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Perceptions, People, and Places

Influences on Cycling for Latino Immigrants and Implications for Equity

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Abstract

The recent growth in cycling in the United States has paralleled a growth in the diversity of cyclists, but what encourages people to bicycle is not the same across all demographic groups. This study uses intercept survey data from predominately Latino-immigrant neighborhoods to understand how social-ecological motivations for cycling differ for immigrants and US-born residents. Both perceptions of cyclist and social relationships with other cyclists are strong predictors of cycling, and more strongly so for immigrants. Planning that supports both social and physical infrastructure may help meet the needs of diverse cyclists and promote equity.

Keywords: transportation equity, bicycling, Latino immigrants, social ecological models, structural equation modeling

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Introduction

Bicycling communities celebrated the growing diversity of cyclists during the previous decade. The rate of cycling grew fastest among people of color (The League of American Bicyclists and Sierra Club 2013), drawing attention to the need to plan for diverse groups when building infrastructure and implementing programming. Continued growth has not held at the same pace into the current decade, however, and examining variation by nativity in addition to race and ethnicity yields contrasts. The rate of cycling to work among US-born Latinos increased by 12 percent between 2009 and 2017 and the rate of cycling for all trip purposes increased by 67 percent. Meanwhile, cycling rates to work and for other trip purposes among foreign-born Latinos *decreased* by 24 percent and 61 percent, respectively (Ruggles et al. 2019; Federal Highway Administration 2018). Immigrant status can be an important indicator of differences in travel motivations and needs.

Social ecological models may help explain this heterogeneity in travel patterns by drawing attention to how complex links between demographics, perceptions, social environments, and physical environments influence and are influenced by behavior (Sallis, Owen, and Fisher 2008; Handy and Xing 2011). For example, immigrants leverage social networks for travel needs and other resources,

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facilitated by living in residential enclaves and in denser neighborhoods amenable to non-auto travel (Ellis, Wright, and Parks 2007; Liu and Painter 2012; Blumenberg and Smart 2014; Smart 2015). Much of what we know about immigrant cycling explores these factors using national datasets like the American Community Survey and National Household Travel Survey, but those surveys have not historically asked questions related to perceptions, attitudes, or preferences, which scholars have argued are critical to understanding cycling (Handy and Xing 2011; Dill, Mohr, and Ma 2014). And while these surveys are statistically representative, the data have few observations per census tract and underrepresent hard-to-reach population groups, making it difficult to draw statistically robust conclusions about immigrant cycling at a neighborhood level. This study addresses this gap in scholarship.

In this study, I examine the relationships between immigrant status, cycling perceptions, social environments, and address-level land use and urban form. A unique intercept survey of San Francisco Bay Area residents who live in or near neighborhoods with significant concentrations of Latino immigrants forms the dataset for analysis. I found that while frequency of cycling between immigrants and non-immigrants was comparable, some social and perception factors more strongly motivated immigrants to bicycle. Cyclists held different perceptions of the suitability of their neighborhood for cycling than non-cyclists—and different still based on immigrant status—suggesting that travel behavior is a causal influence on factors usually assumed to be exogenous.

How does socioeconomic diversity shape active travel behavior?

Bicycling and social ecological factors

Although many factors influence behavior, three main factors shape the decision to bicycle: the physical environment, individual characteristics, and the social environment (S. L. Handy, Xing, and Buehler 2010; van Acker, van Wee, and Witlox 2010). These three interrelated factors derive from social ecological models in public health (Sallis, Owen, and Fisher 2008). A person who wants to bicycle must have access to a bicycle and a neighborhood with good bicycle accessibility; must be physically able to do so and perceive it to be comfortable, safe, and convenient; should feel welcome to do so by family, friends, and peers.

Urban form, infrastructure, and individual characteristics play a role in motivating cycling. Cities with denser networks of dedicated and separated bicycle lanes have more bicycling (Dill 2009; Buehler and Pucher 2012). Bicycle infrastructure encourages cycling in part because most people prefer designated facilities to cycling in mixed traffic (Buehler and Dill 2016), and in part because cyclists demand infrastructure as they grow in number. Cycling is also more common in areas with mixed land use, which facilitates shorter travel by bringing origins and destinations closer together (Heinen, van Wee, and Maat 2010; Forsyth and Krizek 2010; Winters et al. 2010). Women cycle less than men in most places, hypothesized to be a result of greater household burdens and a higher aversion to perceived risk (Garrard, Handy, and Dill 2012). Other socioeconomic characteristics have less influence. For example, income does not have a consistent effect on bicycling (Heinen, van Wee, and Maat 2010), though there is evidence that low-income immigrants to the United States are more likely to bicycle than other nativity or income groups (Smart 2010).

The relationship between personal identity and the social environment is a critical factor in understanding cycling motivations. For example, residents of two bicycle friendly cities—Davis, California and Delft, the Netherlands—were more likely to cycle because other residents generally held a favorable view of cycling as an everyday activity. However, while the Americans faced anti-bicycling sentiment outside of Davis, the Dutch were still encouraged to cycle outside of Delft, revealing how social influence is embedded in multiple spatial and social contexts (Heinen and Handy 2012). Similar social networks predict mode choice for immigrants. Immigrant residential enclaves are sites of strong social ties and, according to spatial assimilation theory, serve as cheaper places where immigrants can accumulate human and financial capital before moving to higher-quality neighborhoods (Massey 1985). Residence in an immigrant enclave is reflected in travel behavior: it is associated with lower rates of driving alone, more carpooling, and more transit use (Liu and Painter 2012; Blumenberg and Smart 2014; Chatman 2014; Smart 2015; Shin 2017). Few studies explore the association between immigrant enclaves and cycling specifically, but those that studied such neighborhood effects on non-motorized travel have found mixed outcomes. For Latino immigrants, Liu and Painter (2012) found no significant association between living in an immigrant enclave and rates of walking and cycling to work in Public Use Microdata Areas in six major metropolitan areas. On the other hand, Smart (2015) found a significant positive association between living in an immigrant enclave and the likelihood of walking or cycling using National Household Travel Survey data and residential information for census tracts. The effects were stronger for immigrants living in immigrant enclaves and for social or recreational trips compared to commute trips.

