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Activity participation as a mediating variable to analyze the effect of land use on travel behavior: A structural equation modeling approach

Yu Ding *, Huapu Lu

Institute of Transportation Engineering, Tsinghua University, Beijing 100084, China

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ABSTRACT

As activity based approach is receiving increased attention over the past decades, a variety of studies have explored the impacts of land use patterns not only on travel behavior but also on activity participation. Using data from the Tengzhou Household Travel Survey, this paper tests the relationships among land use patterns, activity participation and travel behavior, by comparing results from two structural equation models: one model without activity participation and a second model which adds activity participation as a mediating variable between land use patterns and travel behavior characteristics. The results suggest that the indirect effects through activity participation decision play important roles, which may reinforce the direct effects of land use patterns on travel behavior. Moreover, ignoring activity participation as a mediating variable may also lead to insignificant effects of land use patterns. We conclude that the intermediary nature of activity participation should be taken into consideration.

1. Introduction

Over the past two decades, the number of private cars, as well as the vehicle miles travelled (VMT) has increased dramatically in China. Traffic congestion has been a serious problem not only in megacities such as Beijing, but also in a number of medium-sized cities. In order to fight congestion, policy makers have proposed quite a few strategies, such as demand management policy or planning strategy. Among these, land use strategy is considered as an effective solution to reduce car use and VMT, since higher density and mixed land use are found to encourage the use of non-motorized modes (e.g., Kockelman, 1997; Ewing and Cervero, 2001; Dargay and Hanly, 2004; Zegras, 2004; Van Acker and Witlox, 2010).

So far, a variety of studies have investigated the relationship between built environment and travel behavior (e.g., Cervero and Kockelman, 1997, Kitamura et al., 1997; Ewing and Cervero, 2010; Boarnet, 2011). In the research framework widely adopted in many studies, travel behavior is considered to be related to the built environment and socio-demographic characteristics (e.g., Ewing and Cervero, 2001; Schwanen et al., 2004). Short term travel decisions such as trip frequency and car use are affected by long term decisions (e.g., commuting distance, car ownership), and both decisions are influenced by the land use variables and socio demographic characteristics in a hierarchy of choices (Silva et al., 2012).

One recent research advance expanded the framework by incorporating activity participation as a mediating variable, consistent with the activity-based approach (Maat and Timmermans, 2009). It is assumed that travel demand is a derived demand from activities, and travel decisions are consequences of a series of other decisions. However, there is also some evidence that travel is not always a derived demand and has utility itself (Mokhtarian and Salomon, 2001). Although there exist a few empirical studies which have included activity participation as a mediating variable (e.g., Chen and Mcknight, 2007; Wang et al., 2011; Wang and Lin, 2013), the consequences of ignoring this were not discussed. Therefore, this paper will contribute to literature by comparing the results of a model incorporating activity participation as a mediating variable with the results of another model which includes no activity behavior.

Structural equation modeling (SEM) is applied to investigate the complex relationships among socio demographics, land use characteristics, activity participation and travel behavior in this research, as SEM can not only capture the direct effect of one variable on another, but also the indirect effect via mediating variables (Bollen, 1989). The data used in this research come from a Household Travel Survey in Tengzhou, a medium-sized city in China. Therefore, this research can also provide some new insights into the interactions between built environment and travel behavior in developing countries, which remains limited in literature.

The remainder of this paper is organized as follows. The next section presents a brief review of literature on the relationship between built environment and travel behavior. This is followed by an introduction of the data used for this research and the survey. Then, the fourth section describes the model specifications and discussion of estimation

* Corresponding author at: Institute of Transportation Engineering, Heshanheng Building 312, Tsinghua University, Beijing 100084, China.
E-mail address: ding-y11@mails.tsinghua.edu.cn (Y. Ding).

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results. The conclusions and directions for future research are summarized in the final section.

2. Literature review

2.1. Built environment, activity participation and travel behavior

There have been a variety of studies that investigate the relationships between built environment and travel behavior (Ewing and Cervero, 2010; Boarnet, 2011). The built environment variables are usually categorized as the D variables, including density, diversity, design, destination accessibility and distance to transit, while travel behavior characteristics include trip number, vehicle miles travelled (VMT), travel time, car use and more (Cervero and Kockelman, 1997; Ewing and Cervero, 2001). For example, higher densities are found to result in less car use, since in dense areas public transport is organized more efficiently and travelers tend to travel shorter distances (e.g., Cervero and Kockelman, 1997; Schwanen et al., 2004). Mixed land use may bring the origins and destinations closer and thus lead to short travel distance and more walking and cycling (Kockelman, 1997; Frank et al., 2008). However, more diversity is also associated with more trips due to the lower travel cost (Crane, 1996). Neighborhood design is another important issue. Residents of a pedestrian-friendly neighborhood are found to be associated with less car use, while those in a newly-developed suburban neighborhood are found to be more dependent on cars (Wang and Chai, 2009). Moreover, it is noted that Chinese traditional *danwei* compounds have comparable effects with pedestrian-oriented neighborhoods, which result in lower car ownership and less car use (Wang et al., 2011).

