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Catalysts and magnets: Built environment and bicycle commuting

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ABSTRACT

What effects do bicycle infrastructure and the built environment have on people's decisions to commute by bicycle? While many studies have considered this question, commonly employed methodologies fail to address the unique statistical challenge of modeling modes with small mode shares. Additionally, personal characteristics that are not adequately accounted for may lead to overestimation of built environment impacts.

This study addresses these two key issues by using an ordered probit Heckman selection model to jointly estimate participation in and frequency of commuting by bicycle, controlling for demographics, residential preferences, and travel attitudes. The findings suggest a strong influence of attitudinal factors, with modest contributions of bicycle accessibility. Bicycle lanes act as "magnets" to attract bicyclists to a neighborhood, rather than being the "catalyst" that encourages non-bikers to shift modes. The results have implications for planners and policymakers attempting to increase bicycling mode share via the strategic infrastructure development.

1. Introduction

The relationship between bicycling and the built environment, particularly dedicated bicycle lanes and trails, has captivated the attention of researchers and planners for decades. In a state of the practice and research needs paper, Porter et al. (1999) identified critical questions about the role of bicycle infrastructure: how to forecast use of new facilities, how to estimate mode shift due to building new facilities, and how these new facilities may affect mobility, congestion, and air quality. Despite many advances in the field, their questions about the impacts of infrastructure are still salient today.

Common strategies for researching and evaluating transportation projects fail to address the nuances of bicycling. The utility of bicycling, more so than any other mode, is strongly affected by weather phenomena and day-to-day variation in travel needs, such as hauling cargo or goods. As a consequence, many bicyclists are in fact multi-modal travelers (Heinen et al., 2010). Distinguishing between participation and frequency is critical for being able to model the impacts on bicycling (Heinen et al., 2010).

Because bicycling has such a small mode share, standard survey and data collection strategies, especially those that assume people tend to stick to a single mode throughout the week such as the American Community Survey (ACS), underestimate its prominence. Many also employ research design strategies that skew the sample in favor of people who are already prone to bicycling, producing coefficients that are not accurate for modeling behavior among the general population.

What effects do bicycle infrastructure and the built environment have on people's decisions to commute by bicycle? Are some people more inclined to be "bikers" than others? This study explores the gap in research spanning both participation in bicycling and frequency of bicycle commuting, with aims of expanding the understanding of bicycling and the built environment. Existing survey data from Minneapolis, MN and a sample selection model are employed to jointly estimate participation in and frequency of bicycle commuting as a function of the built environment, controlling for demographics, residential preferences, and travel attitudes.

This research is significant because, while the magnitude and direction of the coefficients are consistent with other studies, the unique structure of the sample selection model provide deeper insight to the relationships between individual preferences and the built environment. When interpreted in this framework, it is easy to identify ways of harnessing the residential self-selection effect to increase rates of bicycling.

The extent to which bicycling infrastructure acts as a "catalyst" to induce mode shift among non-bicyclists to biking is unknown, given the difficulty of establishing causality in cross-sectional

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studies (Cao et al., 2009a). However, the evidence of a self-selection effect suggests that certain infrastructure types function as "magnets" for people who are already prone to bicycling for work, due to their demographic, residential preference, and travel attitude profiles. Combined with evidence from variables used to predict frequency after controlling for residential self-selection, the findings from this study can be used to locate new bicycling infrastructure strategically for providing housing choices for current and would-be bicyclists, and maximizing the number of bicycle trips they choose to make.

This paper is organized as follows: Section 2 reviews literature about how studies manage low numbers of bicyclists among the general population. Section 3 describes the survey administration, data, and modeling procedure. Section 4 presents findings from using an ordered probit Heckman selection model to predict participation in and frequency of bicycle commuting among urban residents. Finally, Section 5 concludes with a discussion of the implications of this research for practice.

2. Literature review

2.1. Complications of modeling bicycling

Bicyclists are distinctly "multi-modal" (Heinen et al., 2010). More so than driving and even transit, bicyclists are vulnerable to day-to-day changes in weather or varying travel needs. Having to make additional stops, carry groceries or other bulky items, or travel when it is dark all decrease the utility of bicycling. Many bicyclists, therefore, can be thought of as "part-time" bicyclists.

