ARTICLE IN PRESS

Journal of Choice Modelling xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Choice Modelling

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

An integrated model of intensity of activity opportunities on supply side and tour destination & departure time choices on demand side

Rajesh Paleti[a,*], Ahmadreza Faghih Imani[b], Naveen Eluru[c], Hsi-Hwa Hu[d], Guoxiong Huang[d]

[a] *Civil & Environmental Engineering Department, Old Dominion University, Norfolk, VA 23529, USA*
[b] *Department of Civil Engineering, University of Toronto, Canada*
[c] *Department of Civil, Environmental and Construction Engineering, University of Central Florida, 12800 Pegasus Drive, Room 301D, Orlando, FL 32816, USA*
[d] *Southern California Association of Governments, 818 W. Seventh Street, 12th Floor, Los Angeles, CA 90017, USA*

A R T I C L E I N F O

Keywords:
Mixed logit models
Joint discrete-continuous modeling
Sampling
Endogeneity
Supply and demand interactions

A B S T R A C T

Land use and transportation interactions exist at all time scales – long, medium, and short. In the long term, business location (and relocation) decisions, aggregate travel patterns and transportation infrastructure development are inter-dependent. In the medium-short term, in any neighborhood, the temporal profile of activity opportunities within a day, and destination and departure time (DDT) preferences of travelers are simultaneously determined. This paper explored these short-term interdependencies between the land-use supply and travel demand systems by developing a simultaneous model of time-of-day specific zonal employment intensity and non-mandatory tour DDT choices. The resulting model takes the form a panel linear regression model with employment intensity, as the dependent variable on the supply side and a mixed logit model with combinations of Traffic Analysis Zones (TAZs) and time periods as alternatives on the demand side. The modeling methodology accounts for possible endogeneity between the two systems and also considers importance sampling methods to reduce the computational burden due to explosion of choice alternatives in the discrete choice model component. The model was used to explore supply demand interactions in the Southern California region. The results not only underscore the importance of the proposed integrated modeling framework but also provide several useful insights into the factors that influence the temporal profile of zonal employment and its interaction with daily travel choices.

1. Introduction

Integrated land use and travel demand modeling is considered to be the appropriate modeling paradigm for analyzing the bi-directional interactions between the supply (built environment) and demand (travel patterns) factors (Pendyala et al., 2012). In these integrated models, conditional land use and travel demand models are applied iteratively to replicate the joint distribution of land use and travel patterns in the study region. These integrated models are typically used for modeling long term feedback effects

* Corresponding author.
E-mail addresses: rpaleti@odu.edu (R. Paleti), a.faghihimani@mail.utoronto.ca (A. Faghih Imani), naveen.eluru@ucf.edu (N. Eluru), hu@scag.ca.gov (H.-H. Hu), huang@scag.ca.gov (G. Huang).

http://dx.doi.org/10.1016/j.jocm.2017.03.003
Received 1 October 2015; Received in revised form 16 February 2017; Accepted 6 March 2017
1755-5345/

between the two systems. For instance, how does employment relocate in response to new transportation infrastructure in the region or how do travel patterns change in response to new development (e.g., big shopping mall) in the future. However, strong interactions between land use and transportation exist even at short-medium time scales. For instance, the opening and closing hours of businesses (on the supply side) and destination and departure time choice preferences of travelers (on the demand side) are more likely to be determined simultaneously. However, such interactions are not captured in the current modeling approaches.

Typically, zonal land use and employment data serve as inputs for travel demand models (TDMs) to predict the activity-travel patterns of the residential population in the study region. These models implicitly assume that zonal land use and employment serve as indicators of opportunities that attract travelers to pursue different types of activities. While the characterization of these decision processes in activity based models can vary substantially, in general these frameworks have two main components. The first component is the *activity generation* in which the model predicts the activities that each individual plans to undertake during the day. The second component is *activity scheduling* in which the spatial and temporal choices of the planned activities in the *activity generation* step are determined. Within these two components, land use and employment information is predominantly used as follows 1) for zonal accessibility measures that affect daily planning choices in the *activity generation* step, 2) for zonal accessibility measures that affect scheduling choices that are modeled prior to destination choices in the *activity scheduling* step, and 3) as zonal attraction size variables (which are usually linear combinations of different zonal employment variables) in destination choice models in the *activity scheduling* step (Pinjari and Bhat, 2011).

