Explaining Gender Difference in Bicycling Behavior

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ABSTRACT
Although men and women bicycle at relatively equal rates in industrialized countries such as the Netherlands, Germany, and Denmark, research has consistently found that in the United States men's total bicycle trips surpass women's by a ratio of at least 2:1. Current evidence, although limited, suggests that women are affected to greater or lesser degrees than men by some factors. The purpose of this study is to provide insight on how gender influences the decision to use a bicycle, with the intent of supporting policy development aimed at increasing bicycle ridership, particularly among women. Bicycle use in six small cities in the western U.S. is examined in an effort to determine how gender interacts with individual factors and social and physical environments to influence bicycle behavior. Analysis of data from an on-line survey using a binary logistic regression approach shows strong interaction of gender with certain individual factors, especially safety perception and household responsibilities, and to a lesser degree with social and environmental factors to influence bicycle behavior.

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INTRODUCTION

In light of rising gas prices and concerns over climate change, bicycling is seeing a resurgence of popularity. From Los Angeles to New York, bicycle stores are experiencing higher bicycle sales than usual, especially for commute purposes *(1-3)*. But if current cycling patterns hold, men will be doing much more bicycling than women. Research *(4)* has consistently found that in the United States, men's total bicycle trips surpass women's by a ratio of at least 2:1. What explains this imbalance by gender in U.S. bicycling rates?

Garrard (*3)* was motivated in her study of female bicycle behavior by the observation that industrialized countries such as the Netherlands, Denmark, and Germany, with higher rates of bicycling for both transportation and recreation, have equal or higher rates of female cyclists than males, in contrast to the far greater proportion of male to female cyclists in Australia and the United States. This is attributed to the strong automobile culture of Australia and the United States where low bicycling and walking rates are still the norm in many communities (*5)*. In the United States, emphasis on the automobile in infrastructure design has resulted in less focus on bicyclists' need for safe and efficient access to destinations by public roads; this creates a situation that discourages bicycling for less confident riders *(6-8)*. In this paper, data from a 2006 survey of residents of six small cities in the western U.S. was used to explore differences between men and women in the factors that explain their bicycle use. Bicycle use in these cities is examined in an effort to determine how gender interacts with individual factors and social and physical environments to influence bicycle behavior. Providing empirical insight on how gender influences the decision to use a bicycle will support planners and policy makers attempting to increase bicycle ridership in their communities, particularly among women.

CONCEPTUAL BASIS AND LITERATURE REVIEW

The conceptual model for this study is based on the ecological model commonly used in physical activity research within the public health field to explain individual behavior *(9)*. This model suggests that individual behavior is influenced by factors at multiple levels, including the individual, social environment, and physical environment levels. 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. Interpersonal relationships, including those within households, are also considered social-environment factors. Physical-environment factors depend on the nature of land use patterns and transportation infrastructure. The ecological model was chosen over the more traditional model of travel behavior that focuses on utility maximization and does not readily account for attitudes or social-environment factors.

Research explaining gender differences in bicycle rates is limited, with the few existing studies focusing on female bicycle behavior; this is understandable considering the low rate of female cyclists compared to males. The limited available evidence suggests that women are affected to greater or lesser degrees than men by factors at each level of the model. Two factors that cut across the levels of the model emerge as especially relevant to explaining gender differences in bicycling: concern for safety, and household responsibilities.

Concern for safety
A number of studies, mainly aimed at increasing women's participation in bicycling, indicate that female cyclists have different perceptions of safety and different trip needs then male cyclists, regardless of whether they are advanced or basic cyclists *(4,5,10)*.

Garrard's *(11)* and Garrard et al.'s *(5,12)* studies, based on Australian population samples, concluded that female cyclists' concern for safety – from the perspective of road safety and driver behavior – were the main factors that discouraged them from bicycling. Women are more risk adverse than men and tend to perceive negative consequences of sharing roads with vehicular traffic more than men do *(13)*.

Although this concern for safety is an individual level factor, it is influenced by both the social and physical environments in which the cyclists operate. The probability of fatal injuries for bicyclists increases dramatically on roads where vehicular speed is over 30 mph or approximately 48 km/hr; this is a definite concern in both Australia where the residential speed limit is approximately 31 mph or 50 km/h and in the U.S. where residential speed limits range from 25-35 mph or 40–55 km/h *(14)*. In their 2006 observational study of Melbourne, Australia cyclists, Garrard et al. *(5)* found that female cyclists preferred off-road paths that were separated from traffic; this finding is consistent with other studies of bicycling behavior in which women were more likely than men to prefer bicycling separated from vehicular traffic by on-road lanes designated for bicycle use or off-road paths *(4,8,10,15)*.

Household Responsibilities
Research examining the influence of household responsibilities on travel behavior has found that women tend to make more trips for household and family support activities than men *(16,17)*. Since many of these activities require the transport of goods or passengers, women might prefer the convenience of driving over bicycling to fulfill these activities, especially if they are also using trip-chaining to carry out these responsibilities. Although preferring driving over bicycling is an individual level factor, it is heavily influenced by household and family relationships which are considered a part of the social environment.