How individual characteristics and the social environment interact say much about how transportation choices are embedded in a complex system of influences. Racial and ethnic identities do not explicitly motivate or discourage cycling on their own, but planning processes, spatial structures, and social norms are intertwined with the lived reality of people of color and influence their cycling experiences. Ostensibly neutral planning practices that neglect to distinguish individual needs risk reinforcing entrenched inequalities. Bicycle counts, for example, typically do not record cyclist identities and tend to be located along popular cycling routes, far away from service and manufacturing jobs where lower-income cyclists are more likely to ride (Golub et al. 2016). Even newer sources of data collection, such as crowdsourcing, cannot adequately fill the data gap because people of color are often underrepresented in these systems of data collection (Le Dantec et al. 2016; Blanc, Figliozzi, and Clifton 2016). Some scholars have argued that consequences are evident because active transportation planning seeks to solve problems for a monolithic group of bicycle "users" rather than individuals, abstracting away differences in need and preferences based on identity (Zavetoski and Agyeman 2015). Bicycle planning in communities of color has become contentious in many places as a result of this identity-blindness, manifested most starkly via perceptions that bicycle infrastructure and accelerating gentrification go hand-in-hand (Sheller 2015). There is empirical evidence that in some places this correlation is true (Flanagan, Lachapelle, and El-Geneidy 2016; Braun 2018), but *perceptions* that it is true, whether in fact or not, drive strong calls for more inclusive planning processes. Long-time residents experiencing neighborhood change wonder why planners are only now investing in infrastructure after years of neglect (Lubitow and Miller 2013; Hoffmann 2016).

Social norms affect cycling experiences in more nefarious ways. For example, cyclists get into more crashes in majority low-income and people-of-color neighborhoods even after controlling for infrastructure provision (Barajas 2018a), suggesting other external influences play a role. Implicit racial biases may be a culprit for this phenomenon. Although no studies on the role of bias in cycling safety have been conducted yet, studies of pedestrians have shown that drivers are less likely to yield to people of color in crosswalks than to White people (Goddard, Kahn, and Adkins 2015; Coughenour et al. 2017). Roadway interactions sit at the intersection of individual characteristics, sociocultural norms, and physical design and conditions (Goddard 2016). In other words, identity is a key factor to understanding travel choice in the context of other social ecological factors.

Attitudes, perceptions, and travel behavior

Cycling-related attitudes, perceptions, and preferences predict whether people travel by bicycle. The theory of planned behavior (TPB) describes why such psychological constructs would explain travel behavior (Ajzen 1991; Bamberg, Ajzen, and Schmidt 2003). Attitudes, which measure positive or negative views toward a behavior, influence intentions to perform that behavior, which in turn cause the behavior. How other people perceive the behavior (subjective norms) and whether a person thinks he or she can do it (perceived behavioral control) also predict behavior in TPB. In other words, if someone thinks bicycling is good for her health, her friends agree that bicycling is a healthy activity, and she has access to a bicycle and knows how to ride, she has a higher likelihood of planning to bicycle and executing her plan. Positive attitudes toward cycling strongly predict more cycling trips (Dill, Mohr, and Ma 2014). These attitudes interact with perceptions of the cycling environment: one's internal evaluation of mobility choices and the access and convenience provided by infrastructure that links nearby places constitute a feedback loop in decision-making (van Acker, van Wee, and Witlox 2010; Schneider 2013; Mokhtarian, Salomon, and Singer 2015).

Public health research consistently finds that aesthetic neighborhood perceptions, social support, and bicycling and walking preferences strongly predict levels of physical activity (Giles-Corti and Donovan 2002; Pikora et al. 2003; Haughton McNeill et al. 2006; Trapp et al. 2011). Urban planning research tends to find a strong role of the built environment in predicting travel: higher density and accessibility cause reductions in distance driven (Ewing and Cervero 2010) or increases in bicycling (Heinen, van Wee, and Maat 2010). But research that tests both attitudes and the built environment typically finds that attitudes are more strongly associated with greater levels of bicycling than urban form and infrastructure characteristics are (Dill and Voros 2007; Handy, Xing, and Buehler 2010; Dill, Mohr, and Ma 2014). A person simply agreeing that he or she likes bicycling often has one of the most significant associations with traveling by bicycle (Xing, Handy, and Mokhtarian 2010; Handy and Xing 2011).

But these interrelated causal factors may reveal an endogeneity problem. Some of the influence the built environment has on bicycling may be a result of residential self-selection effects otherwise unaccounted for—just one mechanism by which preferences and attitudes relate to travel (e.g. Chatman and Klein 2009). Positive attitudes toward cycling can also result from living in a bicycle-friendly neighborhood or from bicycling more (Cao, Mokhtarian, and Handy 2009), suggesting that disentangling the relationships can be fraught with difficulty. Recent research suggests just this: behavior may influence attitudes more so than vice versa (Kroesen, Handy, and Chorus 2017).

Research approach

This study seeks to explain how motivations for cycling vary between immigrants to the United States and US-born residents. I test how four social ecological factors—perceptions and attitudes, the built environment, the social environment, and sociodemographic characteristics—influence bicycling and whether those influences differ between the two groups. I expected positive perceptions and attitudes toward bicycling to increase the likelihood of bicycling. Bicycling supportive built environment characteristics, such as land use, density, bicycle infrastructure, and roadway characteristics, should predict more bicycling directly and as mediated by positive perceptions. On the other hand, I expected that higher transit density would decrease the likelihood of cycling because it would make taking transit easier and allow it to substitute for cycling. Supportive social environments, such as immigrants living in immigrant enclaves and knowing other cyclists, should also increase the likelihood of cycling directly. I also hypothesized that being a cyclist influences social relationships and perceptions about cycling.

Data collection

The data come from an intercept survey that I conducted with a research team in predominately Latino-immigrant neighborhoods in the San Francisco Bay Area. English- and Spanish-language surveys were distributed at 44 sites, including public transit stops, public plazas, ethnic businesses, and places where day laborers wait for work (Figure 1). Surveys were administered in the afternoons and early evenings between October 2014 and March 2015 (excluding holidays) during periods of good weather. At high-traffic sites, surveyors recruited every fifth person, but at low-traffic sites, surveyors asked every person to respond to the survey. Surveys took about five minutes to complete and respondents received a granola bar as an incentive. Approximately one-third of people who were approached completed the survey. More details on the survey method are available elsewhere (Barajas, Chatman, and Agrawal 2016). The analysis in this paper is based on 769 responses that could be precisely geocoded to a home address or nearest intersection.

