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The impacts of built environment characteristics of rail station areas on household travel behavior

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A B S T R A C T

Transit-oriented development (TOD) has gained popularity worldwide as a sustainable form of urbanism by concentrating developments near a transit station so as to minimize auto-dependency and maximize ridership. Existing TOD studies, however, have limits in terms of small sample size and aggregate-level analysis. This study examines various travel outcomes – VMT, auto trips, transit trips, and walk trips – in rail-based station areas in eight U.S. metropolitan areas in order to understand the role of neighborhood built environment characteristics. Two-stage hurdle models handle excess zero values in trip count variables and multi-level models deal with three-level data structure – household within station areas within regions. The final models show that automobile use is associated with land-use diversity and street network design of a station area; transit use is strongly related to transit availability and land-use diversity; and walking is related to transit availability, land-use diversity, and street network design. The weakest influence among station-area environment factors is density. In sum, a TOD, a station area having a dense, mixed-use, walkable, and transit-friendly environment, motivates residents to walk more and take transit more while driving less.

1. Introduction

Contemporary urban and transportation planning deals with urban form, land use, and/or transportation facilities in a way to promote sustainable transportation modes such as walking, biking, or taking transit while minimizing automobile-dependency. Many studies have examined associations between the built environment and travel behavior (for meta-analysis of this subject, see Ewing & Cervero 2010; Stevens 2017). In particular, access to transit stations encourages transit use and walking (Ewing & Cervero 2010; Handy 2005; Pikora, Giles-Corti, Bull, Jamrozik, & Donovan 2003). In a way to achieve the contemporary planning goals, transit-oriented development (TOD) has gained popularity worldwide as a sustainable form of urbanism.

The term transit-oriented development (TOD) was coined by Peter Calthorpe (1993), who stated a TOD is a mixed-use community within an average 2000-foot (0.38-mile) walking distance of a transit stop and a core commercial area. Although it has been defined in various terms during the last two decades, the professional transit community agrees on what constitutes a TOD: dense, diverse, pedestrian-friendly land uses near transit nodes that, when successfully implemented, turn out to maximize transit ridership and minimize auto dependency (Cervero 2004). On the contrary, transit-adjacent development (TAD) is often defined as a failure of a TOD. A TAD is a non-compact, segregated neighborhood development that calls for automobile uses instead of inviting walk trips (Belzer & Autler 2002; Cervero & Duncan 2008; Dittmar & Ohland 2012).

Potential benefits of TOD could be multiple from promoting active modes of transportation to improving access to opportunities such as jobs or entertainment, to offering alternative mobility options and affordable housing for low-income people, to reducing greenhouse gas emissions, and to stimulating public and private investments in community (Center for Transit-Oriented Development (CTOD) 2011; Noland, Ozbay, Dipetrillo, & Iyer 2014). Thus, TOD serves interrelated goals of making communities socially, economically and environmentally more robust and sustainable. In order to achieve these multiple goals, a TOD should first create settings that prompt people to drive less and ride public transit more (Cervero 2004). The Center for Transit-Oriented Development (CTOD) (2010) identifies vehicle miles traveled (VMT) as the key performance measure for TOD. Station areas with low VMT tend to have low rates of automobile ownership, more transit ridership, and higher rates of walking and biking than high VMT areas (Center for Transit-Oriented Development (CTOD) 2010).

Regarding its benefits on travel outcome, much of the literature verifies that TODs reduce car usage and enhance the use of public

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transport or active transportation (Cervero 1993, 2004; Cervero & Arrington 2008; Hale 2014; Langlois, Van Lierop, Wasfi, & El-Geneidy 2015; Nasri & Zhang 2014; Olaru & Curtis 2015; Venigalla & Faghri 2015). Based on data from 17 TOD projects in the U.S., Cervero and Arrington (2008) show that residents living in TOD areas are two to five times more likely to commute by transit than their non-TOD counterparts. Nasri and Zhang (2014) find that people living in TOD areas tend to drive less, reducing their VMT by around 21–38%, compared to the residents of the non-TOD areas even with similar land use patterns in Baltimore and Washington, D.C. regions. Hale (2014) finds that the mode share by active transportation including transit, walk, and bike in TOD areas is about 50–80%, which is much higher than 25–40% in non-TOD areas. Olaru and Curtis (2015) confirm that better biking and pedestrian infrastructure results in the higher bike and walk mode shares along with higher transit ridership in TOD precincts.

Existing TOD studies, however, have limits in terms of small sample size and aggregate-level analysis. Most studies cover only single or a few regions. In contrast, this study includes eight metropolitan areas in the U.S. as diverse as Boston and Portland at one end of the urban form continuum and Atlanta at the other. Also, a total of 549 stations in the eight regions covers various rail systems – heavy, commuter, and light rail. In addition, although Renne and Ewing (2013) study 54 regions across the US, the outcome variable is only the percentage of people who commute via public transportation at the aggregate Census tract level. On the other hand, the data in this study is collected from household travel surveys in eight regions with exact XY coordinates for households and trip ends. The surveys are comparable to the National Household Travel Survey (NHTS) and include various travel outcomes such as automobile trips, transit trips, walk trips, and VMT.