McGuckin, et al. *(18)* analyzed data from the 1995 Nationwide Personal Transportation Survey and the 2001 National Household Travel Survey and found that American men's trip chaining increased to twice that of women's from 1995- 2001, mainly for the purpose of buying food and coffee. American women's trip chaining was more for shopping and family errands then men's, with women in two working parent families making twice as many weekday trips as men to pick up or drop off household children under the age of 14 years. Such responsibilities are likely to restrict the viability of bicycling.

When it is possible for women to bicycle for these chores, bicycling rates go up. In Germany, the Netherlands, and Denmark, where the share ratio of female cyclists is equal to or greater than the share of male cyclists, shopping trips account for 20-25 % of overall bike trips versus 5% of all bike trips in the United States *(19)*. However, a 2002 survey of over 400 women conducted by the San Francisco Bicycle Coalition found that 37% of the respondents felt that it was impossible to transport children or groceries on a bicycle *(10)*. This perception could be in part because of a lack of cyclist role models in San Francisco engaging in these tasks. Portland, Oregon addresses this misperception by offering a "Shopping by Bike class" in order to teach residents how to carry their groceries by bicycle *(20)*.

METHODOLOGY

The data used in this study was obtained from an on-line survey conducted in 2006 in six small cities in the western U.S. To ensure variation in potential explanatory variables, Davis, (California) and five communities that are similar to Davis with respect to size, topography, and weather but differ from Davis with respect to bicycle infrastructure and culture were selected for the survey - three in California (Turlock, Chico, and Woodland), one in Oregon (Eugene), and one in Colorado (Boulder). Davis was chosen as the relevant model because of its high level of bicycling, not only encouraged by its flat terrain, moderate weather, and large university, but also supported by a city council that has invested in bicycle infrastructure as far back as 1966 *(21)*. In recognition of its strong bicycling tradition, Davis was named the first platinum-level Bicycle Friendly City in the U.S. by the League of American Bicyclists in 2005.

Five comparison communities were selected for the study based on several factors. Woodland, Chico and Turlock were chosen as comparison cities that differed from Davis with respect to bicycle culture and infrastructure but are geographically close to Davis. Chico is two hour's drive north of Davis and has a reputation of being pro-bicycles, while Woodland is about 10 miles or 16 km north of Davis and has twice the bicycle lane mileage as Chico. Turlock is three hours drive south of Davis and has little bicycling or bicycle infrastructure. Eugene, OR and Boulder, CO were chosen because they have extensive bicycle infrastructure and enjoy reputations as bicycling communities nearly comparable to Davis. This set of cities ensured reasonable comparability with respect to control variables but ample variation with respect to key explanatory variables.

Because of the strong or relatively strong bicycle culture of most of the cities surveyed, it was expected that the ratio of men bicycling versus women would be more equal than reported by most American bicycling surveys, in which male bicyclists tend to outnumber female bicyclists by an average of more than 25 percent *(22,4,23)*. The fact that the ratio is closer to 1 in the survey than in the US overall suggests that social or environmental factors inherent to the Davis survey communities encourage women to bicycle *(19,24-26)*.

For each of the six communities, a random sample of 1500 residents, along with an additional sample of 1000 residents for Davis (to correct for a larger than expected survey return due to incorrect addresses) were each mailed a letter in June 2006 that invited them to participate in the on-line survey. This was followed up by two postcard reminders and an offer to send them a hard copy of the survey if they requested. Of the original 10,000 addresses, over 2000 proved to be incorrect as evidenced by the number of returned surveys. Of the original 10,000 addresses, after accounting for over 2000 returned surveys due to bad addresses, a response rate of over 10% was achieved for every city except Turlock, where the response rate was just 7.2%, with a high of 18.8 % in Davis. The final sample size was 965, with an overall response rate of 12.6%. A follow-up phone survey conducted in Davis in May 2008 to assess non-response bias yielded bicycling levels that were statistically indistinguishable from those in the on-line survey (see Xing et al. *(27)* for more details). In this paper, only those respondents who reported owning a bicycle are included in the analysis.

Variables

The dependent variable is the binary variable of whether the respondent reported bicycling or not in the last week before the survey. Our conceptual model defines three categories of relevant explanatory variables in this context: individual factors, social environment factors, and physical environment factors. This study uses variables developed and tested by Xing et al. *(27)*. Three additional variables were included in this study: "Assisted Children" (presence of children that required travel assistance), "Bike Repair Skill" (index for perceived bicycle repair capability) and "Limitations on Biking" (existence of a physical condition that seriously limited or prevented riding a bicycle). In this study, all the variables in of Xing et al.'s *(27)* paper plus the three additional variables where tested for gender-specific effects using interaction terms. The potential explanatory variables are shown in Table 1.