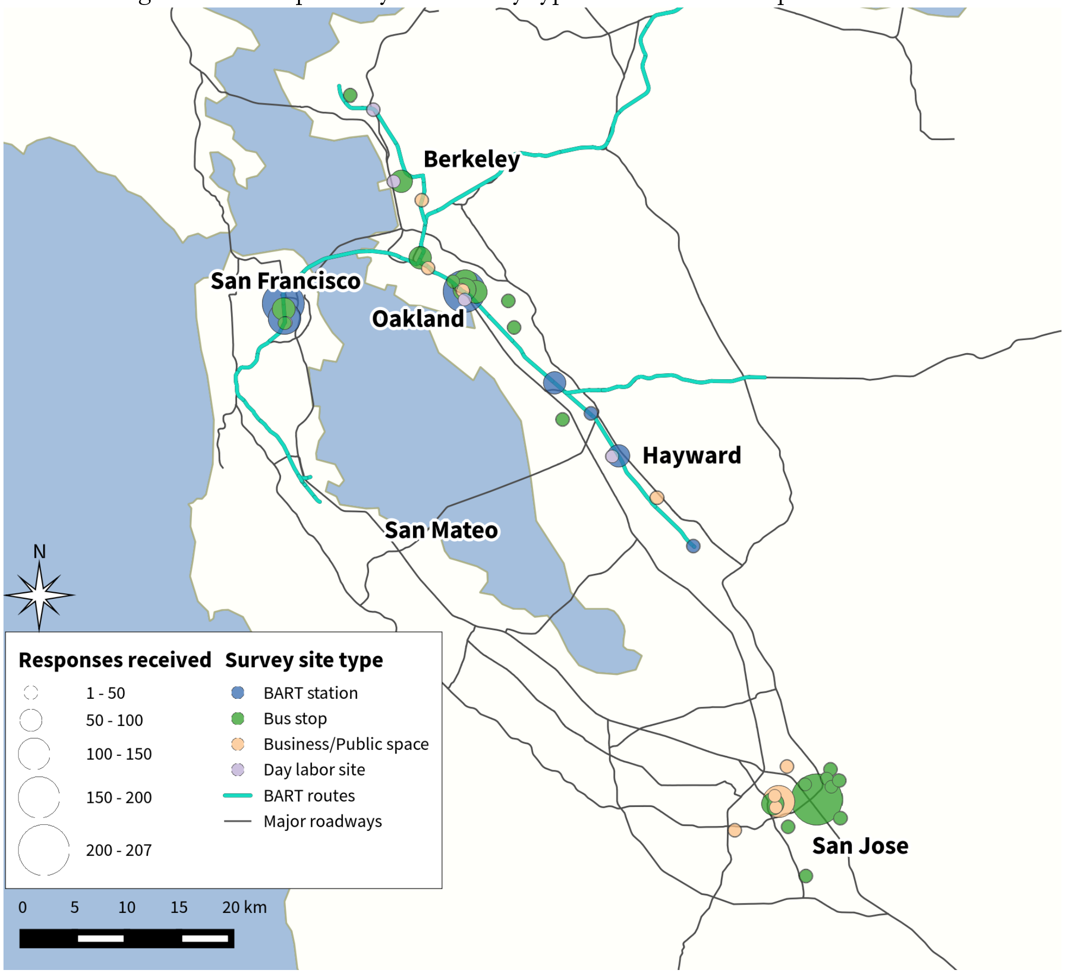
Respondents provided the frequency of travel by mode in the previous week, socioeconomic and demographic characteristics, residential address, and cycling- and neighborhood-related perceptions and attitudes. Some of the perception and attitudinal questions were adapted from other surveys about cycling (e.g. Handy and Xing 2011), but most were generated after a set of pilot interviews with Latino immigrants about their cycling experiences near the surveyed neighborhoods. Most of the questionnaire focused on perception and attitudinal questions, so we asked a limited set of social environmental questions, including one about how many other cyclists a respondent knew, meant to proxy for prevalence of cycling in a respondent's social network (see Pikora et al. [2003] for a comparable question). Other indicators of the social environment were whether the respondent lived in an immigrant enclave, had roommates (e.g. Pike 2014), or was employed. Although employment status is not strictly an indicator of the social environment, working immigrants may be participating in niche employment sectors and may thus have closer ethnic social networks. Furthermore, coworker views on travel to work can set social norms in the workplace and influence commuting behavior, such as cycling or working from home (e.g. Skinner and Rosen 2007; Wilton, Páez, and Scott 2011).

The surveys asked whether respondents were born in the United States but did not ask a question about immigrants' documentation status. Such a question may have been instructive; undocumented immigrants face a unique set of mobility, from inability to obtain a driver's license in many states to fear of deportation via interacting with police during traffic stops (Romero 2006; Stuesse and Coleman 2014). But the research team felt that this question on an intercept survey would have reduced response rates significantly because the short engagement time would not establish the deep trust needed to ask sensitive questions. Current debates about the possible suppressing effects of a citizenship question on the decennial US Census echo these concerns (Meyers 2017). Deeper community engagement with key in-group informants acting as survey leads may be one avenue to collecting such information for future research efforts.

Statistical approach

The complex set of relationships among identity, perceptions and attitudes, social networks, the built environment, and cycling suggests that a usual single-equation regression modeling approach may neglect the simultaneous influences needed to explain travel behavior. Initial exploratory interviews for this project, for example, identified the importance of friends and family in introducing people to cycling, but also how cycling opened new avenues for social interaction. Social ecological models of active travel, introduced earlier, form a foundation for understanding why causality works across and within these environmental domains. Thus, I fit a set of structural equation models (SEMs) that account for simultaneous and mutual causality, the final and best fitting one of which is presented in this paper. Unlike single-equation regression models, SEMs can be estimated with direct feedback

Figure 1: Intercept survey locations by type and number of responses received.



loops between pairs of variables if they are hypothesized to be mutual causes and effects of one another, such as is the case in this study. Although longitudinal data is preferable to explicitly account for time-ordering effects, cross-sectional data can also be used to specify the reciprocal effects, provided they meet theoretical assumptions of equilibrium or stationarity (Kline 2011).

The primary dependent variable in the model is whether the survey respondent bicycled in the previous week.[1] The models also include other survey data such as demographic characteristics of the respondents and access to transportation resources (Table 1). I represent perception and attitudinal responses as three factors using a confirmatory factor analysis (CFA), described below, which determined how well the survey questions matched the hypothesized latent constructs. The ques-

[1]Note that it is the "primary" dependent variable because multiple variables can be specified as dependent or endogenous in SEMs. While the survey question about cycling in the previous week was measured on an ordinal scale, dichotomizing the variable for the model provided the best fit because there were too few responses for each individual number of days greater than 0.

tions assess the degree to which each respondent believes that environmental or structural factors influence their ability to bicycle; in other words, how they perceive neighborhood conditions and personal circumstances to affect mode choice decisions. The factors were selected in advance of the statistical analysis based on results of the pilot interviews. Entering the factors in the model rather than the indicators directly is appropriate because of the degree of correlation between each factor's indicator variables, and because perceptions of cycling conditions and circumstances are composed of multiple influences.

The models treat cycling as an endogenous variable, testing the likelihood that cycling and both perceptions and social environments are reciprocally related. Choice of travel mode is rarely considered as an explanatory variable in travel behavior research (but see Kroesen, Handy, and Chorus 2017). However, models that explain behavior and behavior change, such as the social ecological model upon which I draw for this analysis, posit that a person's actions influence and are influenced by external factors. Likewise, state-of-the-practice integrated land use and travel behavior models forecast changes as an interdependent series of relationships.

