Factors Associated with Bicycle Ownership and Use: A Study of 6 Small U.S. Cities

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Abstract
As a means of transportation and as a form of physical activity, bicycling generates benefits to the bicyclist as well as to the community as a whole. Bicycling now accounts for less than 1 percent of all trips for all purposes in the U.S., but evidence from other western countries suggests that under the right conditions, bicycling levels can be significantly higher. The experiences of Davis, Boulder, and Eugene suggest that it is possible to create conditions conducive to higher levels of bicycling in the U.S. However, the extent to which bicycling policy has contributed to bicycling levels in these communities has not been rigorously assessed. The purpose of this study is to provide a better understanding of the determinants of bicycle ownership as a basis for developing measures and incentives to promote the use of bicycles. A cross-sectional study of six cities was designed to test the importance of bicycle infrastructure and other physical environment factors relative to individual factors and social environment factors. Analysis of data from an on-line survey using a nested dichotomous logistic regression approach shows strong effects of individual attitudes and social environment factors but more limited impacts of bicycle infrastructure on both bicycle ownership and use.

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INTRODUCTION

One hundred and forty years after its invention, the bicycle remains an important element of the transportation system. First, the bicycle is a low-cost, low-polluting alternative to driving that makes efficient use of limited roadway capacity. Second, for individuals who do not have the option of driving, the bicycle can be an important means for getting places, particularly for trips that are too long for walking or are not served by transit (Murphy and Knoblauch 2004). Bicycling also plays a role in public health as a source of physical activity at a time when physical activity is declining and levels of obesity are reaching epidemic proportions (Killingsworth 2003). Whether used as a means of transportation or as a form of physical activity or both, bicycling generates benefits to the bicyclist as well as to the community as a whole. Encouraging more bicycling, assuming this can be done safely and at reasonable expense, is thus a desirable societal goal.

At this point, bicycling accounts for less than 1 percent of all trips for all purposes in the U.S., according to the 2000 National Household Transportation Survey (Pucher and Renne 2003). Evidence from other western countries suggests that under the right conditions, bicycling levels can be significantly higher: levels of biking in Canada are twice the U.S. and levels of biking in European countries are anywhere from four times (in U.K., France, Italy) to 28 times (in the Netherlands) the level of bicycling in the U.S. (Pucher and Dijkstra 2003). However, the physical and social environments in these countries differ in important ways from the environment in the U.S. An important question for transportation planners in the U.S. is thus, can we create conditions here, within the context of our physical and social environments, that will increase levels of bicycling?

The experience of the City of Davis suggests that we can. Davis was named the first platinum-level Bicycle Friendly City in the U.S. by the League of American Bicyclists in 2005. As reported on DavisWiki (http://daviswiki.org/Bicycle_Census), Davis has over twice as many bicycles as people. Data from the 2000 U.S. Census on the usual mode of transportation to work shows that Davis has substantially higher levels of bicycling than other college towns, even those with similar reputations: 14.4% of Davis workers commuted by bike, compared to 6.9% in Boulder, 5.6% in Palo Alto, and 5.5% in Eugene. Because bicycling is more common for recreation trips and for errands than for commute trips (Bureau of Transportation Statistics 2002), the differences for all trips might be even greater.

The conditions in Davis are conducive to biking: good weather, flat topography, a large university, and a town that extends just 6.5 miles in its longest dimension. But public policy has also supported bicycling (Buehler and Handy 2007). In 1966, the Davis City Council made a conscious effort to invest in bicycle infrastructure, and today the city has nearly fifty miles of bike lanes and fifty miles of bike paths in an area of less than ten square miles. In 1973, the city adopted a general plan designed to avert suburban sprawl and its environmental impacts. Guided by this plan, the city adopted policies to encourage infill development, distribute multi-family housing throughout the city, and locate services conveniently within each neighborhood with the explicit goal of moderating the length of trips and facilitating walking, biking, and transit as alternatives to driving.

Can other communities follow this model to achieve higher levels of bicycling? We don't know: the extent to which public policies have contributed to bicycling levels in Davis has not been rigorously assessed. This paper aims to fill that gap by examining bicycle ownership and use in Davis and in selected comparison communities using data collected through an on-line survey conducted in early fall 2006. The study is designed to determine the influence of the physical environment, including bicycle infrastructure and mixed land use patterns, relative to the social environment, consisting of auto drivers' attitudes toward bicyclists, bicycle culture and attitude toward bicyclists in a community, and to individual factors, including socio-demographics, attitudes, and preferences. The purpose of this paper is to provide a stronger empirical basis for policy decisions to promote bicycling behavior by contributing to an improved understanding of factors influencing the decision to own and use bicycle.

CONCEPTUAL BASIS

Bicycling in a community can be characterized by both ownership and use of bicycles. Ownership is a natural precursor of bicycle use. In studies of travel mode choice, mode ownership or availability is always a key factor explaining mode use. For example, auto ownership is one of the principal explanatory factors of auto trip generation and frequency (e.g. Ortuzar and Willumsen 2001, Garling, et al. 1998). Even so, a substantial share of trips made by households that do not own automobiles are nevertheless made by automobile, through getting rides with or borrowing cars from others (Lovejoy and Handy 2007). For bicycling, ownership is likely to be even more important in explaining use, as "getting a ride" is not possible (with the exception, perhaps, of tandem bicycles). Indeed, previous bicycling studies show that bike ownership is a vital and decisive component of biking behavior (e.g. Moudon, et al. 2005). On the other hand, owning a bicycle does not guarantee use, as countless dusty bicycles hidden away in garages will attest. In this study, we therefore examine both ownership and use.