TABLE 1 Description of Variables in Model

Variable name	#Items [Range]	Description
Dependent variable		
Bike or not	1 [01]	0 = owns a bike and did not bike in the last 7 days, 1=owns a bike and biked during last 7 days
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 [1,125]	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
Limit on Biking	1 [0,1]	0=does not have conditions that limit biking, 1= has conditions that limit biking
Child Assistance	1 [0,1]	0=child(ren) do not need assistance travelling, 1= child(ren) do need assistance
Individual Factors: Attitudes		
Biking Comfort	6 [1,3]	Average comfort biking on an (1) off-street path or (2) quiet street, (3) two-lane-local-street with or (4) without bike lane, (5) four-lane-street with or (6) without bike lane, on 3-point scale where 1=Uncomfortable and I wouldn't ride on it, 2=Uncomfortable but I'd ride there anyway, 3=Comfortable.
Safety Concern	5 [1,3]	Average concern of being (1) hit by a car, being (2) hit by another bicyclist while biking, (3) being bitten by a dog, being (4) mugged or attacked, or (5) 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

Variable name	#Items [Range]	Description
		scale*
Limit Driving	1 [1,5]	Agreement that "I try to limit driving as much as possible" on 5-point scale*
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
Bike Repair	6[1,3]	Average response reflecting the capability of repairing bike: (1) "Fix Flat", (2) "Pump Air", (3) "AdjSeat", (4) "AdjBrake", (5) "OilChain", and (6) "FixAnything") on a 3-point scale where 1= Not at all capable, 2= Somewhat capable, 3= Very capable
Social Environment		
Good Driver Attitude	4 [1,5]	Average agreement that (1)"Most drivers [do not] seem oblivious to bicyclists", (2) "Most drivers yield to bicyclists", (3) "Most drivers watch for bicyclists at intersections", (4) "Most people [do not] drive faster than the speed limit" on 5-point scale*
Biking is Normal	2 [1,5]	Average agreement that (1) "Bicycling is a normal mode of transportation for adults in this community" and (2) "It is [not] rare for people to shop for groceries on a bike" on 5-point scale*
Children 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 (1)"Major streets have bike lanes", (2)"Streets without bike lanes are generally wide enough to bike on", (3)"Stores and other destinations have bike racks", (4)"Streets and bike paths are well lighted", (5)"Intersections have push-buttons or sensors for bicycles or pedestrians", (6)"The city has a network of off-street bike paths", (7)"Bike lanes are free of obstacles", (8)"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.

Multivariate analysis
The original dataset (N = 965) was narrowed down to a dataset of N= 912 cases by excluding 53 cases that did not specify whether the respondent was male or female. As an initial analysis step, we analyzed the statistical significance of differences between men and women for all potential explanatory variables (Table 2). The substantial differences between genders on many variables suggested that market segmentation (i.e. segmenting pooled data into two subgroups, male and female) was appropriate. The pooled data was then disaggregated into two subsamples: female (n= 401) and male (n=511). Based on Xing et al. *(27)*, these subsamples were further filtered to include in the models only respondents who were bike owners, yielding a final working data set (n=657) of two subsamples with n= 272 for female and n = 385 for male.

The analysis approach consisted of three major steps: 1) *gender-specific models*: two separate models using female and male subsamples respectively, to explore variables for potential interaction terms in a pooled model; 2) *pooled model*: a combined model for men and women using pooled data; and 3) *pooled model with interaction terms*: starting from the "best" pooled model (obtained from step 2), and then adding potentially valuable interaction terms indicated by the two gender-specific models to form the best combined model. By comparing the final specifications of the two gender-specific models, variables could be identified that appeared in one model but not the other or that appeared to have significantly different coefficients. These variables were then included in the final model as interaction terms with either male or female. If the interaction term was significant in the final model, we concluded that the effect of that variable differed by gender.

A binary logistic regression was used to estimate the models, since it allows the prediction of a discrete outcome such as analyzed in this study. The dependent variable was a binary variable, with discrete values of 1 for "Bicycled in the last 7 days" and 0 if "Did not bicycle in the last 7 days". To find the best sets of explanatory variables, the same procedure used in Xing et al. *(27)* was followed: for each model, socio-demographic factors, individual attitudinal factors, social environment factors, and physical environment factors were entered as sets sequentially, then insignificant variables were deleted in a backwards step-wise process for each set of variables. The best gender-specific models and pooled model (as defined by relative goodness-of-fit and interpretability) derived from steps 1 and 2 are presented in Table 3.

The final *pooled model with interaction terms* (shown in Table 4) was created by adding interaction terms based on the *gender-specific models* to the *pooled model*. For those variables appearing in both the female and male models, a t-test was used to test the equality of the magnitudes of their coefficients. If the coefficients were equivalent, a gender-specific variable was not included in the *pooled model with interaction terms*. If there was a significant difference in coefficients, a gender-specific variable was considered in the model specifications. Those variables that only appeared in one of the two *gender-specific models* were included as gender-specific variables in the *pooled model with interaction terms.*

RESULTS AND ANALYSIS

Of the 657 valid respondents who owned a bicycle, 55.9% reported bicycling within the last week and 44.1% did not. Of the 367 respondents who reported bicycling, 59.7% were men versus 40.3% women. As anticipated, the share of bicyclists who are women is higher than in national surveys. The percentage of female respondents who reported bicycling (37%) was also not significantly different from the percentage of male respondents (43%). Previous research has found that communities with higher levels of bicycling tend to have a higher ratio of female to male bicyclists; Davis, Boulder and Eugene have bicycling rates (17%, 6.9%, and 5.5% respectively) much higher than the national U.S. average of 1% *(27)*, and therefore would be expected to follow the trend of European countries discussed earlier that have more gender equity in bicycling levels *(19)*.