Built environment variables hypothesized to influence bicycle and immigrant travel from previous research guided secondary data variable selection (see literature review). I constructed 400-meter, 800-meter, and 1600-meter road network buffers around each residential location to aggregate spatial data. I used the census tract of each home to measure census variables. Data on neighborhood socioeconomic characteristics, employment density, and presence of a Latin American immigrant enclave derive from 2010-2014 American Community Survey estimates. Street networks, bicycle networks, parcel-level land use, transit stops, and bicycle crash locations come from various state, regional, and research organizations (Table 2).

I fit the SEMs as multiple-group models, splitting the dataset by immigrant status and using the same model specification for both groups. This allows an analysis of how the influences on cycling differ for each group. Before fitting the final model, I also estimated a single-group model where immigrant status was an exogenous variable. This specification tested whether immigrants were more or less likely to cycle than non-immigrants, controlling for the same set of factors as the multiple-group model. I fit the models in R with the lavaan package via diagonally weighted least squares estimation.[2]

Sample characteristics

The sample reflected more ethnic diversity and lower socioeconomic attainment compared to the population of the central San Francisco Bay Area (Table 3). Immigrants comprised 42 percent of the geocoded sample, greater than the one-third share of immigrants in the region. The sample, by design, overrepresented Latino immigrants, also oversampling US-born Latinos at a rate 2.5 times their share in the regional population. Survey respondents were less formally educated, and their median household income was below $25,000—far lower the regional median of $91,500.

Neighborhoods where respondents lived reflect the central urban character of survey sites. Home census tracts had higher population density, about twice the share of Latino immigrants, and a substantially lower median income than regional averages. Just under half of respondents lived in Latino

[2]I tested several alternative model formulations as a test for robustness. The survey measured the frequency of cycling as number of days in the previous week. However, because cyclists were a significant minority in the dataset and the majority of those who rode a bicycle reported doing so every day, the model did not converge when treating cycling as a continuous variable. Coding cycling frequency as an ordinal variable with either three or four categories using different cut-off values for each amount of cycling yielded similar estimates as the final model in which cycling frequency is binary. Using different distances of aggregation for each of the built environment characteristics had little effect on the model coefficients, so I retained built environment characteristics aggregated to the 1600-meter distance to reflect a concept akin to the neighborhood level, while I retained characteristics that reflected access to transportation at the 400-meter distance.

Table 1: Summary statistics and descriptions of survey variables

Variable	Description/Question	Code or unit	Proportions or means (std. dev.)			Significance
			Geocoded sample	US-born	Immigrant	
Bicycling	"In the past 7 days, how many days did you bike all the way somewhere?"	≥ 1 = Yes, 0 = No	21%	23%	19%	
Socioeconomic/social characteristics						
Immigrant	"Were you born in the United States?"	Yes/No	42%			
Age	"What is your age?"	Years	39 (15.3)	37 (15.2)	41 (15.2)	***
Female	"What is your sex?"	Female/Male	41%	45%	35%	**
Income	Previous year's household income	<$25,000 = Low, $25,000-$99,999 = Mid, >$99,999 = High, Missing	34%, 38%, 9%, 19%	37%, 38%, 11%, 13%	47%, 23%, 3%, 27%	***
Race/ethnicity	Respondent's self-identified race or ethnicity	White, Latino, Black, Asian, Other	19%, 50%, 11%, 10%, 10%	30%, 34%, 18% 5%, 13%	3%, 74%, 1%, 17%, 6%	***
Employed	"Are you employed?"	Yes/No	62%	66%	57%	*
Roommates	"Do you live with one or more roommates?"	Yes/No	61%	62%	60%	
People known who bike	"About how many people do you know who bike to work, to school, or for personal errands?"	None, 1–10, 11–20, 21 or more	27%, 54%, 11%, 8%	21%, 58%, 13%, 9%	36%, 49%, 8%, 7%	***
Travel behavior						
Has car	"In the past 7 days, how many days did you have access to working motor vehicle?"	≥ 1 = Yes, 0 = No	36%	39%	32%	
Has bus pass	"In the past 7 days, how many days did you have access to a bus pass?"	≥ 1 = Yes, 0 = No	54%	61%	43%	***
Days walked	"In the past 7 days, how many days did you walk all the way somewhere?"	0-7	2.5 (2.7)	2.4 (2.6)	2.6 (2.9)	

Days took transit	"In the past 7 days, how many days did you take public transportation?"	0-7	4.5 (2.3)	4.9 (2.1)	4.0 (2.6)	***
Perceptions and attitudes						
Companions	"I find it hard to bicycle when I need to travel with others"	1-5 scale: 1 = Completely disagree, 5 = completely agree	3.0 (1.0)	3.0 (1.1)	3.0 (1.0)	
Cycling-and-transit	"I would have a hard time getting to places I regularly go if I could not take my bike with me on the train"	1-5 scale: 1 = Completely disagree, 5 = completely agree	3.1 (1.0)	3.1 (1.1)	3.0 (1.0)	
Crime	Additional cycling in the previous week if there were "little crime near the places you go"	1-4 scale: No change, 1 day more, 2-3 days more, 4+ days more	1.7 (1.1)	1.6 (1.1)	1.8 (1.2)	**
Lanes	Additional cycling in the previous week if there were "good bike lanes or paths where you go"	1-4 scale: No change, 1 day more, 2-3 days more, 4+ days more	1.7 (1.2)	1.8 (1.2)	1.7 (1.2)	
Space	Additional cycling in the previous week if "buses or trains always have space to carry your bike"	1-4 scale: No change, 1 day more, 2-3 days more, 4+ days more	1.7 (1.1)	1.7 (1.1)	1.7 (1.1)	
Parking	Additional cycling in the previous week if there were "enough parking at the bus or train stops you use"	1-4 scale: No change, 1 day more, 2-3 days more, 4+ days more	1.7 (1.1)	1.7 (1.1)	1.7 (1.2)	
Space–transit	Additional transit trips in the previous weeks if "buses or trains always have space to carry your bike"	1-4 scale: No change, 1 day more, 2-3 days more, 4+ days more	1.6 (1.1)	1.6 (1.1)	1.6 (1.1)	

Parking–transit	Additional transit trips in the previous week if there were "more bike parking spaces at the bus or train stops you use"	1-4 scale: No change, 1 day more, 2-3 days more, 4+ days more	1.5 (1.0)	1.6 (1.1)	1.5 (1.0)	
Money	"How often do you bicycle instead of taking the bus or train to save money?"	1-4 scale: Never, at least once per month, at least once per week, more than once per week	1.7 (1.1)	1.7 (1.1)	1.6 (1.1)	
Time	"How often do you bicycle instead of taking the bus or train to save time?"	1-4 scale: Never, at least once per month, at least once per week, more than once per week	1.7 (1.1)	1.7 (1.1)	1.6 (1.1)	
Drive	"How often do you bicycle when you have the option to drive?"	1-4 scale: Never, at least once per month, at least once per week, more than once per week	1.6 (1.1)	1.7 (1.1)	1.4 (0.9)	***

