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Exploring the influence of built environment on tour-based commuter mode choice: A cross-classified multilevel modeling approach

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ABSTRACT

Understanding travel behavior and its relationship to urban form is vital for the sustainable planning strategies aimed at automobile dependency reduction. The objective of this study is twofold. First, this research provides additional insights to examine the effects of built environment factors measured at both home location and workplace on tour-based mode choice behavior. Second, a cross-classified multilevel probit model using Bayesian approach is employed to accommodate the spatial context in which individuals make travel decisions. Using Washington, D.C. as our study area, the home-based work (Home-work) tour in the AM peak hours is used as the analysis unit. The empirical data was gathered from the Washington-Baltimore Regional Household Travel Survey 2007–2008. For parameter estimation, Bayesian estimation method integrating Markov Chain Monte Carlo (MCMC) sampling is adopted. Our findings confirmed the important role that the built environment at both home location and work ends plays in affecting commuter mode choice behavior. Meanwhile, a comparison of different model results shows that the cross-classified multilevel probit model offers significant improvements over the traditional probit model. The results are expected to give a better understanding on the relationship between the built environment and commuter mode choice behavior.

Introduction

The relationships between travel mode choice behavior and its determinants have been received a great amount of attention given the results will provide important guidance for planning practice and policy-making. The commuting trip, an important component of daily travel because of its regularity in time and space, is one of the major sources of traffic congestion and air pollution. Among various public policies to reduce automobile use and improve air quality, land use planning is one of many possibilities to alter travel behavior. A substantial body of literature examines the connection between the built environment and travel behavior (Ewing and Cervero, 2001, 2010; Handy et al., 2005). Yet little consensus has been reached about the impacts of the built environment on travel behavior because of the widely varying estimation techniques,

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units of analysis, empirical contexts, travel behavior dimensions, built environment characteristics, and the scales used across the studies (Bhat and Guo, 2007).

Numerous existing studies have focused on the impact of selected built environment measurements (e.g. land use density, land use mix, street network density, and block sizes et al.) on certain travel dimensions (e.g. car ownership, vehicle miles traveled, number of trips, and mode choice et al.). So far, many researchers have empirically investigated the linkage between the built environment and the travel mode choice dimension (Nielsen et al., 2013; Zhang, 2004; Cervero, 2002). Zhang (2004) analyzed the influences of land use at trip origin and destination on travel mode choice using the survey data from Metropolitan Boston and Hong Kong. A conventional multinomial logit (MNL) model and nested logit (NL) model were used for Boston and Hong Kong, respectively. The empirical modeling confirmed that the role of land use in influencing travel was independent from travel time and travel cost. Cervero (2002) studied the effects of three core dimensions of built environment (i.e. density, diversity, and design) on mode choice. The analysis revealed that intensities and mixture of land use significantly influence decisions to drive alone, shared ride, or transit, while the influences of urban design tended to be more modest. In the existing research, methodologies, data, and geographic scales are variously used, leading to mixed evidence of the influence of the built environment on travel behavior. In contrast to the policy measures such as congestion pricing and gasoline tax, land use planning is widely considered as a fundamental and long-term strategy to reduce the automobile dependency and excessive transportation energy consumption and emissions because land use determines the basic spatial settings for travel activities (Hong et al., 2014; Ewing et al., 2008).

This aim of this study is to provide additional insights to the linkages between the built environment and mode choice behavior, using a cross-classified multilevel probit model with the built environment measured at home location and workplace to accommodate the spatial context in which individuals make travel decisions. Meanwhile, this study uses tours as the basic analysis unit rather than single trips. The remainder of this paper is organized as follows. The next section presents a brief overview of the existing literatures. The third section presents the data sources and the built environment measurements. The following section presents the modeling approach used for the analysis. The model results are explained in fifth section. Finally, the highlights and future directions of this paper are concluded.

Literature review

Studies on the relationship between land use and travel behavior are often conducted at an aggregate geographic unit such as census tract, traffic analysis zone (TAZ), or the zip code level probably due to the land use data availability. In this case, some interrelated spatial analytic issues arise in the estimation of individual or household level models: spatial dependency, spatial heterogeneity, and spatial heteroscedasticity (Bhat and Zhao, 2002). For example, individual travel diaries are collected from the same area (e.g. TAZ) where they may have similar travel behavior. Spatial dependency occurs among individuals clustered within a zone because of locational effects. Spatial heterogeneity refers to differences in relationships between travel behavior and its determinants across spatial units and spatial heteroscedasticity refers to heterogeneity in the variance of the unobserved component across spatial units. In general, ignoring these spatial issues can result in inconsistent parameter estimation (Bhat, 2000; Bhat and Zhao, 2002). To recognize and incorporate the spatial context, the solution is to use a multilevel analysis that can satisfy the requirements of the geographic interrelationships. It accounts for spatial autocorrelation among individuals located in the same spatial unit by estimating coefficients varying by groups, and spatial heterogeneity among places and among individuals by estimating the variances at different levels. In recent years, multilevel/hierarchical modeling framework has been increasingly applied to the relationship analysis between urban form and travel behavior (Hong et al., 2014; Hong and Goodchild, 2014; Hong and Shen, 2013; Loo and Lam, 2013; Wang et al., 2013; Clark et al., 2014; Zhang et al., 2012; Antipova et al., 2011; Shuttleworth and Gould, 2010). Multilevel analysis can account for hierarchies in the dataset and reflect the complex interactions among observations. To account for spatial autocorrelation, Hong et al. (2014) and Zhang et al. (2012) examined the effects of home location built environment factors measured at the TAZ level on vehicle miles traveled (VMT) by employing a Bayesian hierarchical model. By using a Bayesian multilevel model, Hong and Shen (2013) examined the effect of residential density measured at the TAZ level on transportation emissions. Hong and Goodchild (2014) employed a multilevel model to compare the influence of land use on transportation emissions in urban and suburban areas when considering trip speed and vehicle characteristics. Antipova et al. (2011) used a multilevel modeling approach to examine the effects of neighborhood land use types at the TAZ level and socio-demographic attributes on commuting distance and time. These applications to travel behavior suggest that ignoring the spatial context can lead to an inferior data fit and provide erroneous conclusions.

In the multilevel modeling literature, the linear structure has been the one most commonly used because the selected travel dimensions are continuous (e.g. VMT or travel time). Meanwhile, most previous studies considered only one dimension (i.e. built environment at home location) in the spatial analysis. A body of literature showed that land use factors at workplace also have significant effects on work related travel behavior, especially mode choice (Ewing and Cervero, 2001; Cervero, 2002; Chen et al., 2008). However, the dimension of the built environment at workplace was neglected in most current multilevel modeling literature probably due to its complex estimation simultaneously handing more than one dimensions within a multilevel framework. Discrete choice models based on the random utility maximization are widely used to analyze mode choice dimension of travel in previous studies. Especially, MNL has been widely used in such research due to its simple mathematical structure and ease of estimation. However, relatively little attention has been paid toward the case