Men and women diverged significantly on many of the explanatory variables (see Table 2), suggesting that the factors influencing bicycle use might differ for men and women even if their level of bicycling was not significantly different. For example, women report physical limitations that prevent bicycling at a higher rate than do men (15% versus 9% respectively) and agree less on average that they like bicycling (2.53 versus 2.64 on a 5-point scale). However, multivariate analysis is needed to assess the relative importance of these factors in explaining male and female bicycle behavior. Furthermore, it is possible that the importance of the factors, not just their values, differ for men and women. The analysis that follows addresses these issues.

TABLE 2 Variable Mean Scores – Female vs. Male

Variable name	Female mean	Male mean	P-value
Dependent variable			
Bicycled or not in the last 7 days	0.37	0.43	0.063
Explanatory variables			
Individual Factors: Socio-demographics			
Age (years)	**47.54**	**50.65**	**0.002**
Education Level	4.36	4.51	0.122
Household Size	**2.27**	**2.52**	**0.001**
Income ($1000)	**62.49**	**78.15**	**0.000**
Car Ownership	**0.95**	**0.98**	**0.019**
Home Ownership	**0.30**	**0.20**	**0.002**
White	0.76	0.77	0.894
Limit on Biking	**0.15**	**0.09**	**0.004**
Child Assistance	**0.15**	**0.10**	**0.038**
Individual Factors: Attitudes			
Biking Comfort index	**2.29**	**2.47**	**0.000**
Safety Concern index	**1.75**	**1.60**	**0.000**
Like Biking	**2.53**	**2.64**	**0.016**
Like Driving	**2.38**	**2.58**	**0.000**
Need Car	2.76	2.82	0.096
Limit Driving	**3.54**	**3.32**	**0.001**
Like Walking	**4.11**	**3.90**	**0.000**
Like Transit	2.61	2.61	0.947
Environmental Concern	**0.55**	**0.44**	**0.001**
Pro-Exercise index	4.26	4.24	0.828
Good Health	3.95	3.87	0.205

Variable name	Female mean	Male mean	P-value
Biked in Youth	0.04	0.03	0.383
Self Selection index	0.33	0.30	0.315
Bike Repair index	**1.66**	**1.28**	**0.000**
Social Environment			
Good Driver Attitude index	2.98	3.00	0.665
Biking Normal index	**2.96**	**2.62**	**0.000**
Children Bike	3.41	3.49	0.206
Bikers Poor	2.00	2.04	0.488
Bikers Spend	2.81	2.88	0.228
Bikers Not Concerned	**2.83**	**2.98**	**0.042**
Physical Environment			
Bike Infrastructure index	**3.25**	**3.06**	**0.000**
Hilly Topography	1.37	1.28	0.120
Safe Destinations index	**1.68**	**1.51**	**0.000**
Distances index	2.81	2.79	0.595
Transit Access	0.82	0.79	0.258

Note: Boldface indicates a significant difference, p<0.05 (One-way ANOVA)

Initial Models: Gender-Specific Models and Pooled Model

The purpose of the two gender specific models was to identify factors significant for men or women that potentially should be included as interaction effects. The female model was run with n=272 survey cases, the male model was run with n= 385 cases, and the pooled model was run with all the cases (n= 657) that identified as male or female. Criteria for the three models were that sample cases reported both owning a bicycle and whether or not they had bicycled in the week before the survey.

Individual factors: Socio-demographics

Specific to the female model, the older the respondent, the lower the odds that they reported bicycling by a factor of 0.966 for every year increase in age. Significant to all three models was education level with both men and women with higher education levels being more apt to bicycle. In the pooled model, three other socio-demographic factors were associated with greater odds of bicycling: not owning a home, having no physical or psychological conditions that limit bicycling, and having child(ren) that require assistance travelling

Individual factors: Attitudes

Individual attitude factors play a leading role in explaining whether men and women bicycled in the last week. Three factors were unique to the female model. Women who agreed with the statement “I need a car to do many of the things I like to do” decreased the odds of bicycling by a factor of 0.618 for every unit increase in agreement. The second factor unique to the female model was a positive effect of concern for the environment on bicycling (odds ratio = 1.566). Third, women with high comfort index scores were more likely to have ridden than women scoring low on this comfort index. For each step on the comfort scale, the odds of biking increased by 3.764 (Table 3).