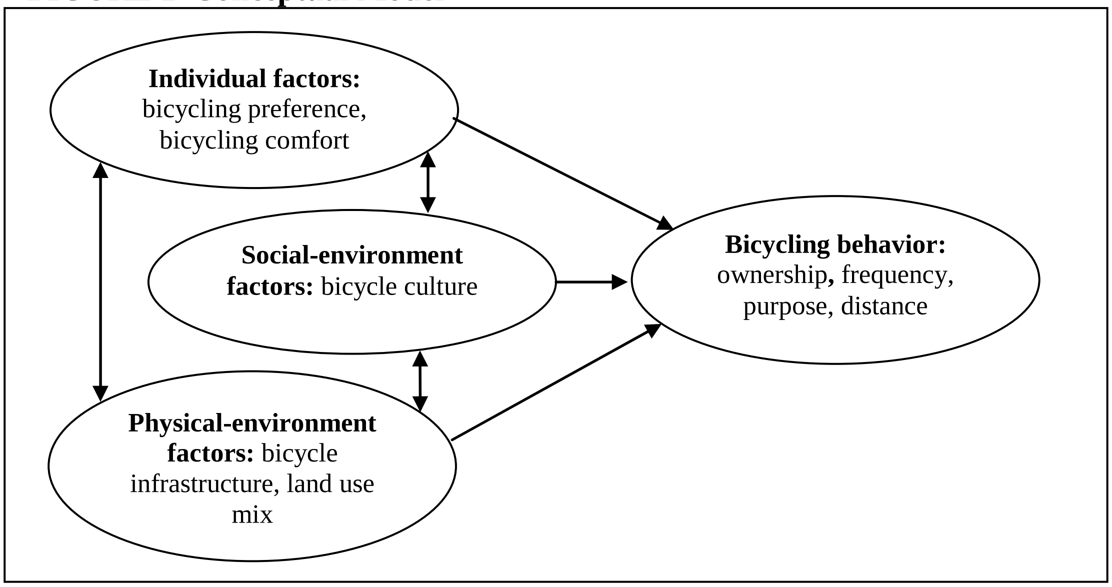
For this study, the ecological model widely used in physical activity research within the field of public health provides a useful conceptual framework (Sallis and Owen 2002). This framework distinguishes between individual factors, social-environment factors, and physical-environment factors in explaining individual behavior. Individual factors include attitudes, preferences, and beliefs, as well as confidence in one's ability to engage in the behavior (a concept called "self-efficacy" in the field of public health). Social-environment factors include the cultural norms of the community as evidenced by the collective behaviors of its residents. Physical-environment factors depend on the nature of land use patterns and transportation infrastructure.

It is plausible to assume that individual factors, social environment factors, and physical environment factors influence bicycle ownership. A previous study shows that hazardous traffic conditions (as aspect of the physical environment) and bicycle theft (an aspect of the social environment) are two of the main reasons for not owning a bicycle (Beck and Immers 1994). Although few studies focus on bicycle ownership, research on other mode ownership gives strong evidence of an influence of environmental factors (e.g. Zegras 2006, Hess and Ong 2001, Tanner 1963).

Previous research provides evidence of the importance of individual, social environment, and physical factors on bicycle use as well. Most of these studies use descriptive analysis (e.g.

Bureau of Transportation Statistics 2002; Federal Highway Administration 1992; National Highway Traffic Safety Administration and Bureau of Transportation Statistics 2003; Pucher and Dijkstra 2003), explanatory analysis with aggregate data (e.g. Dill and Carr 2003, Pucher and Buehler 2006), or explanatory analysis with disaggregate data from surveys designed for other purposes (e.g. Cervero and Duncan 2003; United States Environmental Protection Agency 2003; Plaut 2005; Krizek and Johnson 2006). Two recent studies use original surveys to examine the effect of bicycle experience and infrastructure on frequency of bicycle commuting (Stinson and Bhat 2004) and the link between the built environment and bicycling (Moudon, et al. 2005). Although these studies provide important insights into bicycling behavior, they have not effectively isolated the influence of bicycle infrastructure and other aspects of the physical environment on bicycling behavior after accounting for the influences of community culture and other factors. In addition, these studies have not explored the influence of "self-selection," the possibility that an individual's preference for bicycling leads him to choose to live in a community like Davis (Handy, etc. 2006).

FIGURE 1 Conceptual Model



METHODOLOGY

The study employs a cross-sectional research design to determine the relative influence of individual factors, social-environment factors, and physical-environment factors on both bicycle ownership and bicycle use. The unit of analysis for the study is the individual. In this study, we examine the behavior of residents of Davis and five comparison communities that differ with respect to the physical environment and social environment. This approach enables an assessment of the relationships between these variables and bicycle ownership as well as bicycle use. In this analysis we will control for the possibility of "self-selection," that is, the possibility that residents of a city choose to live there in part because of the supportive bicycling environment.