Notes: A single proportion represents the first category in the code/unit column. Significance for t-tests (continuous variables), chi-square tests (categorical variables), and Mann-Whitney U tests (ordinal scale variables) between US-born and immigrant groups: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2: Summary statistics and descriptions of built environment variables

Variable	Description/Question	Code or unit	Proportions or mean (std. dev)	Source
Immigrant enclave	Ratio of Latin American immigrants in census tract of residence to Latin American immigrants in study area	> 2 = Yes, 0-2 = No	44%	US Census (2015)
Highway %	Proportion of roadway miles classified as interstate freeway, or expressway within 400 meters of residence	Proportion	2.9% (8.9%)	Caltrans (2015)
Retail %	Proportion of parcels classified as retail land use within 1600 meters of residence	Proportion	7.0% (5.2%)	ABAG (2015)
Multifamily %	Proportion of parcels classified as multifamily residential land use within 1600 meters of residence	Proportion	28.9% (17.1%)	ABAG (2015)
Intersection density	Density of road intersection within 1600 meters of residence	Per ha	0.91 (0.30)	Caltrans (2015), author's calculations
Bikeway density	Density of bikeways within 1600 meters of residence	km per ha	1.9 (2.1)	MTC (2015), author's calculations
Rail station	Presence of a rail station (BART, Muni, or Caltrain) within 400 meters of residence	Yes/No	10%	GTFS (2016)
Bus stop density	Density of bus stops within 400 meters of residence	Per ha	6.6 (4.8)	GTFS (2016)
Bicycle crashes	Number of bicycle crashes (2012-2014) within 400 meters of residence	Number	5.3 (7.4)	SafeTREC (2016)

immigrant enclaves[3] compared to 16 percent of the study-area population. Survey respondents' neighborhoods had higher employment and residential density compared to population-weighted averages. One-fifth of survey respondents had bicycled during the previous week, similar to California Household Travel Survey estimates.

Table 3: Select geocoded respondent characteristics compared to regional averages

	Geocoded survey responses		Population	
	Immigrant	US-born	Immigrant	US-born
Immigrant	42%	58%	41%	59%
Avg years in US	15 (11.3)	NA	21 (14.2)	NA
Race/ethnicity				
Hispanic/Latino	76%	35%	27%	16%
White	3%	32%	15%	59%
Black/African American	1%	18%	1%	10%
Asian	18%	5%	55%	11%
Other race/ethnicity	3%	11%	2%	4%
High school or less	64%	30%	39%	24%
Employed	57%	66%	63%	62%
Median household income	\$5k-\$15k	\$25k-\$50k	\$88,119	\$98,813
Biked in last week	19%	23%	15%	18%
Population density (census tract, 1000s per sq km)	6.6 (4.3)	6.7 (5.4)	5.0 (5.2)	4.2 (4.5)
Employment density (census tract, 1000s per sq km)	3.1 (10.7)	3.8 (11.7)	2.2 (7.7)	1.7 (5.7)
Share in Latin American immigrant enclaves	51%	39%	12%	18%
n	321	448		

Notes: denominator in "employed" in census comparison includes those not in labor force; density calculations are population-weighted by subgroup; Racial/ethnic categories are mutually exclusive. Population figures source: ACS 2010–2014.

The 769 complete responses represent 37 percent of all surveys received; the remaining 1,318 responses could not be geocoded. Because of the large number of missing records, I tested for potential nonresponse bias in three categories: immigrant status, income group, and bicycle riders. The subsample underrepresents immigrants by about six percentage points compared to the full dataset, but low-income respondents and bicycle riders were proportionally represented. Missing income was treated as such in the models, while other missing variables were imputed.

Results

Perception and attitudinal factors

Three factors, labeled *bicycling environment*, *bicycling convenience*, and *bicycling complexity*, best described perceptions toward cycling (Table 4). *Bicycling environment* reflects how people perceive the importance of neighborhood characteristics in supporting bicycling, including how cycling and transit are complementary modes of travel. Four of the six indicators describe how much more the respondent would have bicycled if (a) there were little crime, (b) there were good bike lanes or paths, (c) transit vehicles always had space for bicycles, and (d) there were enough bicycle parking at transit stops. The remaining two describe how much more the respondent would have taken transit if (e) transit vehicles always had space for bicycles, and (f) there were enough bicycle parking at transit stops. Standardized loadings are high (> 0.74), telling that the factor correlates well with each of its

[3]For this study, I measure a Latin American immigrant enclave using a residential concentration quotient: a census tract that has at least twice the concentration of Latin American immigrants compared to the share in the five-county central San Francisco Bay Area. I also tested other concentrations; results did not meaningfully change.

indicators. Although the crime indicator seems distinct enough from the other indicators to warrant inclusion in a different factor altogether, interviews with Latino immigrants suggested that their perceptions of cycling safety did not distinguish between traffic safety and personal security (Barajas 2018b).

Bicycling convenience reflects perceptions that cycling is more convenient than other modes or is a convenient travel option itself. The factor comprises three indicators: how often the respondent (a) cycled instead of took transit to save money, (b) cycled instead of took transit to save time, and (c) cycled when the respondent had the option to drive. *Bicycling complexity* consists of two indicators describing perceptions of the difficulty of cycling: agreement with (a) finding it hard to cycle when traveling with others and (b) finding it hard to travel if the respondent could not use a bicycle with transit. Standardized loadings of the indicators on both factors are lower than for the *bicycling environment* factor, indicating less explanatory power.

Table 4: Unstandardized and standardized loadings for confirmatory three-factor analysis of cycling perceptions for US-born and immigrants

Factor or Indicator	Estimate	SE	Std. Est.	Estimate	SE	Std. Est.
	US-born			Immigrants		
Bicycling environment						
Crime	1.000		0.741	1.000		0.745
Lanes	1.096	0.039	0.794	1.086	0.039	0.792
Space	1.181	0.040	0.839	1.165	0.039	0.832
Parking	1.165	0.038	0.830	1.136	0.044	0.818
Space-transit	1.126	0.039	0.810	1.142	0.040	0.821
Parking-transit	1.127	0.039	0.811	1.151	0.041	0.825
Bicycling convenience						
Money	1.000		0.730	1.000		0.725
Time	1.072	0.044	0.759	1.028	0.045	0.734
Drive	1.017	0.039	0.737	0.904	0.058	0.688
Bicycling complexity						
Companions	1.000		0.320	1.000		0.513
Cycling-and-transit	3.187	1.019	0.914	1.722	0.383	0.835

Notes: SE = Standard error. Standardized estimates of indicators that are closer to 1 indicate better correlation with their assigned factor. Indicators fixed at 1 are not evaluated for statistical significance. All other unstandardized estimates are statistically significant at $p < 0.005$.

