Journal of Transport Geography 54 (2016) 194–204

Contents lists available at ScienceDirect

Journal of Transport Geography

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

How does the propensity of living near rail transit moderate the influence of rail transit on transit trip frequency in Xi'an?

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ARTICLE INFO

Article history:
Received 25 September 2015
Received in revised form 22 March 2016
Accepted 26 May 2016
Available online xxxx

Keywords:
Residential self-selection
Residential dissonance
Travel behavior
Transit-oriented development
Propensity score
Sustainability

ABSTRACT

Many cities have made massive investments on rail systems to substitute transit for driving. Some studies have considered the confounding effect of attitudes in the connections between rail transit and travel behavior. However, they often focused on the average effect of rail transit and assumed that individuals' responses to transit improvements do not vary by their tastes. Using the 2014 data from Xi'an in China, this study explores the interaction effect between metro transit (heavy rail) and the propensity (i.e., predicted probability) of living in neighborhoods with metro transit on transit use. The propensity is positively associated with commute by metro transit and bus. Further, individuals with a strong propensity use transit equivalently no matter whether they live near metro transit, but metro transit tends to promote transit commute for those with a weak propensity of living near metro transit. Overall, building a rail line helps enhance transit ridership. Planners should also consider the variation in responses by individuals with different tastes when using policies to shape urban travel.

1. Introduction

Rail transit systems have been considered as an effective way to mitigate urban traffic congestion, alleviate environmental impacts of transport, and stimulate economic growth by virtue of their good quality of service and capability of converting automobile users into transit users (Bhattacharjee and Goetz, 2012; Garrett and Castelazo, 2004; Knowles, 1996). Many cities worldwide have made massive investments on rail systems, especially in fast-growing developing countries. In India, urban rail is operational in nine cities, under construction in seven cities, and planned in 14 cities (Sharma et al., 2015). In mainland China, 95 rail transit lines were in operation in 22 cities by 2014 (Wang and You, 2016). Many of the cities have planned to expand and upgrade existing rail systems and some cities will build new systems.

Many studies have explored the impacts of rail transit and/or transit-oriented development (TOD) on travel behavior. They often compare travel behavior between station area residents and the residents in the city/county/region as a whole. However, the choice of inappropriate controls tends to overstate the impact of rail transit on travel behavior (Cao and Schoner, 2014). Several studies have also disentangled the confounding effect of residential self-selection by controlling for travel attitudes and preferences. However, most of them focused on the average or independent effect of rail transit and did not consider that residents' travel responses to built environment interventions may differ among those with heterogeneous preferences (Chatman, 2014). Several studies have investigated the interaction between the built environment and attitudes to assess the moderation effect of attitudes on travel choices (Schwanen and Mokhtarian, 2004, 2005b). However, few have explored how residents' behavioral responses to rail transit development vary by individuals' tastes.

This study attempts to fill the gaps by exploring ridership benefits of station area residents of metro transit Line 2 in Xi'an. It accounts for the influences of the predicted probability (i.e., propensity) of living in neighborhoods with metro transit; given residents' demographics, travel attitudes, and residential preferences. This study is novel in the literature of residential dissonance and travel behavior. In particular, it innovatively adopts propensity score (Rosenbaum and Rubin, 1983) as an indicator for the propensity of living in neighborhoods with metro transit and examines the effect of its interaction with metro transit on transit use. Previous studies often used a factor score of land use or travel attitudes to measure residents' preference for a certain type of neighborhoods (Schwanen and Mokhtarian, 2004). By contrast, the propensity score integrates multiple factors that influence residential location choice, including demographics and various attitudes, and hence is better than using an attitudinal variable alone.

The remainder of this paper is organized as follows. Section 2 reviews the literature on the effects of rail transit, built environment,

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http://dx.doi.org/10.1016/j.jtrangeo.2016.05.016
0966-6923/

and residential neighborhood dissonance (or mismatch) on travel behavior. Section 3 discusses the data and method. Results are presented in Section 4. The final section summarizes the key conclusions.

2. Literature review

Many studies have examined ridership benefits of TOD and concluded that households living near rail stations have substantially higher rates of patronage on transit than those away from rail transit (Arrington and Cervero, 2008). Cervero's reports (1993, 1994) showed that station area residents commuted by transit around five times as many as an average resident in the same city, and that 52% of residents who drove to work prior to moving to TODs switched to transit after residing near rail transit. Using a 2003 survey of 4785 residents living at 26 sites along California's major urban rail systems, Lund et al. (2006) found that compared to residents in the corresponding city, TOD residents tended to use transit more frequently for work (more than 5 times) and non-work (about 3.5 times) purposes. Dittmar and Ohland (2004) compiled the 2000 Census journey to work data and found that both transit and walking were more prevalent at rail station areas than in the county as a whole. Using the 2000 census data on households living in 103 TODs, Renne (2005) showed that 16.7% of TOD residents used transit for commute whereas 7.1% of residents in the 12 metropolitan regions in which the TODs were located commuted by transit.