Survey Sampling and Administration

Five comparison communities were selected for the study based on several factors. First, we looked for stand-alone cities (i.e. cities that are not directly bordered by other cities within a metropolitan area) comparable in size to Davis, with weather and topography similar to Davis, and with universities within their boundaries. Our hope was to then find communities that differed from Davis with respect to bicycle infrastructure and culture, in order to ensure variation in these potential explanatory factors. No communities perfectly fit our criteria. Chosen as comparison communities were Woodland, just 10 miles to the north of Davis, Chico, about two hours north of Davis, and Turlock, a few hours to the south. Woodland has about half the total miles of bike lanes and paths per capita as Davis, but considerably more than Chico, despite the fact that Chico is a college town with a reputation for a pro-bicycle culture. In addition, we included Eugene, OR and Boulder, CO as comparison cities. Both cities have extensive bicycle infrastructure and enjoy reputations as bicycling communities nearly comparable to Davis' reputation. This set of cities ensures reasonable comparability with respect to control variables but ample variation with respect to key explanatory variables. Individual-level variations will be accounted for in the analyses.

For each of the six communities, we purchased a random sample of 1500 residents from Martin Worldwide, a commercial provider; for Davis, we ordered an additional sample of 1000 residents who had moved in the previous year. We mailed a letter in June 2006 to the residents in the sample inviting them to participate in the on-line survey and providing instructions on how to access the survey. In addition, we offered to send a hard copy of the survey on request. On July 18, we sent a postcard reminder to the residents who had not yet responded, with a second postcard reminder sent August 15. As an enticement for participation, respondents could choose to be entered into a drawing for one of three $100 prizes. Of the original 10,000 addresses, over 2000 proved to be incorrect, as evidenced by the return of the letter to UC Davis. After accounting for these bad addresses, we achieved a response rate of over 10% in every city except Turlock, where the response rate was just 7.2%, with a high of 18.8 % in Davis. The overall response rate for the survey was 12.6 %, for a sample size of 965.

Given the relatively low response rate, non-response bias is a serious concern in the survey. In fact, the survey results show that 32% of Davis respondents usually commute to work by bike, in comparison to 14% in the 2000 Census; the survey share was higher than the census share for all cities except Turlock (Table 1). Although we designed the survey to be relevant to all individuals, not just bicyclists, it is possible that individuals who do not bike were less inclined to complete the survey. Budget limitations prohibited a direct assessment of non-response bias. However, because the focus of our study is on explaining bicycle behavior as a function of other variables rather than on describing the simple univariate distribution of bicycling per se, these differences are not expected to materially affect the results (Babbie 1998).

As shown by chi-square tests, Davis, Boulder, and Eugene have significantly higher levels of bicycling than other cities. The differences between Boulder and Davis are not significant, while Eugene is somewhat lower than Boulder and Davis on all measures except bicycle ownership. The shares of respondents who report frequent bicycling and bicycling for transportation are higher in Davis than in Boulder. Response rates were highest in Davis and lowest in Turlock, where bicycling rates were lowest. The correlation between response rates and bicycling levels suggests that non-response bias is similar across all cities.

TABLE 1 Biking Levels: Census vs. Survey

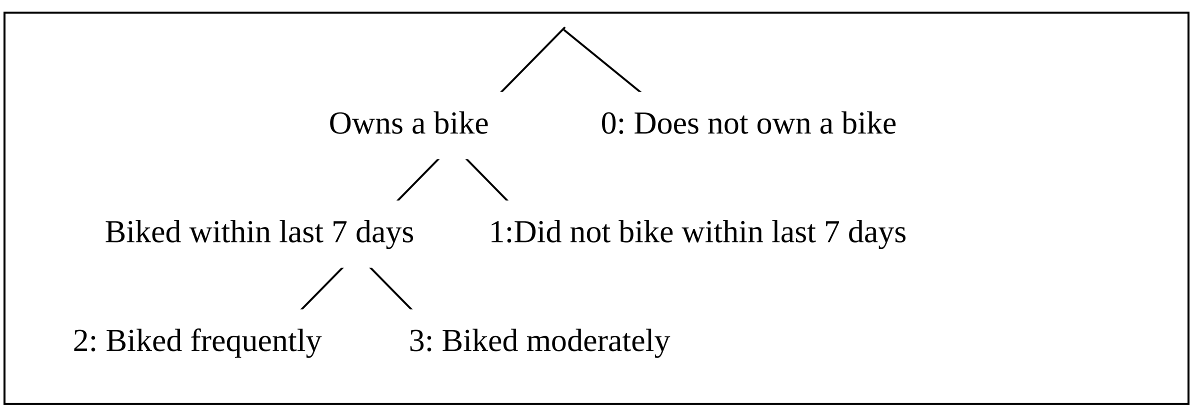
	Davis	Chico	Woodland	Turlock	Eugene	Boulder
Census						
Share usually biking to work	14.4%	5.2%	2.0%	1.1%	5.5%	6.9%
Survey						
Share usually biking to work	32.3%	13.7%	7.2%	0.0%	17.8%	22.7%
Share bicycle ownership	78.0%	67.4%	55.3%	60.9%	72.3%	80.5%
Share biking in last 7 days	53.0%	37.3%	20.2%	12.0%	37.7%	50.0%
Share frequent bicyclist in last 7 days	40.8%	30.0%	25.0%	9.1%	39.6%	29.0%
Share transportation-purpose bicyclist within last year	49.6%	20.0%	14.6%	9.5%	32.9%	28.9%
Number of respondents	354	135	125	92	130	129
Response rate	18.8%	11.7%	10.2%	7.2%	12.1%	12.2%

Model Structure and Variable Definitions

We use dichotomous logistic regression (Cohen etc., 2003),involving a nested series of logistic regressions, to test the relative importance of the physical and social environments on bicycle ownership and bicycle use, while controlling for socio-economic and attitudinal factors, including the importance of bicycling when choosing to live in that city. The models show whether and to what extent these factors influence bicycle ownership and bicycle use.

