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Models for anticipating non-motorized travel choices, and the role of the built environment

Mobashwir Khan [a], Kara M. Kockelman [b,*], Xiaoxia Xiong [c]

[a] Travel Demand Modeler, Cambridge Systematics, Oakland, California
[b] Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, 6.9 E. Cockrell Jr. Hall, Austin, TX 78712-1076, United States
[c] The University of Texas at Austin, United States

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ABSTRACT

This paper uses detailed travel data from the Seattle metropolitan area to evaluate the effects of built-environment variables on the use of non-motorized (bike+walk) travel modes. Several model specifications are used to understand and explain non-motorized travel behavior in terms of household, person and built-environment (BE) variables. Marginal effects of covariates for models of vehicle ownership levels, intrazonal trip-making, destination and mode choices, non-motorized trip counts per household, and miles traveled (both motorized and non-motorized) are presented. Mode and destination choice models were estimated separately for interzonal and intrazonal trips and for each of three different trip purposes, to recognize the distinct behaviors at play when making shorter versus longer trips and serving different activities.

The results underscore the importance of street connectivity (quantified as the number of 3-way and 4-way intersections in a half-mile radius), higher bus-stop density, and greater non-motorized access in promoting lower vehicle ownership levels (after controlling for household size, income, neighborhood density and so forth), higher rates of non-motorized trip generation (per day), and higher likelihoods of non-motorized mode choices. Intrazonal trip likelihoods rose with street connectivity, transit availability, and land use mixing.

Across all BE variables tested, street structure offered the greatest potential behavioral impacts, alongside accessibility indices (for both motorized and non-motorized access). For example, non-motorized trip counts are estimated to rise 26% following a one standard deviation increase in this variable, and walk probabilities by 27% following a one standard deviation increase in this index at the destination zone. Regional and local accessibility and density (of population plus jobs) variables were also important predictors, depending on the response being modeled. Simulated model applications illuminate when and to what extent significant travel behavior changes may be witnessed, as land use settings and other variables are changed, to reflect existing neighborhoods.

1. Introduction

The 2009 National Household Travel Survey (NHTS 2009) data suggest that 9.7% of all person-trips made in the U.S. relied on non-motorized travel (NMT) modes, versus just 6.3% in 1995 (Kuzmyak et al., 2011). NMT offers many benefits to individuals and the wider community. For example, researchers have found that those traveling more often by non-motorized modes enjoy better physical and mental health (Frank and Engelke, 2001; Litman, 2003). Shorter trips and non-motorized trips also reduce a variety of emissions and roadway congestion (see, e.g., Litman (2003) and Rietveld (2001)). Travel time savings from reduced congestion, along with cost-savings from a reliance on less expensive forms of transport, can provide significant economic benefits (Litman 1999).

In order to achieve higher NMT shares, engineers, planners, and policymakers must understand how various built environment (BE), household, personal and other factors affect NMT choices. Despite the abundance of literature on non-motorized modes, there is still a lack of consensus among studies and researchers in this area. This paper adds to the NMT literature by analyzing the effect of different land-use characteristics at very fine spatial resolutions. The analysis is based on a variety of behavioral models

* Corresponding author. Tel.: +1 512 471 0210.
E-mail addresses: mobashwir@gmail.com (M. Khan), kkockelm@mail.utexas.edu (K. M. Kockelman), summerholiday623@gmail.com (X. Xiong).

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estimated (and then applied) using household travel survey data from the Seattle region in Washington State (PSRC, 2006). These include models of vehicle ownership, household vehicle-miles and non-motorized-miles traveled, NMT trip generation, the choice of destination outside one's origin zone (which has important mode-choice implications), destination, and mode choice models. Taken together, the results highlight a variety of recurring, key factors for NMT choices. Before presenting data set details, model specifications and results, a review of the extensive NMT literature is provided.

2. Literature review

Despite a number of NMT and BE investigations, this field of research is not yet conclusively understood (Kuzmyak et al., 2011; Pratt et al., 2012). One of the more detailed studies is by Cervero and Duncan (2003), using San Francisco Bay Area data to investigate the effect of BE factors on biking and walking. After controlling for various demographic, environmental, and design factors, their discrete-choice model results suggest that built-environment factors have relatively little effect. They conclude that demographic factors and trip conditions are far better predictors of NMT choice than BE characteristics.

