundary condition issues are avoided by accommodating the fact that adjacent time slots are, in fact, correlated in commuters' perception of alternative departure time choices. We use a Heteroskedastic Generalized Logit (Het-GenL) model that can accommodate all of these issues along with capturing the heterogeneity of departure time choices across the population. Empirical models are estimated using data from the Transportation Tomorrow Survey (TTS), a Revealed Preference (RP) household travel diary collected in the GTHA in 2006.

The paper is arranged as follows: the next section presents a review of existing relevant literature on departure time choice modelling to define the warrants for this work and to position this study in its context. Subsequently, the econometric model formulation for the departure time choices is presented. The empirical models are presented with interpretations of the model parameters and performance of the advanced models for sensitivity analyses. The study concludes by summarizing the key findings and by identifying potential future projects that may make use of this work.

## 2. Literature Review of Departure Time Models

Departure time models represent an individual's choice of a point or interval in time at which to begin a trip. Types of stochastic models used to represent the departure time choice include the multinomial logit model, the nested logit model, the cross-nested logit model, the mixed logit model, continuous time model, the Ordered Generalized Extreme Value (OGEV) model and its variants. Two key challenges in departure time choice modelling are accurately representing the continuous nature of time while allowing the comparison of non-adjacent alternative departure time slots and capturing the choice captivity to specific time slots. In most cases, investigations in the literature are focused on one of these issues specifically.

An early example of departure time choice modelling was reported by Small (1982) who used the multinomial logit (MNL) model for modelling commuting departure time. Hendrickson and Plank (1984) also used MNL models of departure time interval choice jointly represented with mode choice to investigate the relative influence of different variables on mode choice versus departure time choice. Chin (1990) used the MNL model to represent morning commuting departure time in Singapore. In all of these applications of MNL, the day is divided into a number of discrete alternatives and MNL is applied to capture the tradeoffs between alternative time-of-day options. In the MNL model, systematic utility functions are specified as linear-in-parameter functions of choice for commuting as a function of socio economic, level-of-service and work related variables. These applications of the MNL model show that it can capture systematic influences of various variables on departure choices, but there is no way to validate the accuracy of the estimates. There are doubts about the application of MNL for departure time choices as it does not capture the similarities/correlations between adjacent time interval choices. In the case of researcher defined time discretization, such correlation is obvious (as the commuters may not perceive time interval discretization in the same way as the researcher) and would cause a serious violation of the Independent and Irrelevant Alternative (IIA) assumption of MNL formulation (Russo et al., 2009).

Nested logit (NL) or Generalized Extreme Value (GEV) models can relax the IIA assumption by considering the nesting of alternatives in the form of hierarchical decision structures suitable for modelling departure time choice (Whelan et al., 2002). Polak and Jones (1994) used a NL/GEV model to represent departure time choice for an investigation of road pricing policies. The nesting/clustering of discretized departure time forms the context of daily tours. This is a very specialized application of a departure time choice model. In such cases, an alternative can only be part of one nest or cluster and the alternative clusters are fully independent. It cannot capture multiple adjacent correlations between alternative departure time choices. For example, 7 am and 8 am can be correlated in the same way that 8 am and 9 am are correlated. So a single alternative may be nested/clustered with different alternatives separately (such as 7 and 8 am; 8 am and 9 am).

The cross-nested logit (CNL) modelling structure can allow correlation between alternatives by placing alternatives in multiple nests and removing the assumption of fully independent subsets of alternatives as in NL or GEV (Vovsha, 1997; Papola, 2004). In a recent application, Bajwa et al. (2006) applied a CNL approach in the form of a mixed nested logit model for departure time choice. They considered only three alternative departure time options: early departure, on-time departure and late departure. This version of CNL is a mixed logit with an error component; the resulting likelihood function is in open form that requires a simulation estimation technique. As a variation on the cross-nested model structure, a continuous