The model structure is based on the assumption that an individual confronts four alternatives: does not own a bike; owns a bike and did not bike within the last seven days; owns a bike and biked moderately (one to four days[1]) within last week; owns a bike and biked frequently (five to seven days) within last week (Figure 2). Because only 4 respondents who did not own a bike reported having biked in the last 7 days, this alternative is not included. We assume that individuals choose the alternative that maximizes their utility, in the following sequence: to own a bike or not; to bike or not, conditional on owning a bike; and to bike frequently or moderately, conditional on owning a bike and having biked within the last 7 days. The decision at each step is assumed to potentially depend on a different combination of factors than the decisions at the other steps.

FIGURE 2 The Set of Four Alternatives



[1]Based on a "regular" level of activity as recommended for maintaining good health (Lee and Moudon, 2006).

The dependent variable is defined as a series of nested partitions of the multiple categories shown in Figure 2. To make the partitions of dependent variable clear, we coded the category “Not own a bike”=0; “Own a bike and did not bike within last 7 days”=1; “Owns a bike and biked moderately within last 7 days”=2; “Owns a bike and biked frequently within last 7 days”=3. Three contrasts – 0 versus 1+2+3[2], followed by 1 versus 2+3; followed by 2 versus 3 – are treated in separate successive dichotomous logistic regressions to examine the influence of factors on bicycle ownership, biking or not, and biking frequency respectively. The nested dichotomies approach is preferred to ordinal logistic regression if the proportional odds assumption does not hold, that is, that a single slope does not apply to the whole continuum, across the thresholds for each category of the dependent variable. The Score test for the ordinal logistic regression model for this variable was significant, and the proportional odds assumption was rejected.

Explanatory variables fell into three categories: individual factors, social environment, and physical environment (Table 2). For several variables, indexes were created from a set of survey questions, either through factor analysis or simple mathematical computation (e.g. taking a count or averaging); all indexes were tested for internal consistency and found to be satisfactory.

TABLE 2 Description of Variables in Model

Variable name	#Items [Range]	Description
Dependent variable		
Bicyclist Type	1 [0,3]	0 = Does not own a bike; 1=Owns a bike and did not bike during last 7 days; 2=Owns a bike and biked frequently during last 7 days; 3=Owns a bike and biked moderately within last week
Explanatory variables		
Individual Factors: Socio-demographics		
Age	1 [17,73]	Age in years
Female	1 [0,1]	1=female, 0=male
Education Level	1 [1,6]	Highest level of education. 1=grade school or high school, 2=high school diploma, 3= college or technical school, 4=four-year degree or technical school certificate, 5=some graduate school, 6=completed graduate degree(s)
Household Size	1 [1,6]	Number of persons living in household
Income	1 [0,125]	Continuous, in thousand dollars
Car Ownership	1 [0,1]	0=does not own or have regular access to car, 1=owns or has access to car
Home Ownership	1 [0,1]	0=rents, 1=owns.
White	1 [0,1]	1=white, not of Hispanic origin, 0 = all others
Individual Factors: Attitudes		
Biking Comfort	6 [1,3]	Average comfort biking on an off-street path or quiet street, two-lane-local-street with or without bike lane, four-lane-street with or without bike lane, on 3-point scale where 1=Comfortable, 2=Uncomfortable but I'd ride there anyway, 3=Uncomfortable and I wouldn't ride on it.
Safety Concern	5 [1,3]	Average concern of being hit by a car, being hit by another bicyclist while biking, being bitten by a dog, being mugged or attacked, or crashing because of road hazards on 3-point scale where 1=Not at all concerned. 2=Somewhat concerned. 3=Very concerned.
Like Biking	1 [1,5]	Agreement that “I like riding a bike” on 5-point scale*
Like Driving	1 [1,5]	Agreement that “I like driving” on 5-point scale*
Need Car	1 [1,5]	Agreement that “I need a car to do many of the things I like to do” on 5-point scale*
Limit Driving	1 [1,5]	Agreement that “I try to limit driving as much as possible” on 5-point scale*

[2] The group coded 0 versus the group formed by combining the groups coded 1, 2 and 3.