Similar to the female model, individual attitude factors play a leading role in explaining whether or not men bicycled in the week before the survey. Two factors were unique to the male model. First, bicycling as a youth (youth defined as around 12 years) increased the odds of bicycling by a factor 3.810. Second, if bicycling was a relatively important factor in residential location choice, the odds of bicycling increased by 1.925

Of the three significant factors that only appeared in the female model, two were also significant in the pooled model: Bicycling Comfort and Need Car. Neither individual factor that was significant in the male model but not the female model (Biked in Youth and Self Selection) was significant in the pooled model. Agreement with the statements "I like biking" and "I am in good health" were positive determinants of both male and female bicycling behavior in all three models. In contrast, agreement with the statement "I like transit" decreased the odds of bicycling in all three models, suggesting a substitution effect between bicycling and transit.

TABLE 3 Logistic Regression Models for Bicycled or Not – Female Model, Male Model, and Pooled Model

Variable Name	**Model 1: female model**		**Model 2: male model**		**Model 3: pooled model**	
	Coefficient	OR	Coefficient	OR	Coefficient	OR
Constant	-6.436	0.002	-9.018	0.000	-6.752	0.001
Individual factors: Socio-demographics						
Age	-0.035**	0.966				
Education Level	0.266**	1.304	0.159*	1.172	0.235***	1.265
Home Ownership					-0.609**	0.544
Limit of Biking					-1.868**	0.154
Child/Children Assistance					0.684**	1.982
Individual factors: Attitudes						
Biking Comfort	1.325***	3.764			0.776**	2.174
Like Biking	1.227***	3.411	1.354***	3.871	1.306***	3.693
Need Car	-0.481**	0.618			-0.351**	0.704
Like Transit	-0.919***	0.399	-0.269*	0.764	-0.443***	0.642
Environmental Concern	0.449**	1.566				
Good Health	0.370**	1.447	0.254*	1.289	0.306***	1.358
Biked in Youth			1.338**	3.810		
Self Selection			0.655*	1.925		
Social Environment						
Good Driver Attitude	0.635***	1.886				
Biking is Normal			0.271*	1.311		
Bikers Poor					-0.313**	0.731
Physical Environment						
Safe Destinations					0.370*	1.448
Transit Access			1.085***	2.960	0.791***	2.205
Valid N	254		369		587	
Pseudo R^2	0.331		0.269		0.312	
Model Chi-square	249.478		389.714		587.427	

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

Social environment

In the female model, women's perception that drivers in the community behave safely toward cyclists, as measured by the Good Driver index, had a positive effect on bicycling (odds ratio = 1.886). This factor was not a significant influence on men's bicycling behavior and did not appear in either of the pooled models. One social environment factor influenced men’s bicycling behavior. A one unit increase in the Biking is Normal index increased the odds of bicycling by a factor of 1.311. The only social factor that was a significant influence in the pooled model was the perception that bicyclists are poor; it was not significant, however, in either gender specific model.

Physical environment
There were no significant physical environment factors in the model for women. However, the physical environment may have an indirect influence through its impact on Biking Comfort.
Significant in both the male model and the pooled model was the transit access factor. In the male model, men that lived within a five minute walk of bus or transit service had an increased odds of bicycling versus men that lived over five minutes away (odds ratio = 2.960), while for the pooled model, the odds increased by 2.205. The likelihood of bicycling increased if respondents felt safe bicycling to neighborhood destinations such as the post office, elementary school, grocery store, and restaurant or bike repair shop, an influence that was only significant in the pooled model.

TABLE 4 Logistic Regression Model for Bicycled or Not – Pooled Model with Interaction Terms

Variable Name	**Pooled model with interaction terms**		
	Coefficient		OR
Constant	-7.899		0.000
Individual factors: Socio-demographics			
Education Level	0.241	***	1.272
Home Ownership	-0.681	***	0.506
Limit of Biking	-1.379	*	0.252
Child/Children Assistance	0.744	**	2.105
Individual factors: Attitudes			
Like Biking	1.370	***	3.935
Like Transit	-0.488	***	0.614
Good Health	0.265	**	1.304
Biking Comfort_female [a]	1.952	***	7.046
Need Car_female [a]	-0.537	***	0.585
Biked in Youth_male [b]	1.637	***	5.138
Self Selection_male [b]	0.844	**	2.326
Social Environment			
Bikers Poor	-0.320	**	0.726
Physical Environment			
Safe Destinations	0.321	*	1.379
Transit Access_male [b]	1.046	***	2.847
Valid N			590
Pseudo R^2			0.327
Model Chi-square			577.599

10% significance level, ** 5% significance level, * 1% significance level.*
[a]: Interaction term with female; [b]: Interaction term with male

Final Model: Pooled Model with Interaction Terms

The final model, shown in Table 4 above, was developed starting from the final pooled model (Table 3) and adding potentially significant interaction terms as suggested by the two gender-specific models. The significant interaction terms point to important differences in the factors that influence bicycling for women versus men.

Individual factors: Socio-demographics

The same four socio-demographic factors that were significant in the pooled model are significant in the final pooled model with interaction terms: education level and having children who need travel assistance, both with positive effects; and home ownership and physical conditions limiting bicycling, with negative effects. No interaction terms were significant.

Individual factors: Attitudes

Three gender-neutral attitude factors appeared in the final model: “Like Biking” and “Good Health”, with positive effects, and “Like Transit, with negative effects. This result was robust across the models, and liking biking was one of the most important determinants of bicycling in all models.