In sum, this study seeks to examine the impacts of TOD characteristics of rail-based station areas on household travel behavior, using household-level survey data from eight U.S. regions. We expect to find that a TOD, a station area having a dense, mixed-use, walkable, and transit-friendly environment, motivates its residents to walk more and take transit more while driving less. There is broad interest in the planning and policy communities in accurate tools to predict the consequences of TOD on the generation of transit ridership and reduction of automobile usage. Our analysis will help guide transportation planners and decision makers to evaluate TOD projects relative to their performance.

2. Research design

2.1. Study regions and household travel data

This study includes eight metropolitan regions meeting three criteria (Table 1). First, they must have household travel survey data with XY coordinates for households and trip ends. Second, a region must provide land use databases at the parcel level with detailed land use classifications so that we can study land use mix for the same years as the household travel surveys. Third, they must have had a rail-based transit system before the survey was conducted.

For the eight regions (Table 2), household travel surveys were conducted between 2006 and 2012. While being conducted by individual regional 'organizations such as metropolitan planning organizations (MPOs), the regional household travel surveys have quite similar structure and questions, akin to U.S. DOT's National Household Travel Survey (NHTS). To gather comprehensive data on travel and transportation patterns, the survey data consistently includes, but is not limited to, household demographic information, vehicle information, and data about one-way trips taken during a designated 24-hour period on a weekday, including travel time, mode of transportation, and purpose of trip information. The survey data have exact XY coordinates so we could geocode the precise locations of households and estimate the lengths of trips while the NHTS provides geocodes of households only at the Census Tract level. The regional survey data was acquired from individual MPOs or state DOTs with confidentiality agreements.

Jurisdictional fragmentation of metropolitan areas means that parcel-level land use data must be obtained from large numbers of county tax assessors (sometimes with different land use codes and often with monetary charges). The regions included in our sample met all three criteria and, also, were able to supply GIS data layers for streets and transit stops, population and employment for traffic analysis zones, and travel times between zones by different modes, for calculating the various built environment variables.

In these eight regions, there are 549 rail-based transit stations according to the National TOD Database (Center for Transit Oriented Development, http://toddata.cnt.org/). Transit types include heavy rail (109 stations), commuter rail (148 stations), and light rail (272 stations). Boston has the greatest number of stations (n = 239), followed by Portland (n = 94) and Miami (n = 50), and Minneapolis-St. Paul has the smallest number (n = 20).

Station areas were drawn as a ½-mile buffer in network distance from each rail transit station. Then, we allotted individual households to their nearest station based on network distance. The resulting pooled data set in station areas consists of 24,535 trips by 2431 households in the eight regions (see Table 2). Then, we calculated vehicle miles traveled (VMT), automobile trips, transit trips, and walk trips by individual households. Dummy variables of the automobile, walking, or transit use for each household were first calculated and then the

Table 1
Characteristics of eight study regions.

No	Region	Population	Employment	Area (square miles)	Compactness index (Hamidi & Ewing 2014)
1	Atlanta, GA	5,173,196	2,173,573	6404	41.0
2	Boston, MA	4,459,130	2,394,530	2864	142.0
3	Denver, CO	2,796,466	1,425,431	3608	107.1
4	Miami, FL	2,475,945	1,125,068	634	144.1
5	Minneapolis-St. Paul, MN	2,854,015	1,421,211	2977	88.7
6	Portland, OR	1,453,978	754,099	430	109.9
7	Salt Lake City, UT	2,085,315	1,176,975	4255	107.0
8	Seattle, WA	3,467,641	1,765,592	6875	116.1

Source: Atlanta (Atlanta Regional Commission); Boston (Boston Region MPO CTPS); Denver (Denver Regional Council of Governments); Miami (Miami-Dade TPO); Minneapolis-St. Paul (Metropolitan Council); Portland (Portland Metro); Salt Lake City (Wasatch Front Regional Council); Seattle (Puget Sound Regional Council).

Table 2
The number of transit stations by types and survey households[a].

No	Region	Year (survey)	Heavy rail	Commuter rail	Light rail	Total Stations	Survey Households (within ½ mile from a station)
1	Atlanta, GA	2011	38	0	0	38	138
2	Boston, MA	2011	49	121	72	239[b]	1586
3	Denver, CO	2010	0	0	36	36	152
4	Miami, FL	2009	22	4	24[c]	50	24
5	Minneapolis-St. Paul, MN	2010	0	4	16	20	97
6	Portland, OR	2011	0	7	87	94	304
7	Salt Lake City, UT	2012	0	1	36	37	114
8	Seattle, WA	2006	0	11	25	35[b]	16
	Total		109	148	272	549	2431

[a] This study includes only transit stations which had opened before a survey.
[b] The total number of station is not equal to the sum of the columns because there are some stations having two or more types of transit systems.
[c] Miami's People Mover, an automated guideway transit, is included under the LRT category.