Variable name	#Items [Range]	Description
Like Walking	1 [1,5]	Agreement that “I like walking” on 5-point scale*
Like Transit	1 [1,5]	Agreement that “I like taking transit” on 5-point scale*
Environmental Concern	1 [1,4]	Importance of environmental benefits when choosing mode, on 4-point scale where 1=Not at all important, 2=Somewhat important, 3=Important, 4=Extremely important.
Pro-Exercise	2 [1,5]	Average agreement that “It’s important to get regular physical exercise” and “I enjoy physical exercise” on 5-point scale*
Good Health	1 [1,5]	Agreement that “I am in good health” on 5-point scale*
Biked in Youth	1 [0,1]	Ever rode a bicycle when about 12 years old, 0=no, 1=yes.
Self Selection	5 [0,1]	A good community for cycling is important, at least not less important than any other reason, for choosing a residential location. 0=Not important, 1=Important
Social Environment		
Good Driver Attitude	4 [1,5]	Average agreement that “Most drivers [do not] seem oblivious to bicyclists”, “Most drivers yield to bicyclists”, “Most drivers watch for bicyclists at intersections”, “Most people [do not] drive faster than the speed limit” on 5-point scale*
Biking is Normal	2 [1,5]	Average agreement that “Bicycling is a normal mode of transportation for adults in this community” and “It is [not] rare for people to shop for groceries on a bike” on 5-point scale*
Kids Bike	1 [1,5]	Agreement that “Kids often ride their bikes around my neighborhood for fun” on 5-point scale*
Bikers Poor	1 [1,5]	Agreement that “Most bicyclists look like they are too poor to own a car” on 5-point scale*
Bikers Spend	1 [1,5]	Agreement that “Most bicyclists look like they spend a lot of money on their bikes” on 5-point scale*
Bikers Not Concerned	1 [1,5]	Agreement that “Many bicyclists appear to have little regard for their personal safety” on 5-point scale*
Physical Environment		
Bike Infrastructure	8 [1,4]	Average perceived that “Major streets have bike lanes”, “Streets without bike lanes are generally wide enough to bike on”, “Stores and other destinations have bike racks”, “Streets and bike paths are well lighted”, “Intersections have push-buttons or sensors for bicycles or pedestrians”, “The city has a network of off-street bike paths”, “Bike lanes are free of obstacles”, “The bike route network does not have big gaps” on 4-point scale where 1=Not at all true, 2=Somewhat true, 3=Mostly true, 4=Entirely true.
Hilly Topography	1 [1,4]	Perception that “The area is too hilly for easy bicycling” on 4-point scale where 1=Not at all true, 2=Somewhat true, 3=Mostly true, 4=Entirely true.
Safe Destinations	5 [1,3]	Average perception of safety bicycling to “your usual grocery store”, “the nearest post office”, “the local elementary school”, “a restaurant you like”, “the nearest bike shop” on 3-point scale where 1=Comfortable, 2=Uncomfortable but I'd ride there anyway, 3=Uncomfortable and I wouldn't ride there.
Distances	6 [1,4]	Average perception of distances from home to “your usual grocery store”, “the nearest post office”, “a restaurant you like”, “a bike repair shop”, “your workplace”, “the local elementary school” on 4-point scale where 1=Less than a mile, 2=1-2 miles, 3=2-4 miles, 4=More than 4 miles
Transit Access	1 [0,1]	There is bus or train service within a 5 minute walk of home. 0=No, 1=Yes.

*1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly agree.

We entered socio-demographic factors, individual attitudinal factors, social environment factors, and physical environment factors as sets in steps into the dichotomous logistic regressions. At each step, only the statistically significant ($p<0.05$) variables were retained and insignificant variables were dropped by using a backward stepwise process. All the regressions were tested for multicollinearity among the explanatory variables and found to meet accepted standards. Final models are presented; variables listed in Table 2 that are not shown in the model were not significant. Odds ratios are presented as a measure of effect size: the odds ratio for each variable shows the increase in the probability of being in the group for which the dependent variable equals 1 that results from being in the group for whom the explanatory variable equals 1 or, for continuous explanatory variables, that results from a one unit increase in that variable.

RESULTS

Bicycle Ownership

In this survey, 71.3% of the total valid respondents (n=965) own or have regular access to a bicycle. Factors affecting bike ownership are shown in Model 1 in Table 3.

TABLE 3 Nested Dichotomous Logistic Models for Bicycle Ownership and Use

Variable Name	Model 1: Own a bike vs. Not own a bike			Model 2: Biked vs. Did not bike			Model 3: Biked frequently vs. Biked moderately		
	Coefficient		OR	Coefficient		OR	Coefficient		OR
Individual factors: Socio-demographics									
Age	-0.029	***	0.971	-0.020	***	0.980	--		--
Education Level	--		--	0.231	***	1.260	--		--
Household Size	--		--	--		--	-0.262	**	0.770
Income	0.016	***	1.016	--		--	--		--
White	0.507	*	1.660	--		--	--		--
Car Ownership	--		--	--		--	-1.602	*	0.201
Individual factors: Attitudes									
Biking Comfort	0.720	**	2.054	--		--	--		--
Like Biking	1.166	***	3.210	1.252	***	3.496	1.045	***	2.842
Need Car	-0.329	**	0.720	--		--	-0.389	**	0.678
Limit Driving	--		--	0.312	***	1.366	0.606	***	1.834
Like Walking	--		--	-0.602	***	0.548	--		--
Like Transit	-0.216	**	0.806	--		--	-0.237	**	0.789
Pro-Exercise	-0.438	***	0.645	0.244	**	1.276	--		--
Good Health	0.361	***	1.434	--		--	-0.333	**	0.717
Self Selection	--		--	0.524	**	1.689	--		--
Social Environment									
Bikers Spend	-0.208	*	0.812	--		--	--		--
Bikers Poor	-0.264	**	0.768	-0.373	***	0.689	--		--
Physical Environment									
Safe Destinations	--			0.617	***	1.854	0.338	***	1.402
Transit Access	--			0.694	**	2.001			
Valid N	769			600			334		
Pseudo R^2	0.333			0.268			0.200		
Model Chi-square	297.440			220.717			86.941		
P value	0.000			0.000			0.000		

*10% significance level, ** 5% significance level, *** 1% significance level.