Given the importance of considering appropriate land use and employment information in ABMs, there is growing recognition in the field to develop user and context specific measures. Towards this end, space-time accessibility measures that consider variation of activity opportunities both in space and time have been proposed. There are primarily two components to these accessibility measures – (1) size of opportunities, and (2) ease of reachability measured as generalized travel costs and/or mode and time-of-day choice logsums. While gravity-based measures characterize accessibility through a generalized cost function, opportunity-based measures represent size of opportunities within a pre-selected boundary defined based on a generalized cost function (Chen et al., 2011; Paleti et al., 2015). Irrespective of the type of measures, most of the earlier studies account for temporal variation in accessibility measures using the second component (*i.e.* travel cost) due to changes in the transportation network conditions. For example, increased congestion levels can reduce accessibility during peak time periods. While this is very useful, it is also necessary to recognize that accessibility varies temporally due to variation in size of opportunities arising from opening and closing hours of businesses. For example, neighborhood with restaurants and night life are likely to experience increase traffic in the evening periods while affecting the neighborhood negligibly in the morning peak hours. To be sure, to address this issue, some of the recent studies have started to explicitly model the impact of varying business hours on space-time accessibility measures (Weber and Kwan, 2002; Kim and Kwan, 2003; Paleti et al., 2015).

While these new methods are a significant step forward in capturing linkages between supply and demand side factors, there are avenues for considerable improvements. First, there is no literature on modeling temporal variation of activity opportunities due to varying business hours. The traditional space-time accessibility measures that quantify the impact of this temporal variation use business hours information as an external input. Second, typical modeling frameworks employed to capture the land-use and travel interactions in the short to medium term time scales are sequential in nature and thus do not recognize that these are bi-directional in nature. For instance, daily departure time and destination choices are modeled conditional on employment information. However, there is no feedback from demand components to the supply side components. The primary objective of the current study is to address these two shortcomings of existing methods by developing an integrated modeling framework for analyzing both supply demand side outcomes jointly.

As alluded to earlier, one common assumption across most ABMs is that the supply side opportunities (*i.e.,* zonal employment) do not vary across different hours of the day, *i.e.*, a constant zonal employment profile is assumed. In reality, a more reasonable hypothesis would be a bell-shaped temporal profile of zonal employment consistent with the expected opening and closing hours of most businesses (Paleti et al., 2015). This bell shaped temporal profile of opportunities on the supply side has significant implications to the way Destination and Departure Time (DDT) choices are modeled. *First*, DDT choices must be bundled together and viewed as simultaneous choices because zonal attractiveness (typically measured using size variables in destination choice models) changes significantly depending on the departure time. People are likely to compare and evaluate combinations of departure times and destinations instead of making these decisions in any pre-determined sequence. *Second*, the temporal profile of opportunities on supply side is not necessarily a collective decision of business establishments in the zone independent of the travel preferences of people in that region. For instance, businesses are open late night in Manhattan because they see people interested in pursuing activities during late hours. Similarly, people go shopping late night in Manhattan because they know shops are open for longer hours. The observed temporal profile of activity opportunities and the observed DDT choices are most likely the outcomes of equilibrium between the supply and demand factors. So, these two systems (*i.e.,* supply and demand) cannot be analyzed as two separate independent outcomes. A simultaneous model that captures the dynamic interactions between activity opportunities on supply side and DDT choices on demand side is better suited for this choice context. The choices of interest in this study, zonal employment by time-of-day (which is an aggregated outcome of opening and closing hours of business establishments on a day-to-day basis) on the supply side and daily DDT choices on the demand side are typically made in the medium-to-short time horizons. So, in the current study, we aim to uncover these supply and demand side interactions that operate over relatively shorter time periods compared to the long-term land-use and transportation interactions. *Third*, simultaneous modeling of DDT choices will lead to explosion in the number of alternatives because all combinations of time periods and zones in the study region constitute the choice set. So, it is essential to use appropriate sampling mechanisms that can provide consistent parameter estimates for the integrated model.