Although these studies offer important insights regarding the impact of TOD on transit use, it is inappropriate to compare TOD to the city/county/region as a whole. Because rail transit is often planned in the key corridors that already have good bus services and high transit demand than the city/county/region as a whole (Giuliano, 2004), choosing residents in the city/county/region as control groups will overstate transport impacts of rail transit (Cao and Cao, 2014; Cao and Schoner, 2014). In a cross-sectional case-control design, it is ideal for control areas to have similar characteristics (in terms of location context, built environment elements and demographic profile) to treatment areas, except the absence of rail transit.

Furthermore, most of these studies are from North America or developed countries, and this tells only part of the story. Land use and transportation development in fast-growing developing countries has a more important effect on the environment than that in developed countries. Any environmental gains from developed countries, often costly, will be eclipsed if developing countries repeat the mistakes of developed countries in land use and transportation policies (Cervero, 2013). To maintain/increase transit ridership and curb the growth of traffic congestion, rail transit has recently proliferated in China. Although transit planners expect that rail transit will guide urban development and affect travel patterns, few studies have examined how it is shaping urban travel in China. Cervero and Day (2008) conducted a retrospective survey of 900 households that recently moved to 20 housing developments served by metro transit in three suburban districts in Shanghai. They found that more than 10% of household heads have switched from non-motorized transport and bus to rail transit, but few of them have given up their cars. Therefore, metro transit in suburban neighborhoods has a limited impact on the substitution for vehicular travel. Further, about 60% of household heads did not change their commute mode before and after the move. This implies that individuals choose their residential location to match their travel attitudes (Krizek, 2000). In other words, residential self-selection may be at work.

Residential self-selection has been reported to confound the relationship between the built environment and travel behavior. It means that people choose where to live based on their preferences and needs for activities and associated travel. For example, individuals preferring transit may choose to live in transit-friendly neighborhoods and use transit more. In this case, the difference in transit use results from the unobserved and heterogeneous travel attitudes in determining residential location, rather than the "independent" effect of transit-friendly neighborhoods. If self-selection effect exists but is not controlled for, the relationship between TOD and travel behavior may be at least partly spurious (Bhat and Guo, 2007; Cao and Schoner, 2014). On the other hand, residential self-selection can be considered as a mechanism under which the built environment influences travel behavior (Naess, 2014). Previous studies have offered empirical evidence for residential self-selection relevant to TOD and travel behavior. Cervero (2007) found that self-selection effect was substantial in transit mode choice, accounting for approximately 40% of the decision to commute by rail. Cao and Schoner (2014) used a survey of 1303 respondents in 2011 to explore the impact of the Hiawatha LRT on transit use. They applied the propensity score matching method to account for self-selection effect. They found that residents who moved to the Hiawatha light rail corridor before its opening used transit more frequently than residents in control corridors whereas residents moving to the Hiawatha corridor after its opening used transit similar to those in control corridors. However, they did not differentiate the impacts of rail transit itself and station area environments on travel behavior. If station environments play a key role, building a rail line is insufficient to enhance transit ridership. Well-coordinated land use and transportation policies should be in order (Houston et al., 2015). Chatman (2013) surveyed households living within two miles of 10 rail stations in Northern New Jersey and examined the impact of rail transit on auto ownership and auto use. He found that residential preferences are significantly correlated with auto commuting and the low auto use in TODs is not due to rail transit but built environment elements. In this study, the effect on auto use is the average treatment effect of built environment elements. He did not consider the possibility that residents' responses to built environment elements may differ among those with heterogeneous residential preferences (Chatman, 2014). Built environment variables and preferences may have an interaction effect; that is, the effect of one variable depends on the level of the other variable. Thus, just simply "controlling for" demographics and preferences may miss important distinctions among individuals (Adler et al., 1994; Manaugh and El-Geneidy, 2011). In other words, the effect of the built environment on travel is not "one size fits all" but varies based on individuals' preferences.

Several studies have explored the interaction between the built environment and attitudes to assess the moderation effect on travel choices. Using a survey of 1358 commuters in three neighborhoods in the San Francisco Bay Area, Schwanen and Mokhtarian (2004) measured residential dissonance (or mismatch) between actual and preferred residential location. They distinguished urban residents from suburban residents and individuals with urban land use preferences from those with suburban land use preferences, and identified four groups: urban consonants, suburban consonants, urban dissonants, and suburban dissonants. The former two groups reside in the neighborhoods that are in congruence with their land use preferences whereas the latter two groups live in the neighborhoods that they do not prefer. Schwanen and Mokhtarian (2005a) further investigated the impact of residential dissonance on travel distance and found that dissonant urban residents traveled longer than consonant urbanites, but suburban consonants and suburban dissonants showed similar travel distance. Schwanen and Mokhtarian (2005b) compared mode choice among the four groups of people and concluded that the impact of residential dissonance was larger for suburban residents than for urban residents. Applying similar methods, De Vos et al. (2012) used 1657 individuals in Flanders, Belgium, to evaluate the impact of residential dissonance on commute mode choice. They showed that residential dissonance influenced travel behavior of mismatched respondents, and that public transit use was mainly determined by preferences and only to a limited degree by the built environment.

Few studies have explored how residents' behavioral responses to rail transit/TOD vary by preferences. Cao (2015) explored the interaction effect of the Hiawatha LRT (in urban neighborhoods in South Minneapolis) and pro-transit attitude on transit commute frequency. He found that non-LRT consonants had the lowest frequency, followed by LRT dissonants, non-LRT dissonants, and then LRT consonants.