Modeling cycling motivations

Now that the perception factors have been defined, how do they influence cycling among immigrants and non-immigrants, accounting for social factors and the built environment? The model suggests that perceptions and social environments have the biggest roles to play, but the strength varies by immigrant status. Figure 2 depicts the final model structure. (See Appendix for full model coefficients.) Common model fit statistics suggest a good fit ($\chi^2 = 1000.3$, df = 754, $p < 0.001$, RMSEA = 0.029

[0.024–0.034], CFI = 0.986).[4] As described earlier, I also tested whether immigrants were more or less likely to cycle than the US-born in a single-group model with a similar structure. The modeled path was insignificant, meaning that immigrants and the US-born were just as likely to cycle when accounting for other influences.

Perceptions related to cycling were strongly associated with cycling likelihood. The coefficients were strongest in the direction from cycling to perceptions and attitudes; in other words, being a cyclist was more likely to influence how people perceived cycling than vice versa. Cyclists were likely to agree that improvements in the neighborhood environment, such as reductions in crime and better cycling and transit infrastructure, would encourage them to bicycle more (*environment*). They were also more likely to agree that cycling was difficult when traveling with others or that completing trips by transit would be difficult without a bicycle (*complexity*), reflecting familiarity with the challenges associated with traveling by bicycle. They saw cycling as a time- and money-saving alternative to transit (*convenience*). Immigrant cyclists held these perceptions to a marginally stronger degree ($p < 0.10$) than non-immigrant cyclists.

Accounting for the reciprocal influence of cycling on perceptions revealed different interpretations than for a single direction alone. None of the perception factors significantly influenced the likelihood of cycling for the US-born. Both the bicycling environment and convenience factors were negatively associated with cycling among immigrants, however. Immigrants who agreed that improving neighborhood conditions like infrastructure and crime were less likely to cycle currently, suggesting a latent demand for cycling. Coupled with the reverse association, it implies that neighborhood conditions would need to improve to encourage immigrants to cycle, but once they began to cycle further improvement would reinforce their cycling practice. The bicycling convenience coefficient was marginally significant in the immigrant group. It indicates that people who thought that cycling was less preferable to transit for saving time or money, or who thought cycling was less attractive than driving, were more likely to cycle. This finding is difficult to interpret without also taking the reverse direction of association into effect. Because the standardized coefficient from cycling to the bicycling convenience factor is nearly three times as great as the opposite direction, it means that immigrants likely recognize the time- and money-saving advantages of cycling only once they become cyclists.

The social environment, measured directly by the number of people the respondent knew who bicycled, is also strongly associated with cycling. As with the perception factors, the model contains paths for a reciprocal relationship between cycling and the social environment. Both paths were statistically significant for US-born respondents, while only the direction from the social environment to cycling was significant for immigrants. Curiously, there is an inverse relationship from knowing other cyclists to cycling for the US-born. Taken with its complementary path, it implies that knowing more cyclists has more influence on the decision to cycle for non-immigrants. Some of the other social environment variables also predicted cycling. Both being employed and having roommates predicted knowing more cyclists for immigrants, and both factors were indirectly positively associated with cycling. Contrary to findings from other studies, living in an immigrant enclave was not significant for either group, suggesting that other factors account for social influences on cycling.

Some personal and travel behavior characteristics were significantly associated with cycling even after accounting for perceptions and the social environment. Consistent with most published re-

[4] The statistics indicated here are those commonly given in SEM diagnoses. The χ^2 statistic is from the test of the hypothesis that the model fits the data exactly. A statistically significant result indicates discrepancy between the data and model covariances. However, this statistic is sensitive to sample size; larger samples are more likely to produce a statistically significant result. Root-mean square error of approximation (RMSEA) is an approximate fit index; values below 0.05 are generally considered good fits. The Bentler Comparative Fit Index (CFI) measures the relative improvement in the model over a null model; values above 0.95 are generally considered good fits (Kline 2011).

search, women were less likely to cycle, though only marginally significantly so ($p < 0.10$). Although the coefficient was not statistically significantly different between immigrants and non-immigrants, being a male immigrant had the strongest direct effect on cycling among personal characteristics. Older US-born respondents were less likely to cycle. This was the strongest individual characteristic in the US-born group, though it was not significant for immigrants. Although riding transit more frequently was not associated with cycling for either group, walking frequency was positively associated with cycling among US-born individuals ($p = 0.06$) and negatively associated with cycling among immigrants ($p = 0.04$). The results suggest that walking is complementary to cycling for non-immigrants, while it competes with cycling for immigrants.

Notably, the built environment as measured in this study was mostly insignificant as a predictor of cycling when controlling for the other factors. Only a higher intersection density predicted a greater likelihood of cycling. This was true even after testing multiple different distances of aggregation of land use and transportation characteristics. What is more, the built environment had no significant effect on perceptions of the cycling environment as measured by the bicycling environment factor. These results reflect the primacy of soft factors to influence cycling, which includes perceptions and social aspects of cycling.

Discussion and conclusions

This study advances how we understand the roles individual perceptions, social environments, and the built environment play in shaping cycling behavior, and how those factors differ between immigrants and non-immigrants. Methodologically, it innovates in a couple of ways. It is one of the few studies in the planning and travel behavior literature that uses structural equation modeling to specify explicitly causal and reciprocal relationships, and it is also one of the few that uses mode choice as a predictor in a statistical model. Future studies that examine complex social behaviors in transportation could benefit from these types of model specifications, though explanatory power could be increased with the use of longitudinal data.

Three key differences in the relationship between cycling and social ecological factors emerged. First, immigrant cyclists more strongly perceived cycling to be a convenient mode of travel than non-immigrants. Second, the links between social contacts and cycling were also stronger for immigrants. Third, immigrants tended to substitute walking for cycling, while walking and cycling were complementary for the US-born. Equity in bicycle planning requires attending to the reasons for these differences.

The built environment variables had minimal effects on cycling across both groups, though spatial aggregation limits the generalizability of this claim. The residential area buffers omit route-level factors that may affect perceptions. Potential cyclists consider the quality of travel between locations when deciding how to travel (Winters et al. 2010) and network connectivity rather than route density may be more informative about cycling environment quality (Furth, Mekuria, and Nixon 2016; Lowry and Loh 2017). Research using residential-area buffers similarly finds minimal effects of the built environment on cycling (Moudon et al. 2005). To some extent, however, the bicycling convenience factor reflects a sense of route-level effects on cycling because it includes an indicator of infrastructure perceptions where the respondent typically travels. Additional research on how perceptions of the built environment are correlated with route-level cycling characteristics and how those differ from area-level characteristics would confirm this relationship.