Individual factors

Individual factors play a dominant role in explaining household bike ownership. Agreement with the statement “I like biking” dwarfs all other individual factors and is the major determinant of owning a bike; the odds ratio indicates that each step on the agreement scale for this statement increases the odds of owning a bicycle 3.2 times. Other factors associated with higher likelihood of owning a bike include better health, greater comfort bicycling, being white and not of

Hispanic origin, and higher income. Factors associated with lower bike ownership are older age, a preference for transit, and a car-dependent attitude. A positive attitude toward physical exercise also disfavors bike ownership, a counter-intuitive result. One possible reason is that other physical activity forms, such as walking, are more attractive than biking for these respondents, and consequently decrease the probability of owning bikes.

Social environment
Two social environment factors have negative impacts on bicycle ownership: the perception that bicyclists spend a lot of money on bikes, and the perception of that most bicyclists look like they are too poor to own a car. This interesting result suggests that the extreme financial ends of the bicycling population spectrum are a deterrent to bicycle ownership; conversely, the perception that the middle of the spectrum dominates is an encouragement to ownership.

Physical environment
After accounting for individual and social environment factors, no physical environment variables were significant predictors of bicycle ownership.

Bicycle Use
Of the 688 respondents who reported owning a bicycle, only 44.5% of the respondents bicycled in the last 7 days and 55.5% did not. The best-fitting model for bicycle use, conditional on bicycle ownership, is shown in Table 3.

Individual Factors
According to the model, only two socio-demographic variables correlate with bicycle use: age has a negative effect on bicycling, while higher education levels are associated with an increased odds of bicycling. Income, an established predictor of mode choice, was not a significant predictor of bicycle use. After accounting for socio-demographics, individual attitudes are dominant in explaining people's biking behavior. A one unit increase in agreement with the statement "I like biking" increases the odds of bicycling by a factor of 3.5, all else equal. The attitude of trying to limit driving as much as possible also increases the odds of cycling. However, those who like walking are less likely to bicycle, perhaps because walking and cycling are substitutable forms of exercise and/or travel, at least for short trips. Positive attitudes toward physical exercise increase the likelihood of bicycling. Finally, residents who choose to live in a city in part because of the supportive bicycling environment are 1.69 times more likely to bicycle than residents who do not, suggesting a significant self-selection effect.

Social Environment
The model also shows that the social environment is significant in explaining whether people bicycle or not. The perception of that most bicyclists look like they are too poor to own a car in a community is associated with lower likelihood of biking. No other social environment factors were significant.

Physical Environment
The physical environment also has an influence on bicycle use. The model shows no link between bicycle use and perception of bicycle infrastructure (e.g., if the major streets have bike lanes, streets without bike lanes are wide enough to bike on, usual destinations have bike racks,

bike paths are well lighted, push-buttons or sensors for bicyclists at signals, the city has a network of off-street bike paths, bike lanes are free of obstacles). However, the perception of safety of bicycling to selected destinations (grocery, post office, school, etc.) is positively related to cycling, this result suggests the potential of an indirect role for bicycle infrastructure on bicycle use, through its impact on perceived safety. Transit access also increases the probability of bicycle use. The explanation for this result is not obvious. It is possible that it reflects a synergy between bicycle and transit use, encouraged, perhaps, by bicycle racks on busses. It is also possible that transit access is a proxy for other characteristics of the built environment not captured by other variables measured in the survey. Transit access tends to be higher, for example, in areas with higher population density.

Bicycling Frequency

The third model examines which factors affect the frequency of bicycling, for those who bicycled within the last 7 days. One hundred and thirty-two respondents biked frequently, defined as 5 or more days, accounting for 35.3% of those who biked in the last 7 days; 242 respondents, or 64.7%, were moderate bicyclists who biked one to four days in the last 7 days.

Individual factors

Two socio-demographic factors are related to bike use frequency: household size and auto ownership are both negatively associated with frequent bike use. Among attitudinal variables, agreement that “I like biking” again has the largest impact on frequent biking. The attitude of limiting driving is also associated with more bike use. On the other hand, the attitude of needing a car to do many things disfavors bicycling frequently. A preference for transit is also related to lower bicycling frequency, perhaps reflecting a substitution relationship between these two modes. An unexpected finding in this model is that people who report better health tend to bicycle moderately rather than frequently. It is possible that healthier individuals enjoy other forms of physical activity over bicycling, thereby decreasing bicycle use.

Social environment

No associations between social environment factors and frequent bicycle use were found in the model, implying that the social environment does not affect bicycling frequency for those who bicycle at least once per week.

Physical environment

As was the case for bicycle use, perceived bicycle infrastructure is not related to biking frequency in this model while the perception of safety of bicycling to selected destinations is positively associated with frequent bicycling; again, this result suggests the potential of an indirect role for bicycle infrastructure on bicycle use, through its impact on perceived safety.

Discussion of the Effect of Bicycle Infrastructure

The limited effect of bicycle infrastructure on both bicycle ownership and bicycle use merits further exploration. One possible explanation is that the strength of the association between them is weakened by a connection between biking levels and awareness of the limitations of the bicycle infrastructure; in other words, people who bike more see more of the flaws of the system, which may seem perfectly adequate to someone who has never tried to bicycle in the community. Another explanation is that our measure of perceptions of bicycle infrastructure is not valid;

either because we did not ask the right questions in the right way or because of the way we made use of the responses to the questions we did ask. Although in the final model we use an index constructed as the average of the scores on the items in the set, we also tried an index constructed through factor analysis and used the individual items as separate variables in the model. Neither of these alternatives showed a significant effect of bicycle infrastructure on bicycle ownership or bicycling either.