Two male-specific and two female-specific attitude factors were significant in the final model. Men placing strong emphasis on living in a community that is good for bicycling were more likely to bicycle. More importantly, the odds of bicycling for male respondents who had biked in their youth was higher by a factor 5.138, making it the second most significant influence on bicycling in the final model. There have been few studies that have conducted gender-specific analysis of physical activity in children and how it correlates to adult physical activity. A number of social and environmental influences could be involved with this variable; research has found that males are more active than females in youth *(28)* and are allowed by their parents to roam further spatially than female youths, suggesting that girls are more restricted in their bicycling than boys *(29-31)*.

Female respondents who agreed that they need a car were less likely to bicycle, with a decrease in odds by a factor of 0.585 for every unit increase in agreement. Since this variable does not differentiate what the car is needed for (e.g. work, household tasks, or recreation) this result could have multiple interpretations. The negative influence could be partially explained by research discussed earlier that has found that women in two working parent families make many more stops for pick-up, drop-off, and errands *(18)*. However, the most important determinant of bicycling for women was their level of comfort bicycling, with an odds ratio of 7.046, the highest in all four models. To better understand the gender difference with respect to the influence of bicycling comfort, the mean scores for each of the survey questions used to create the comfort index were examined (Table 5). These questions asked about comfort bicycling on six types of bicycling facilities using a three-point scale (1= Uncomfortable and I wouldn't ride on it, 2=Uncomfortable but I'd ride there anyway. and 3=Comfortable). Although men experienced approximately as much discomfort on average as women on facilities not separated from heavier traffic, they were also more likely to report that they would ride on them anyway, in contrast to women who indicated that they would not. This result is consistent with both Garrard, Roes et al.’s *(12)* and Krizek, Johnson et al.’s *(4)* observations that women have a stronger preference for bicycling on facilities that were separated from traffic than men did.

TABLE 5 Biking Comfort Variable Mean Scores with Respect to Gender Difference

Variable name	Female mean	Male mean	P-value
Biking Comfort index	**2.29**	**2.47**	**0.000**
(1) Off-street path	**2.74**	**2.85**	**0.002**
(2) Quiet street	2.91	2.92	0.658
(3) Two-lane-local-street with bike lane	**2.70**	**2.84**	**0.000**
(4) Two-lane-local-street without bike lane	**1.65**	**1.97**	**0.000**
(5) Four-lane-local-street with bike lane	**2.38**	**2.59**	**0.003**
(6) Four-lane-local-street without bike lane	**1.36**	**1.63**	**0.000**

Note: Boldface indicates a significant difference, p<0.05 (One-way ANOVA)

Social environment
Only one social variable, the perception that bikers are poor, is significant in the final model. Social environment effects did not differ for men and women. It is notable that positive perceptions of the bicyclists in the community (e.g. bicycling is normal for adults) were not significant predictors of bicycling.

Physical environment
Two variables in this category were significant: safe destinations and the interaction term of transit access with male, both positively associated with bicycling. A perception of safe destinations to bicycle to in the respondent's neighborhood increased the likelihood of bicycling regardless of gender. However, this variable is only marginally significant ($0.05<p < 0.10$) and could be overshadowed by the very strong effect of bicycle comfort. The male-specific transit access variable could perhaps be serving as a proxy for a set of neighborhood characteristics; denser neighborhoods that are easier to access by bicycle might also have more transit facilities.

CONCLUSIONS

This analysis offers new insights into the factors that explain gender differences in bicycling. Study results show that individual, social, and physical factors all play an important part in determining bicycle use and that these influences are often the same for men and women. However, they also highlight important differences in the factors that matter to men and women.

Individual factors were the most important influences both for the gender-specific samples and the pooled sample. Consistent with Xing et al. *(27)*, the most important gender-neutral factor was agreement with the statement "I like biking". Gender-specific influences were stronger determinants of bicycle use, however. Biking in youth was the strongest positive influence on men choosing to bicycle. As discussed earlier, more research to determine why bicycling in youth is an important influence on men but not women choosing to bicycle is required. Feeling comfortable using bicycle facilities was the strongest positive influence on women's bicycle use, a finding which is supported by previous research on gender differences in bicycling. This finding, in conjunction with the significant positive influence of perception of bicycling safety to selected neighborhood destinations, suggests an indirect effect of bicycle facilities on bicycle use through their influence of perceptions of bicycling safety.

These results point to a need for gender sensitivity in the bicycle planning process and a reevaluation of the definitions of "experienced" vs. "non experienced" bicyclist categories that guide U.S. bicycle infrastructure design *(32-33)*. The U. S. Federal Highway Administration (FHWA) classifies bicyclists into 3 standardized categories: (a) Group A *advanced bicyclists*: experienced riders who operate under most traffic conditions, (b) Group B *basic bicyclists*: casual or new adult and teenage riders who are less confident of their ability to operate in traffic without specific provisions for bicycles, and (c) Group C *children (33)*. This classification system is widely used to guide U.S. bicycle facility design. However, it does not explicitly take into account gender differences in bicycling behavior.