Overall travel patterns also suggest differences between the two groups in the way they view travel choices, though the significance of these differences diminish when controlling for other factors. For immigrants, cycling appears to substitute for travel by other modes, particularly walking. For those born in the United States, cycling is a complementary mode of travel. It suggests for some segments of the population, people are willing to make additional trips by bicycle. For example, bicycling to transit was higher among non-immigrants in the non-geocoded dataset, so this may spur cycling for extra trips beyond the station. But it also suggests that immigrants who switch to less sustainable modes of travel may not be willing to go back to cycling. For example, driving and car access can be crucial for immigrants for getting and maintaining jobs, leading many to rely on vehicles even when it is difficult to do so (Lovejoy and Handy 2008).

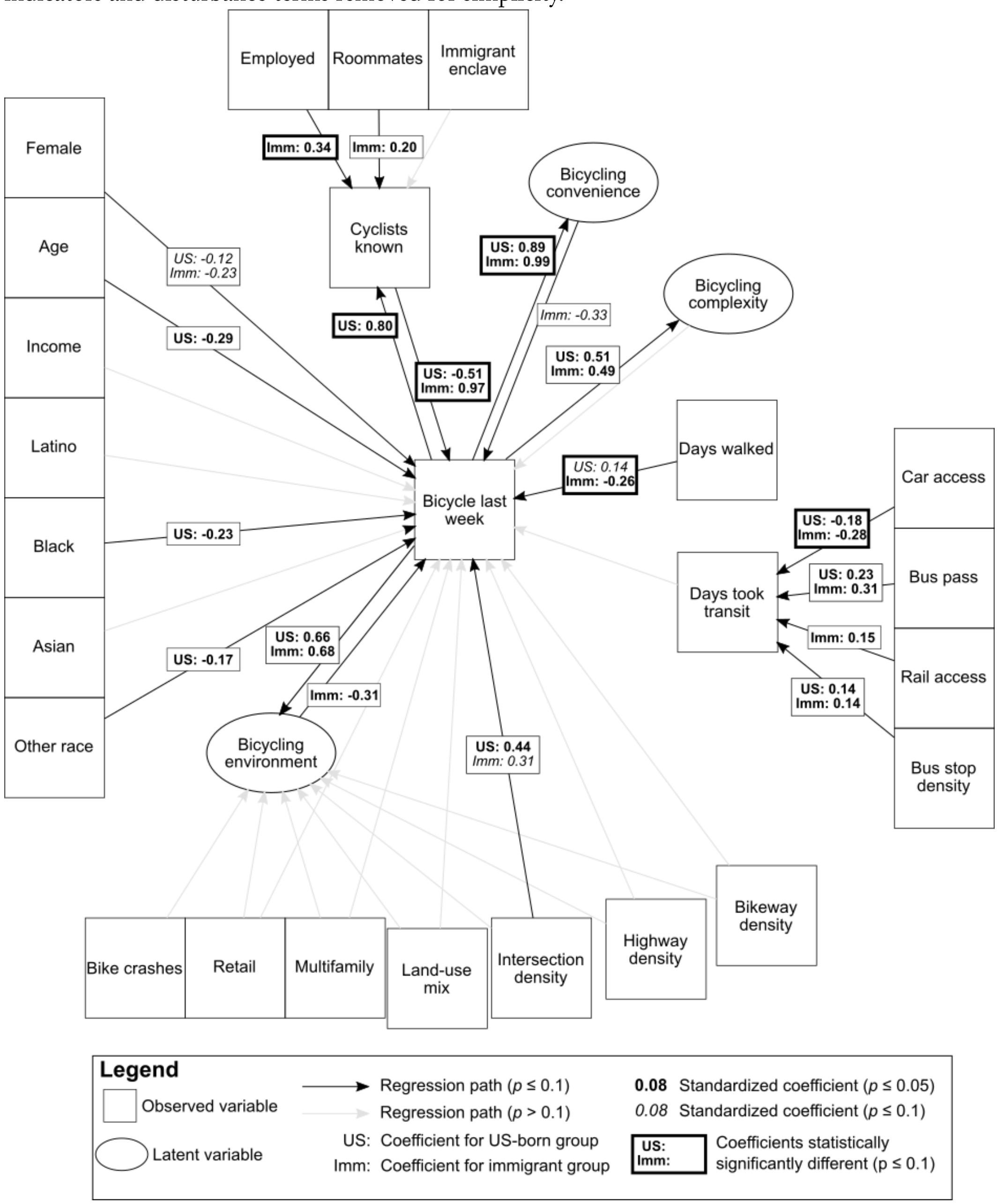
Several of the hypothesized causal influences on cycling turned out to be insignificant in the models. Latino immigrant enclaves, which other researchers have shown to have significant effects on mode choice, did not influence cycling in this study. An alternate model specification, where the Latino immigrant enclave variable was hypothesized to directly influence cycling in the previous week, did not yield different results, nor did changing the threshold defining an immigrant enclave to a lower concentration of Latino immigrant residents. The social environment effects associated with Latino immigrant neighborhoods must be captured in other variables in the model. There are at least two potential explanations for this. First, immigrant enclaves represent neighborhoods where immigrants have both strong network ties—neighbors, friends, family—and weak network ties—friends of friends, employers, social clubs. The migration literature has shown the importance of weak ties for resettlement and job seeking, and both strong and weak ties help residents accumulate social capital and "trade up" for other forms of capital (Wilson 1998; Pfeffer and Parra 2009). Knowing other cyclists reflects strong ties; in other words, cycling participation is part of a close social environment. Follow-up interviews with Latino immigrants for this study suggested friends and family who were cyclists or part of cycling groups normalized bicycling and encouraged them to cycle. People born in the United States, on the other hand, have different social affiliations and so the same personal network mechanisms do not exist. The evidence in this study suggests that environmental support through other external factors, such as living in a dense urban environment, first promote cycling. Enlarging one's cycling-related social network follows, though this network does not appear to directly reinforce cycling behavior. Future work could use a more robust set of indicators of the social environment or use network analysis to trace the causal relationships on cycling perceptions and choice.

The second explanation is that perceived barriers are better explanatory variables for understanding motivations or deterrents to cycling. This also helps explain why some of the expected associations, such as lower rates of cycling among women, are only marginally significant. Perceptions and attitudes toward cycling explain much of why people ride and capture factors left unobserved in explanatory models that would otherwise show statistically significant relationships from other variables. Immigrant enclaves are sites of social interactions, but they are also physical locations in a metropolitan area. They may additionally serve as proxies for the quality of infrastructure and the urban environment in other studies of mode choice.