As an alternative, we estimated an additional model in which we substituted perception of bicycle infrastructure with an objective measure of physical infrastructure, the length of bike lanes per square mile in a city. This measure was estimated for each city based on information gleaned from its planning documents. Although perceptions of bicycle lanes did not influence bicycle use, the models for both ownership (Model 4 in Table 4) and use (Model 5) show a significant influence of the length of bike lanes per square mile: for each additional mile of bike lanes, people are 1.05 times more likely to own bikes and 1.05 times more likely to have bicycled within the last 7 days. Notice that both of significance and magnitude of other variables in the two models do not change much as a result of the substitution of miles of bike lanes for perceived bicycle infrastructure. Therefore, bike lanes appear to play a significant positive role in promoting bicycle ownership and use, controlling for other variables, including the possibility of "self-selection".

Future studies might explore other angles to further test the connection between infrastructure and bicycling. First, the insignificance of hilly topography is possibly because all the selected cities are, by intention, relatively flat in topography. Future studies could examine a sample of cities that varied on this dimension. Second, the insignificance in the models of the distance from home to selected destinations, which reflects the extent of land use mix, possibly results from the mixing of recreational bicycling with bicycling as a mode of transportation in this analysis. Future analysis of these data focusing on bicycling for transportation purposes may highlight the importance of distance. Third, the impacts of other aspects of bicycle infrastructure (bike racks, how well the bike paths are lighted at night, bike lane condition, etc.) could also be explored, and different ways of measuring perceptions of bicycle infrastructure could be tried.

It is important to note that this study is fundamentally limited by its cross-sectional design. Although we have controlled for the possibility of "self-selection" in this study, it is also possible, for example, that if an individual lives in a community with a strong bicycle culture and with good bicycle infrastructure, his preferences for bicycling increase over time. In other words, bicycle infrastructure may have many indirect effects on bicycling, even if the direct effect is limited. Testing for these possibilities requires a longitudinal approach that can account for bi-directional relationships between these variables.

TABLE 4 Logistic Models for Bicycle Ownership and Use with Objective Measure of Bicycle Infrastructure

Variable Name	Model 4: Own a bike Vs. Not own a bike		Model 5: Biked Vs. Did not bike	
	Coefficient	**Odds ratio**	**Coefficient**	**Odds ratio**
Individual factors: Socio-demographics				
Age	-0.029 ***	0.972	-0.019 **	0.981
Education Level	--	--	0.198 **	1.219
Household Size	--	--	--	--
Income	0.015 ***	1.015	--	--
White	0.513 *	1.670	--	--
Individual factors: Attitudes				
Biking Comfort	0.718 **	2.050	--	--
Like Biking	1.176 ***	3.241	1.260 ***	3.524
Need Car	-0.306 **	0.737	--	--
Limit Driving	--	--	0.313 ***	1.367
Like Walking	--	--	-0.626 ***	0.535
Like Transit	-0.231 **	0.794	--	--
Pro-Exercise	-0.447 ***	0.640	0.247 **	1.281
Good Health	0.351 ***	1.420	--	--
Self Selection	--	--	0.508 *	1.662
Social Environment				
Bikers Spend	-0.241 *	0.786	--	--
Bikers Poor	-0.201 *	0.818	-0.311 **	0.733
Physical Environment				
Safe Destinations	--	--	0.601 ***	1.825
Transit Access	--	--	0.664 **	1.942
Miles of bike lanes per square mile	0.044 *	1.045	0.046 *	1.047
Valid N	769		600	
Pseudo R^2	0.336		0.272	
Model Chi-square	300.539		224.377	
P value	0.000		0.000	

*10% significance level, ** 5% significance level, *** 1% significance level.

CONCLUSIONS

This analysis of bicycle ownership and use provides new and potentially important insights into factors associated with the decision to own a bicycle, use a bicycle, and use a bicycle frequently. The results demonstrate the significant role that individual factors, particularly individual attitudes, play. By far the most important variable in all three models was agreement with the statement, “I like biking.”. The models also show a significant effect of the social environment on both bike ownership and use, at least with respect to the perception of who else is bicycling rather than the perception that bicycling is common or normal in the community. The results for bicycle infrastructure are less clear: while perceptions of bicycle infrastructure proved insignificant in all the models, an objective measure of miles of bike lanes per square mile was significant at least in biking choice model. It is notable that the perception of cycling safety to selected destinations is significant, pointing to the possibility of an indirect effect of bicycle infrastructure on perceptions of bicycling safety.

These results together suggest that communities can increase bicycle ownership and use to some degree by expanding the bicycling network and otherwise improving bicycling conditions. But they also suggest that programs that aim to improve individual attitudes toward bicycling are important, at least given adequate bicycle infrastructure to begin with. However, the self-selection effect cannot be ignored: residents who choose a community in part because of its bicycle orientation are more likely to bicycle. In other words, communities that promote bicycling (through both infrastructure and promotional programs) may also succeed in increasing bicycling within the community by attracting more bicycle-oriented residents as well as by changing the behavior of existing residents. Although these issues cannot be resolved without further research, this study offers important insights into the importance of individual and social factors relative to the physical environment in explaining bicycling behavior.

