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Exploring the influence of built environment on travel mode choice considering the mediating effects of car ownership and travel distance

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ABSTRACT

Though there is a growing literature on the connection between the built environment and travel behavior, limited efforts have been made to consider the intermediary nature of car ownership and travel distance simultaneously while modeling the relationship between the built environment and travel mode choice behavior. The mediating effects from car ownership and travel distance, as an important piece, are not sufficiently investigated. To fill this gap, in this study the relationships among travel mode choice, car ownership and travel distance were described using a framework of integrated structural equation model (SEM) and discrete choice model (DCM). Drawing on a rich dataset of National Household Travel Survey (NHTS) and numerous built environment measurements in Baltimore metropolitan area, this research applied the integrated SEM and DCM approach to investigate how the built environment affects travel mode choice through influencing car ownership and travel distance. Therefore, the direct and indirect effects of built environment on travel mode choice were revealed. This study hopes to give transportation planners a better understanding on how the built environment influences travel mode choice, and consequently develop effective and targeted countermeasures to reduce car use.

1. Introduction

In recent years, with higher demand for automobile use in cities, the vehicle miles traveled (VMT) has been rapidly increasing. The issues of energy consumption and air pollution from transportation sector have become pressing needs for sustainable transportation studies. Taking the U.S. as an example, the average household VMT increased by 50% from 1970 to 2005 (Bureau of Transportation Statistics, 2007). The greenhouse gas emissions generated from the transportation sector account for about 30% of the total emissions in the U.S. (Liu and Shen, 2011). Two potential solutions that can tackle

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serious transportation energy consumption and emissions issues include sustainable mobility and sustainable urbanism (Ewing et al., 2008; Cervero and Murakami, 2010). The sustainable mobility solution includes strategies such as improving the fuel efficiency by exploring low-carbon fuels and new technologies. Another solution is through the sustainable urbanism such as re-planning our cities (i.e. by changing the built environment) so there is less demand to drive.

Through the scenario studies, Condon (2008) and Frank et al. (2007) found that it is difficult for the U.S. to achieve the 2050 emission targets if the policies purely focus on the improvements in vehicle and fuel. The emissions reduction generated by the sustainable mobility solutions can be offset by the rapid increase in automobile ownership and usage. Urban form fundamentally determines the spatial distribution of people's daily activities and it has a long-term effect on individual daily travel behavior. In this context, a growing body of literature has focused on how to reduce automobile ownership and usage in the field of urban planning and transportation (Ewing and Cervero, 2010; Boarnet, 2011; Millard-Ball and Schipper, 2011; Gim, 2013; Næss, 2015). Most existing studies investigated the connection between the built environment and different dimensions of travel behavior (e.g. travel mode choice, car ownership, and travel distance) in a separated way. For example, certain studies treated car ownership and travel distance (or travel time) as the endogenous variables explained by the socio-demographic characteristics and built environment (Senbil et al., 2009; Zegras, 2010; Sun et al., 2014; Ding et al., 2016), whereas other studies considered them as the important exogenous variables that explain the travel mode choice behavior (Cervero, 2002; Zhang, 2004; Ding et al., 2014a,b). The intermediary nature of car ownership and travel distance is not thoroughly studied while modeling the influences of built environment on travel mode choice behavior. Traditional isolated approaches are not suitable to handle the complexity of these relationships. The goal of this study is to investigate the influence of built environment on individual travel mode choice considering the mediating effects of car ownership and travel distance. The relationships among travel mode choice, car ownership and travel distance were described using a framework of integrated structural equation model (SEM) and discrete choice model (DCM). Drawing on a rich dataset of National Household Travel Survey (NHTS) and numerous built environment measurements, this research applied the integrated SEM and DCM approach to explore the extent that the built environment affects travel mode choice through influencing car ownership and travel distance. Therefore, the direct and indirect effects of the built environment measurements on travel mode choice can be revealed. This study provided significant contributions to the literature on how the built environment influences travel mode choice, and consequently developed targeted countermeasures to reduce automobile usage.

The remainder of this paper is organized as follows. The following section presents a literature review related to our study. The third section describes the modeling approach used in this study. Data sources and description are provided in the fourth section. In the following section, empirical model results are analyzed. In the end, the conclusions and limitations of this study are provided.

2. Literature review

In recent years, a growing body of literature investigates the influence of built environment on travel mode choice behavior (Cervero, 2002; Zhang, 2004; Lee et al., 2014; Khan et al., 2014; Munshi, 2016). However, empirical results provide mixed evidences. The debate on the impacts of different built environment measures on travel mode choice behavior is far away from reaching the consensus due to the different empirical contexts, geographical scales, residential self-selection, and methodologies (Handy et al., 2005; Limtanakool et al., 2006; Mokhtarian and Cao, 2008; Antipova et al., 2011; Wang and Lin, 2014; Cao, 2015). Using the binary logit model and MNL model, Cervero (2002) investigated the influences of density, diversity and design on the mode choice in Montgomery County, Maryland. The model results indicated that intensities and land use mixture have significant effects on driving mode choice, whereas the impact of urban design tends to be more modest. After controlling for socio-demographic factors, the research conducted by Reilly and Landis (2003) proved that some built environment measures and travel mode choice are correlated. However, the effects of built environment factors are generally moderate. Zhang (2004) studied the impact of land use on travel mode choice based on MNL model in Boston and Hong Kong. The empirical results indicated that land use played a key role in travel mode choice behavior which is independent from travel time and travel cost. With complementary traffic demand management (TDM) strategies and pricing policies, the effect of land use on travel mode choice will be more effective. Density is a key component in the recent surge of mixed-use neighborhood developments. Pinjari et al. (2007) studied the effects of built environment and self-selection on commute mode choice. Though the significant self-selection effect was found, the built environment factors still had significant effects on commute mode choice. Using the dataset collected in the New York Metropolitan Region, Chen et al. (2008) investigated the impact of built environment on car ownership and the propensity to use auto. Specially, the role of density on home-based travel mode choice was confirmed. Using a cross-classified multilevel probit model, Ding et al. (2014a,b) investigated the built environment of residential location and workplace on tour-based mode choice behavior. Employment density at workplace was found to have a more important role than densities at residential location. Munshi (2016) studied the relationship between built environment and commute mode choice in Rajkot, India. Among the built environment measures, only population density was found to have significant effects on all commute mode choice. Moreover, the effect of land use mixture was weak.

However, the consensus as to the influence of household car ownership on travel mode choice has been reached: car ownership is an important determinant of travel behavior such as travel mode choice and motorized trips. Therefore, many researchers already studied the influence of built environment on household car ownership (Hess and Ong, 2002; Bhat