The findings support the notion that bicycle planning is not a one-size-fits-all proposition. People have different needs based on identity, social interactions, and neighborhood of residence. Planners interested in promoting or expanding bicycle use in Latino immigrant neighborhoods might find ways to engage with communities that take advantage of the links between cycling and social environments, given the strength of the statistical relationship between knowing other cyclists and using bicycles for immigrants. Building relationships with community leaders who are already organizing cycling-related activities, and thus who are lynchpins of these social networks, would make them full partners in planning processes. These types of partnerships move planning away from top-down decision making or token participatory exercises to meeting communities where they are and providing opportunities for full involvement from idea inception to implementation. Even when equity-minded processes expand access to cycling programming to previously neglected areas, neighborhood opposition can arise when those processes fail to engage with historical and cultural community concerns (Small 2017). Community-led cycling planning addresses concerns from the grassroots level.

Successful cycling promotion also depends on ensuring that people perceive cycling to be a safe and convenient mode of travel, and that it solves mobility challenges. While necessary anywhere, the model in this study indicates that immigrant neighborhoods would especially benefit from increased attention on the quality, and not just provision, of infrastructure. Policy prioritization could include a commitment to building a fully-connected, low-stress bicycle network that serves people of all abilities, such as Seattle's Bicycle Master Plan does (Seattle Department of Transportation 2014). Equitable implementation of such a network could include context sensitive solutions such as multilingual wayfinding and connections to important destinations, like clinics, schools, grocery stores, and job centers. And safety includes not only protection from motor vehicles, but also personal security in higher-crime areas. Although the policy responses to traffic safety and crime will be different, the public does not necessarily see these as separate issues: safety is safety, no matter who needs to address it.

Figure 2: Final model specification. Notes: Statistically insignificant paths left unlabeled. CFA indicators and disturbance terms removed for simplicity.



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Appendix

Table 5: Structural equation model estimates

	Est.	SE	p-val	Std. Est.	Est.	SE	p-val	Std. Est.
	US-born				Immigrants			
Bicycling ←								
Female	*-0.231*	*0.134*	*0.084*	*-0.124*	*-0.415*	*0.227*	*0.067*	*-0.233*
Age	**-0.018**	**0.005**	**0.001**	**-0.291**	-0.01	0.007	0.187	-0.173
Income (med)	-0.181	0.151	0.231	-0.097	0.356	0.234	0.128	0.193
Income (high)	-0.008	0.222	0.971	-0.003	0.276	0.397	0.486	0.067
Income (missing)	-0.121	0.208	0.56	-0.046	-0.019	0.235	0.936	-0.01
Latino	-0.132	0.171	0.441	-0.067	0.816	0.671	0.224	0.424
Black	**-0.55**	**0.205**	**0.007**	**-0.225**	1.03	1.36	0.449	0.117
Asian	0.058	0.341	0.864	0.014	0.792	0.689	0.25	0.352
Other race	**-0.483**	**0.22**	**0.028**	**-0.177**	0.614	0.724	0.396	0.167
Days walked**	*0.05*	*0.027*	*0.06*	*0.144*	**-0.076**	**0.038**	**0.044**	**-0.259**
Days took transit	-0.007	0.029	0.797	-0.016	-0.035	0.032	0.273	-0.104
Cyclists known**	**-0.438**	**0.205**	**0.033**	**-0.514**	**0.845**	**0.291**	**0.004**	**0.972**
Retail	-1.887	1.7	0.267	-0.107	-0.648	2.25	0.773	-0.041
Multifamily residential	-0.241	0.45	0.592	-0.045	-0.775	0.787	0.324	-0.153
Land use mix	-0.11	0.425	0.796	-0.022	-0.343	0.691	0.62	-0.067
Int. dens.	**1.322**	**0.298**	**0**	**0.435**	*0.912*	*0.517*	*0.078*	*0.311*
Bikeway dens.	-0.006	0.041	0.886	-0.014	-0.095	0.065	0.144	-0.235
Highway dens.	-0.42	0.626	0.502	-0.045	-0.434	1.344	0.747	-0.038
Bicycling complexity	-0.05	0.409	0.903	-0.017	-0.125	0.293	0.669	-0.078
Bicycling environment	-0.085	0.188	0.65	-0.078	**-0.308**	**0.155**	**0.047**	**-0.309**
Bicycling convenience	0.176	0.228	0.441	0.181	*-0.269*	*0.155*	*0.084*	*-0.327*

Cyclists known ←								
Immigrant enclave	-0.307	0.193	0.112	-0.138	0.002	0.204	0.99	0.001
Roommates	0.206	0.199	0.302	0.092	**0.404**	**0.182**	**0.027**	**0.203**
Employed**	-0.068	0.211	0.746	-0.03	0.67	0.177	0	0.339
Bicycling**	**0.939**	**0.18**	**0**	**0.801**	**-0.184**	**0.169**	**0.276**	**-0.16**
Days took transit ←								
Car access**	**-0.734**	**0.21**	**0**	**-0.179**	**-1.519**	**0.298**	**0**	**-0.283**
Bus pass	**0.958**	**0.193**	**0**	**0.233**	**1.565**	**0.313**	**0**	**0.31**
Rail nearby	0.47	0.441	0.286	0.074	**1.386**	**0.614**	**0.024**	**0.151**
Bus stop density	**0.058**	**0.027**	**0.035**	**0.144**	**0.08**	**0.039**	**0.041**	**0.143**
Bicycling environment ←								
Retail	-0.013	1.079	0.99	-0.001	-1.237	1.183	0.296	-0.078
Multifamily residential	-0.029	0.346	0.933	-0.006	-0.223	0.471	0.636	-0.044
Land use mix	0.287	0.287	0.317	0.065	0.025	0.439	0.955	0.005
Int. dens.	-0.176	0.221	0.426	-0.063	-0.338	0.307	0.272	-0.115
Bikeway dens.	-0.039	0.027	0.146	-0.098	0.041	0.036	0.258	0.102
Highway dens.	-0.128	0.504	0.8	-0.015	-0.933	0.916	0.308	-0.082
Bicycle crashes	-0.011	0.012	0.337	-0.105	0.009	0.013	0.478	0.074
Bicycling	**0.601**	**0.107**	**0**	**0.659**	**0.679**	**0.107**	**0**	**0.676**
Bicycling convenience ←								
Bicycling*	**0.912**	**0.117**	**0**	**0.886**	**1.21**	**0.131**	**0**	**0.997**
Bicycling complexity ←								
Bicycling	**0.179**	**0.067**	**0.007**	**0.511**	**0.302**	**0.091**	**0.001**	**0.486**

$\chi^2 = 1000.3$, $df = 754$, $p < 0.001$, RMSEA = 0.029 [0.024–0.034], CFI = 0.986.

Table notes: Indented parameter names beneath a parameter with an arrow indicate independent variables in the path model for the top-most parameter in that group. Statistically significant values highlighted with bold ($p < 0.05$) or italic ($p < 0.10$) text. Variables with stars indicate group coefficients are statistically significantly different from each other (* $p < 0.10$, ** $p < 0.05$).