REFERENCES

Babbie E. (1998). "The Practice of Social Research, 8th Edition". *Belmont, CA: Wadsworth Publishing Company.*

Bech, M. J. H., and Immers, L. H. (1994). "Bicycling Ownership and Use in Amsterdam". *Transportation Research Record 1441, TRB, National Research Council, Washington, D.C.*, pp. 141-146

Buehler, T. and S. Handy. (2007). "Fifty Years of Bicycle Policy in Davis. " *Paper accepted for presentation at the 2008 Annual Meeting of the Transportation Research Board, Washington, DC.*

Bureau of Transportation Statistics. (2002). "Bicycle Use Among Adult US Residents." *Omnistats*, 2(6).

Cervero, R., and Duncan, M. (2003). "Walking, Bicycling, and Urban Landscapes: Evidence from the San Francisco Bay Area." *American Journal of Public Health*, 93(9), 1478-1483.

Cohen, J., Cohen, P., West, G. Stephen and Aiken, S. Leona (2003). "Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences". *Lawrence Erlbaum Associates, Inc., Publishers*. Third Edition. pp 519-522.

Dill, J., and Carr, T. (2003). "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them." *Transportation Research Record*, 1828, 116-123.

Federal Highway Administration. (1992). "National Bicycling and Walking Study. Case Study No. 1: Reasons Why Bicycling and Walking Are and Are Not Being Used More Extensively as Travel Modes." *FHWA-PD-92-041*, Washington, DC.

Gärling, T., T. Laitila and K. Westin. (1998). "Theoretical Foundations of Travel Choice Modeling". *Oxford, UK: Pergamon*

Handy, S., X. Cao, P.L. Mokhtarian (2006). "Self-Selection in the Relationship between the Built Environment and Walking: Evidence from northern California." *Journal of the American Planning Association*, 72(1): 55-74.

Hess, Daniel Baldwin and Ong, Paul M. (2001). "Traditional Neighborhoods and Auto Ownership". *The Ralph and Goldy Lewis Center for Regional Policy Studies at UCLA, Working Paper #37 in the series.*

Killingsworth, R. E. (2003). "Health Promoting Community Design: A New Paradigm to Promote Healthy and Active Communities." *American Journal of Health Promotion*, 17(3), 169-170.

Krizek, K. and P.J. Johnson. (2006). "Proximity to Trails and Retail: Effects on Urban Cycling and Walking." *Journal of the American Planning Association*, 72(1): 33-42.

Lee, Chanam and Vernez, Anne. (2006). "Correlates of Walking for Transportation or Recreation Purposes". *Journal of Physical Activity and Health 2006, 3, Suppl 1*, S77-S98.

Lovejoy, K. and S. Handy. (2007). "Mobility Patterns and Travel Choices of Special Population Groups." *Paper accepted for presentation at the 2008 Annual Meeting of the Transportation Research Board, Washington, DC.*

McMillan, T.E. (2005). "Urban Form and a Child's Trip to School: The Current Literature and a Framework for Future Research," *Journal of Planning Literature*, 19: 440-456.

Moudon, A.V., C. Lee, A.D. Cheadle, C.W. Collier, D. Johnson, T.L. Schmid, and R.D. Weather. (2005). "Cycling and the built environment, a US perspective," *Transportation Research D*, 10: 245-261.

Murphy, N.B. and R. Knoblauch. (2004). "Hispanic Pedestrian and Bicycle Safety". *Washington, DC: The Federal Highway Administration (FHWA) and National Highway Transportation Safety Administration.*

National Highway Traffic Safety Administration, and Bureau of Transportation Statistics. (2003). "National Survey of Pedestrian & Bicyclist Attitudes and Behaviors: Highlights Report." *U.S. Department of Transportation, Washington, DC.*

Plaut, P.O. (2005). "Non-motorized commuting in the US," *Transportation Research D*, 10: 347-356.

Pucher, J., and Dijkstra, L. (2003). "Promoting Safe Walking and Cycling to Improve Public Health: Lessons from The Netherlands and Germany." *American Journal of Public Health*, 93(9).

Pucher, J., and Renne, J. L. (2003). "Socioeconomics of Urban Travel: Evidence from the 2001 NHTS." *Transportation Quarterly*, 57(3), 49-77.

Pucher, J., and R. Buehler. (2006). "Why Canadians cycle more than Americans: A comaprative analysis of bicycling trends and policies," *Transport Policy*, 13: 265-279.

Ortuzar, Juan de Dios and Willumsen, Luis G.. (2001). “Modelling Transport”, *Third Edition,* pp126-127.

Sallis, J. F., and Owen, N. (2002). "Ecological Models of Health Behavior." *Health Behavior and Health Education: Theory, Research, and Practice, K. Glanz, Barbara K. Rimer, and Frances Marcus Lewis, ed., Jossey-Bass, San Francisco, CA.*

Stinson, M.A. and C.R. Bhat. (2004). "Frequency of Bicycle Commuting: Internet-Based Survey Analysis." *Transportation Research Record*, 1878: 122-130.

Tanner, J. C. (1963). "Car and Motorcycle Ownership in the Counties of Great Britain in 1960". *Journal of the Royal Statistical Society. Series A(General), Vol. 126, No.2.* pp276-284

United States Environmental Protection Agency. (2003). "Travel and Environmental Implications of School Siting." *EPA 231-R-03-004*, Washington, DC.

Zegras, P. Christopher. (2006). "The Built Environment and Motor Vehicle Ownership &Use: Evidence from Santiago de Chile." *Working Paper.*