Behind the association between the built environment and travel behavior, the role of residential self-selection has been noticed and discussed in recent years, which could lead to the overestimation of the impact of built environment (e.g., Bagley and Mokhtarian, 2002; Cao et al., 2006; Bhat and Guo, 2007; Mokhtarian and Cao, 2008; Zhou and Kockelman, 2008; Cao et al., 2009). People may self-select themselves in different residential locations, based either on their attitude and lifestyle, or on socio-demographic characteristics (Bagley and Mokhtarian, 2002). With the effect of self-selection controlled, the built environment is found to retain little influence on travel behavior (Bagley and Mokhtarian, 2002; Cao et al., 2006). However, some other studies state that built environment shows a significant impact even if attitude and lifestyle are accounted for (Handy et al., 2005; Bhat and Guo, 2007). While the research findings are not consistent, it is suggested that the residential location choice is a long-term decision related to individual characteristics, and the effect of built environment cannot be analyzed exogenously.

In addition to travel behavior characteristics, a few studies have also examined the effects of built environment on activity behavior (Ettema et al., 2007; Maat and Timmermans, 2009; Lee et al., 2009). Chen and McKnight found that homemakers in the city center tend to spend more time on discretionary activities and less time on maintenance activities than those in suburban areas (2007). However, the self-selection effect was not considered in their research. Zhang investigated the relationship between accessibility and non-work activities, and found that accessibility had significant positive effects on social and personal business activities, but no significant effects on shopping activities (2005). Moreover, the correlations between different types of activities were considered in the modeling but the results were not further discussed.

The relations between activity participation and travel behavior are taken into account in a few studies as well (e.g., Chen and Mcknight, 2007; Maat and Timmermans, 2009; Wang et al., 2011; Wang and Lin, 2013). As travel is treated as a demand derived from activities, activity participation is considered as a mediating variable between built environment and individual's travel behavior, consistent with activity based approach. It is found that activity participation has significant positive impacts on daily trip making and travel time (Wang et al., 2011). The indirect effects via activity participation may reinforce or reduce the direct effects of built environment on travel behavior (Maat and Timmermans, 2009). However to the best of our best knowledge, no study before has compared these two kinds of models and discussed the results of ignoring the mediating effects of activity participation on travel behavior.

2.2. Conceptual model

The aim of the paper is to investigate the complex relationships among socio-demographics, land use characteristics, activity participation and travel behavior. Based on the previous literature review, two possible structural equation modeling frameworks were laid out as shown in Fig. 11.

Model A adopts a frequently used approach in research on the interactions between built environment and travel behavior (e.g., Van Acker and Witlox, 2011; Silva et al., 2012). Land use patterns are assumed to be influenced by socio-economic demographic characteristics of the individuals and households, which allows the model to partly account for the residential-selection effects due to the socio demographic characteristics. As the data source does not include information on attitudes, residential-selection effects due to attitudes are not able to be considered, which may be left for future research. Both land use patterns and socio-demographics are assumed to influence the travel behavior. Car ownership is considered as a long-term decision, through which the indirect effects of the land use patterns on personal short-term decisions (e.g., trip frequency, model choice) can occur (Van Acker and Witlox, 2010).

In model B, we add activity participation as another mediating variable between the built environment and travel behavior, consistent with the activity based approach. Thus, the indirect effects of land use patterns on travel behavior via activity participation are able to be captured (Maat and Timmermans, 2009; Wang and Lin, 2013). Similar to travel behavior, activity participation is considered as a short-term decision as well, influenced by socio-demographics and land use patterns directly and indirectly via car ownership (Wang et al., 2011).

3. Data and variables

3.1. Data

The data used in this research come from the Tengzhou Household Travel Survey in 2012. Tengzhou is a medium-sized city in the Shandong Province of China, and the total population of the study area is about 340,000 inhabitants. The Tengzhou Household Travel Survey was conducted as the local government was preparing for the new urban transportation planning and aiming to understand the personal travel behavior and overall travel demand in Tengzhou.

In this survey about 3400 individuals were asked to participate, who were selected randomly in each neighborhood based on the house number. In addition to the questionnaire which collected information of personal and household socio demographic characteristics, each respondent had to complete a one-day trip diary. Thus, all the out-of-home activities and trips were recorded in the trip diary, including activity type, activity location, travel mode, departure time and more. All the respondents were reached with the help of the local neighborhood committee, and would receive small gifts (e.g., umbrella) after finishing the whole survey. 2788 questionnaires and diaries were returned in total and the response rate was about 82%. After controlling for the quality of respondent records by reducing samples with missing activity/travel information, the final sample used for the analysis in this research consisted of 2049 individuals and 5426 trips.