Another example of the classification of experienced and inexperienced being based on cyclists' comfort level of driving in traffic is the Bicycle Compatibility Index (BCI) used by the FHWA as an important guideline for bicycle infrastructure design and assessment *(32)*. Since women have been shown to be less comfortable with traffic at all levels of experience, women might be more apt to be classified as inexperienced than men. In Harkey and Reinfurt et al.'s study *(32)* experienced riders were "comfortable riding under most traffic conditions, including major streets with busy traffic and higher speeds"; when the participants were clustered into groups, there were twice as many women in the casual (i.e. inexperienced) bicyclist group than either of the two experienced bicyclist groups.

Our study suggests that gender differences in perceptions of bicycling safety combined with the effect of bicycle facility type could help explain different cycling rates for men and women. If this is the case, it is possible that the FHWA design guidelines actually discourage instead of support women's bicycle use. If as research suggests, women prefer to use traffic-separated facilities even as experienced bicyclists, does the use of facilities which are usually designed for the "inexperienced" cyclist *(32,33)* discourage women from bicycling because these facilities are often not as convenient to services *(8,4)*?

Although providing bicycle facilities that equally support the needs of both male and female bicyclists is an important step towards increasing U.S. bicycling levels, there are a number of other approaches that should be combined with bicycle facility design for a more comprehensive program. The FHWA *(34)* suggests a joint approach of engineering, education, enforcement, and promotion of bicycling *(35)* to increase the U.S. bicycling rate. These approaches, combined with the understanding of how gender differences affect bicycling rates could form the basis for strategies to increase bicycling among women. This will first require further research to understand how the combination of gender differences interacts with individual, social and physical factors to affect bicycling levels. The high rates of bicycling for women in other countries suggest much room for improvement in the U.S.

REFERENCES

1. Richards, L.K. Gas prices up bicycle sales, in *TimesRecordNews*, Wichita Falls, April 23, 2008. http://www.timesrecordnews.com/news/2008/apr/23/gas-prices-bicycle-sales/. Accessed July10, 2008.
2. Earnest, L. Bikes help commuters get around gas prices, in *Los Angeles Time*, July 8, 2008. Los Angeles. http://www.latimes.com/business/la-fi-pennywise8-2008jul08,0,6515708.story. Accessed July 20, 2008.
3. Kassel, R. A smoother ride for cycling in the city, in *Gotham Gazette*, May 2008. New York. Accessed July 19, 2008. http://www.gothamgazette.com/article/environment/20080527/7/2534
4. Krizek, K.J., P.J. Johnson, and N. Tilahun. Gender Differences in Bicycling Behavior and Facility Preferences. In *Conference Proceedings 35*, *Research on Women's Issues in Transportation Volume 2: Technical Papers. Conference on Research on Women's Issues in Transportation*, Transportation Research Board of the National Academies. Chicago, Illinois, 2004, pp. 31-40.
5. Garrard, J., S. Crawford, and N. Hakman. *Revolutions for Women: Increasing women's participation in cycling for recreation and transport. Summary of key findings*. School of Health and Social Development. Deakin University: Victoria, Australia. 2006.
6. Forester, J. *Bicycle Transportation A Handbook for cycling transportation engineers 2nd edition*, ed. T.M. Press. Cambridge MA. 1994.
7. Barnes, G. and K. Krizek. *Tools for Predicting Usage and Benefits of Urban Bicycle Network Improvements*, Minnesota Department of Transportation, Research Services Section, St. Paul , MN, 2005.
8. Nelson, A.C. and D. Allen. If You Build Them, Commuters Will Use Them: Association Between Bicycle Facilities and Bicycle Commuting. *Transportation Research Board: Journal of the Transportation Research Board*, 1997, pp. 79-83.
9. Sallis, J.F. and N. Owen. Ecological models of health behavior. In *Health Behavior and Health Education: Theory, Research, and Practice*,, K. Glanz, B.K. Rimer, and F.M. Lewis, Editors. Jossey-Bass, San Francisco, CA. 2002.
10. Brown, N. *Why Aren't Women on Wheels?* 2004. San Francisco Bicycle Coalition. www.sfbike.org/?women_mb. Accessed July 14, 2008.
11. Garrard, J. Health revolutions: promoting cycling among women. *Health Promotion Journal of Australia*, Vol. 14, No. 3, 2003, pp. 213-215.
12. Garrard, J., G. Roes, and S.K. Lo. Promoting Transportation cycling for women: The role of bicycle infrastructure. *Preventative Medicine*, Vol. 46, No. 1, 2008, pp. 55-59.
13. Harris, C., R. and D. Glaser. Gender Differences in Risk Assessment: Why do Women Take Fewer Risks than Men? *Judgement and Decision Making*, Vol. 1, 2006, pp. 48-63.
14. Yang, J. and J. Daniel. *Study of optimal travel speed limits for shared traffic*. FHWA-NJ-2004-12. New Jersey Department of Transportation, and Federal Highway Administration, U.S. Department of Transportation, 2004.
15. Tilahun, N.Y., D.M. Levinson, and K.J. Krizek. Trails, lanes, or traffic: Valuing bicycle facilities with an adaptive stated preference survey. *Transportation Research Part A: Policy and Practice*, Vol. 41, 2007, pp. 287-301.