This phenomenon results in conventional survey questions underestimating bicycling. Surveys that ask about a single primary commute mode, such as the ACS, miss people who bike only 1–2 days per week, or only for non-work purposes. These questions tell us how many people are bicycling frequently, but do not tell us how many people are biking infrequently and how many trips this translates to.

Surveys that ask what mode was used "yesterday" in theory should average out over the whole population to a representative value of the amount of bicycling being done, but this assumes bicyclists choose their biking days randomly and that sample sizes are large enough to reflect the ground truth of bicycling. With small sample sizes and such a low mode share, these types of questions have low chances of catching a part-time bicyclist on their biking days.

Much of the literature on bicycling employs binary logit models that predict who is a bicyclist in any capacity, and do not tell us how much bicycling is actually being done. Heinen et al. (2010) describes this problem in this way: "It is of interest to distinguish between (1) mode choice in general, that is to say, the bicycle is at least one of the modes used; and (2) daily choice, in terms of frequency. The latter is useful because many bicycle commuters choose not to cycle every day."

2.2. Bicycling as a small mode share

Bicycling represents a relatively small mode share, particularly for commuting. In the United States, the ACS estimates that only 0.51% of commuters use a bicycle as their primary commuting mode. While the average is higher when focusing on central cities (0.95% in all Principal Cities, and 3.86% in the City of Minneapolis), the overall rates are still extremely low relative to driving, and even other so-called "alternate" modes such as transit.

A review of the literature on bicycling behavior and the built environment found five strategies for modeling bicycling, given the low mode share. The strategies include inclusion criteria, strategic over-sampling, hybrid inclusion criteria and strategic over-sampling, statistical distributions and no technique.

Table 1 summarizes the studies reviewed in each of these five categories. Some studies appear multiple times in the table

Table 1
Research design techniques for managing low mode share in selected studies of bicycling and the built environment.

Citation	Data source	Technique	Model
No specific technique used – General population			
Cao et al. (2009b)	Original Survey		SURE[a] – Bike/Walk Frequency
Krizek and Johnson (2006)	Regional Survey		Logit – Bike trip(s) in travel diary
Parkin et al. (2007)	Census		Logit – Bike commute share
Inclusion criteria to select bicycling subset			
Handy and Xing (2011)	Original Survey	Biked within past year	Logit – Primary bike commute
Wardman et al. (2007)	Census & Survey	Current/Potential Bicyclists	MNL[f] – Mode Choice
Winters et al. (2010)	Original Survey	Current/Potential Bicyclists	Multilevel Logistic – Bike (vs. car) trip
Xing et al. (2010)	Original Survey	Biked within past year	Logit – Utilitarian v. Recreation Biking
Xing et al. (2010)	Original Survey	Biked within past year	OLS[b] – Log-miles of Utilitarian Bike
Strategic survey to oversample bicyclists			
Akar and Clifton (2009)	Original Survey	University Affiliates	MNL – Mode Choice
Heinen et al. (2011b)	Original Survey	High biking cities	Logit – Bike commute
Hunt and Abraham (2007)	Original Survey	Bicyclists	Logit – SP experiment
Moudon et al. (2005)	Original Survey	Suitable geography	Logit – Biking at least weekly
Sener et al. (2009)	Original Survey	Bicyclists	OLogit[c] – Bike commute frequency
Thakuriah et al. (2012)	Original Survey	Bicyclists	Binary GMM[d] – Former captive car user
Inclusion criteria & strategic survey			
Heinen et al. (2011b)	Original Survey	High biking cities & Cyclists	Logit – FT vs. PT Bike Commute
Heinen et al. (2011a)	Original Survey	High biking cities & PT Cyclists	GEE/RCA Logit – Mode Choice
Rodríguez (2004)	Original Survey	City & University Campus	MNL, Nested, & HEV[e] – Mode Choice
Statistical techniques			
Buehler (2012)	Regional Survey	RELogit	RELogit – Bike commute

[a] Seemingly Unrelated Regression Equations (SURE).
[b] Ordinary Least Squares Regression (OLS).
[c] Ordered Logistic Regression (OLogit).
[d] Generalized Mixed Model (GMM).
[e] Heteroscedastic Extreme Value Model (HEV).
[f] Multinomial Logistic Regression (MNL).