A more recent study, by Cervero et al. (2009), takes a close look at Bogotá, Colombia, which boasts an extensive network of bike lanes and is known for its sustainable urban transport system. Their work suggests that cycling choices are affected more by the configuration, connectivity and density of streets rather than other BE factors (such as density, land-use mix and destination accessibility). Pratt et al.'s (2012) extensive review of the NMT effects of system changes concludes that the “if you build it, they will come” phenomenon mostly exists with bike and walk facilities (and policies), particularly if system connectivity is thoughtfully provided. Dill and Gliebe's (2008) GPS-based data set from 164 adult cyclists in Portland, Oregon suggest that cyclists prefer roadways with bicycle infrastructure and low traffic volumes, and try to reduce travel times by minimizing waits at traffic signals and signs (consistent with results by Stinson and Bhat (2004)).

Ewing and Cervero's (2010) meta-analysis of the travel–BE relationship suggests that the extent of walking (measured as either trip frequency, trip length, mode share or vehicle-miles traveled [VMT]) is mostly affected by intersection density, jobs-housing balance, distances to stores, and transit stop proximity – after controlling for demographic attributes. Moudon et al. (2005) also found that a household's distances to neighborhood destinations (such as grocery stores, retail shops, and restaurants) had a significant effect on walk time per week. And Kitamura et al. (1997) noted how sidewalk presence, higher population densities, and distance to one's nearest bus stop, among other attributes, are positively correlated with the number of NMT trips made by a person per day. Of course, bicycling and walking are also affected by climate, topography, darkness, and safety concerns (Kuzmyak et al., 2011), though these are less commonly controlled for in models (in part because they vary by time of day, day of year, and route).

One common problem that researchers face when evaluating the relationship between BE characteristics and travel is self-selection. Self-selection essentially is an individual's decision to live in a particular residential location based on his/her travel preferences (Frank et al., 2008), which is counter to the causal direction normally assumed by researchers (from BE to behavior). Cao et al. (2006a) concluded that self-selection has more influence on non-motorized trip making than automobile and transit trips. Kitamura et al. (1997) found that attitudinal effects (or self-selection) have greater impact than the BE on the extent of NMT trip-making, while Schwanen and Mokhtarian (2004), Khattak and Rodriguez (2005), and Zhou and Kockelman (2008) all concluded that BE effects exceed those of self-selection (for overall travel decisions, proxied by VMT). Despite some specific differences in magnitude and sometimes order of effect, there is a general consensus among leading researchers that BE characteristics do affect travel choices. For example, Cao et al. (2006b) reviewed 28 empirical studies on this very topic and showed how BE characteristics have statistically significant effects on travel, even after self-selection is controlled for. The question that remains is how great are such BE effects, and will design decisions and public policy make a cost-effective difference on travel choices? This paper analyzes a spatially detailed data set for a closer look at this important question.

3. Data description

The data used in this paper come from the Puget Sound Regional Council (PSRC) 2006 household travel survey, which obtained data from 10,510 individuals across 4741 households residing in the King, Kitsap, Pierce and Snohomish counties of Washington State. The data are summarized in Table 1, and contain a substantial proportion of non-motorized trips (8.77%). Each respondent was asked to keep a travel diary for two consecutive days, all of which were weekdays (with all two-weekday combinations being distributed equally). The sample appears reasonably representative of the Seattle population across household sizes and auto-ownership levels (Cambridge Systematics, 2007).

In addition to the travel survey, very fine parcel-level information from the region was inventoried by PSRC. The entire region consists of 1,177,140 parcels, and each trip in the trip file is connected to an origin and destination parcel identification number or “id”. Each household is connected to a household parcel id. In contrast to other regions' traffic-analysis-zone-(TAZ-) based data sets, land-use information is reported *for each parcel*, and each trip in the Seattle data is associated with an origin-parcel and a destination-parcel, along with parking, transit and land use attributes within quarter-mile and half-mile buffers/radii around each of these parcels (as summarized in Table 2). Buffer-based variables include number of housing units, numbers of jobs (by sector), average parking costs (both hourly and daily), number of free *off-street* parking spaces, number of intersections (by type: four-way, three-way, and “point”/dead-end nodes), number of local and express bus stops, (network) distance to nearest bus stop, and other variables. The wealth of information provided makes this data set unique and well suited for the analyses performed in this paper.

4. Zone-level characteristics for destination choice (DC) models

4.1. Accessibility indices

The logsum of a multinomial logit- (MNL-) based destination choice (DC) model's systematic utilities is the expected maximum utility for such a choice set shifted by a constant, and so can be used as a measure of accessibility (Ben-Akiva and Lerman, 1985; Niemeier, 1997; Handy and Niemeier, 1997). Two such accessibility indices (for each TAZ) were constructed: one for the drive-alone mode (SOV AI) and the other for the non-motorized modes (NMT AI).