16. Turner, T. and D. Niemeier. Travel to work and household responsibility: new evidence. *Transportation*, Vol. 24, No. 4, 1997, pp. 397-419.
17. Gossen, R. and C.L. Purvis. Activities, time, and travel: Changes in women's travel time expenditures, 1990–2000. In *Conference Proceedings 35*, *Research on Women's Issues in Transportation Volume 2: Technical Papers. Conference on Research on Women's Issues in Transportation*. Transportation Research Board of the National Academies. Chicago, Illinois, 2004, pp. 21-29.
18. McGuckin, N. and Y. Nakamoto. *Differences in Trip Chaining by Men and Women*. In *Conference Proceedings 35*, *Research on Women's Issues in Transportation Volume 2: Technical Papers. Conference on Research on Women's Issues in Transportation*. Transportation Research Board of the National Academies. Chicago, Illinois, 2004, pp. 49-56.
19. Pucher, J. and R. Buehler. Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany. *Transport Reviews*, Vol. 28, No. 4, 2008, pp. 495-528.
20. Portland Transportation. *Options Newsletter Summer 2006: Transportation Options Gets Practical*. Portland. http://www.portlandonline.com/TRANSPORTATION/index.cfm?a=122067&c=44270. Accessed July 5, 2008.
21. Buehler, T. and S. Handy. Fifty Years of Bicycle Policy in Davis. Presented at the *2008 Annual Meeting of the Transportation Research Board.* Washington, DC., 2008.
22. Moudon, A.V., C. Lee, A.D. Cheadle, C.W. Collier, D. Johnson, T.L. Schmid, and R.D. Weather. Cycling and the built environment, a US perspective. *Transportation Research Part D: Transport and Environment*, Vol. 10, No. 3, 2005, pp. 245-261.
23. Goldsmith, S. A. *National Bicycling and Walking Study, Case Study No. 1: Reasons Why Bicycling and Walking Are Not Being Used More Extensively as Travel Modes.* Federal Highway Administration, U.S. Department of Transportation, 1992.
24. Pucher, J. and L. Dijkstra, Promoting Safe Walking and Cycling to Improve Public Health: Lessons From The Netherlands and Germany. *American Journal Public Health*,Vol. 93, No. 9, 2003, pp. 1509-1516.
25. Bengoechea, E., J. Spence, and K. McGannon, Gender differences in perceived environmental correlates of physical activity. *International Journal of Behavioral Nutrition and Physical Activity*, Vol. 2, No. 1, 2005.
26. Rietveld, P. and V. Daniel, Determinants of bicycle use: do municipal policies matter? . *Transportation Research Part A: Policy and Practice*, Vol. 38, No. 7, 2004, pp. 531-550.
27. Xing, Y., S.L. Handy, and T.J. Buehler, *Factors associated with bicycle ownership and use: A study of 6 small U.S. cities.* Presented at the 87th *Transportation Research Board Meeting.* Washington, D.C., 2008.
28. Sallis, J.F., J.J. Prochaska, and W.C. Taylor, A review of correlates of physical activity of children and adolescents. *Medicine & Science in Sports & Exercise*, Vol. 32, No. 5, 2000, pp. 963-975.
29. Valentine, G., 'My Son's a Bit Dizzy.' 'My Wife's a Bit Soft': Gender, children

and cultures of parenting. *Gender, Place & Culture*, Vol. 4, No. 1, 1997, pp. 37 - 62.

30. Matthews, H. and M. Limb, Defining an agenda for the geography of children: review and prospect. *Progress in Human Geography*, Vol. 23, No. 1, 1999, pp. 61-90.
31. Harth, A., Open Space and Gender - Gender-Sensitive Open-Space Planning. *German Journal of Urban Studies*, Vol. 4, No. 1, 2007.
32. Harkey, D.L., D.W. Reinfurt, and M. Knuiman, *Development of the bicycle compatability index: A level of service concept*. FHWA-RD-98-072. Federal Highway Administration, U.S. Department of Transportation, 1998.
33. Wilkinson, W.C., III, , A. Clarke, B. Epperson, and R. Knoblauch, *Selecting roadway design treatments to accommodate bicycles*. Federal Highway Administration, U.S. Department of Transportation, 1994.
34. *Pedestrian and Bicycle Safety Research Page: Current Research*. Turner-Fairbank Highway Research Center. Federal Highway Administration, U.S. Department of Transportation. McLean, Virginia. http://www.tfhrc.gov/safety/pedbike/research/current.htm. Accessed November 12, 2008.
35. *Bicycling Solutions: Implement Solutions*. Pedestrian and Bicycle Information Center, University of North Carolina Highway Safety Research Center, Chapel Hill, NC. Available from: http://www.bicyclinginfo.org/solutions/. Accessed November 12, 2008.