# Do Attitudes Moderate the Built Environment Impact on Bicycling Commuting? Findings from the 2009 National Household Travel Survey from the United States 

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#### Abstract

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To tackle some of the negative externalities of driving, transportation policies encouraging more bicycling for commuting are gaining momentum. One of the most popular policy prescriptions is to change the built environment by improving physical conditions of bicycling. While travel behavior literature suggests that the built environment influences people's travel pattern, attitudinal factors are believed to moderate this relationship. Using the 2009 National Household Travel Survey, this study explores the moderating effect of attitudinal factors on the relationship between the built environment and bicycle commuting while taking into account socioeconomic and demographic characteristics. The results show that the built environment has some significant impact on bicycle commuting, but much of the impact is moderated by attitudinal factors. Attitudinal factors appear to have separate impact on bicycling, having similar direction and magnitude across different built environments. This research suggests that attitudinal factors may play a critical role in facilitating the built environment impact on bicycle use, calling for the need to include soft policy as an effective way to promote bicycle commuting.


주제어: 자전거 계획, 자전거 출퇴근, 환경 요인
Keywords: Bicycle planning, Bicycle commuting, Built environment

## I. Introduction

Due to increasing awareness of negative externalities of auto travel, policies to encourage alternative transportation like walking and bicycling have been gaining popularity in many U.S. cities. Portland and Seattle, for example, have adopted bicycle master plan, largely focused on implementing bicycle lanes in conjunction with existing land use policies containing growth within urban areas. While physical improvements and land use policies are believed to play an important role in encouraging bicycle use, some argue that such policies are more likely to succeed in certain community due to personal attitudes and preference (Cao, Mokhtarian, \& Handy, 2009). That is, people who are committed to bicycling would bicycle more regardless of the built environment, and these people will eventually relocate to more bikeable neighborhoods to match their travel preference.

From a public policy perspective, the role of attitudes and preference is an important topic because they can mediate the policy impact of encouraging bicycling through physical improvements such as expansion of bicycle lanes or bicycle racks. In some neighborhoods, the majority of residents may prefer to drive than to bicycle to work. Improving physical environment on these neighborhoods would have little or no effect on bicycling. In addition, bikeable neighborhoods might coincide with some general characteristics that many people value, such as safety, school quality, microclimate, and ethnic/racial mix (Giuliano, 1991; Wachs et al, 1993). Therefore, even if people do relocate to good bikeable neighborhoods, it is difficult to determine what their motives are (Krizek, 2003). If people moved to those places based on priorities other than travel preference, they may not necessarily bicycle more, just because their neighborhood is more supportive of bicycling. Given this complexity, this paper explores the moderating effect of attitudes on the relationship between the built environment and bicycling, while accounting for socioeconomic and demographic factors.

## ㅍ. Literature Review

Travel is an induced demand, so there are multiple factors that influence individual trip-making decisions. Bicycling shares the same characteristics with this general travel behavior; however, it is different from motorized travel because of two distinctive reasons for bicycling: utilitarian vs. recreational. Utilitarian bicycling involves travelling for work or for family occasions, whereas recreational bicycling is usually for fun and leisure. Travel behavior researchers agree that the built environment influences the purposes for which people bicycle. Residents in central urban environment bicycle more for utilitarian purpose; but their suburban counterparts typically bicycle for recreational purpose (Blanco et al., 2009). However, researchers are torn between the degree to which neighborhood environment plays a role in utilitarian bicycling, and to what extent the relationship between environment and bicycling can be explained by attitudes and self-selection.
Traditionally, urban and transportation researchers have shown that built environment factors have significant impact on bicycling, regardless of personal attitudes. Plaut (2005) used a comprehensive set of socioeconomic factors along with other housing and neighborhood characteristics to compare different types of non-motorized commuters to car commuters. She concluded that gender, education, auto ownership and the built environment trump other measures in terms of their effects on bicycling, suggesting that attitudes and self-selection might not be significant. Along the same line of inquiry, Van Dyck et al (2009) investigated whether different built environments lead to different levels of physical activity. Their results showed that participants from the high walkable neighborhood had significantly more physical activity than those from the low walkable neighborhood. Looking at bicycling levels, however, the authors did not find any significant difference between the neighborhoods in terms of bicycling. To isolate the true effect of the built environment on travel, Krizek (2003) examined a 11-year prospective panel design study, where individuals' travel behavior was traced after they moved to a different neighborhood. He
found that the individuals changed their travel behavior after they moved to a more walkable neighborhood; however, the author acknowledged that there might be some self-selection effect in place.

On the other hand, researchers have argued that built environment alone does not affect people's behavior much, let alone their attitudes. Handy and Xing (2011) used an ecological model to explain the relationship between bicycle commuting and a comprehensive set of individual, social, and physical factors. The authors found that while physical and social environment factors influence bicycle commuting, individual factors and constraints had the strongest influence. As the authors pointed out, physical environment may be closely related with individual and social factors. Supportive bicycling environment can improve comfort and safety levels of bicycling, which in turn, can help change resident's attitudes toward bicycling over time. Similarly, Bagley and Mokhtarian (2002) found attitude variables had the greatest influence on travel behavior, while the built environment factors had little impact. Pro-driving attitude had a negative effect while pro-alternative attitude (positive attitudes toward alternative transport modes) had a positive effect on walking and bicycling. Their findings suggest that the relationship between built environment and travel behavior might be explained by personal attitudes.

To summarize, there is little consensus among the literature regarding the magnitude of the built environment effect on bicycling, and to what extent attitudes and self-selection have a role in this relationship. It seems plausible that neighborhood environment has some impact on travel behavior; however, the evidence is scant and inconsistent among different geographic and social contexts. If nothing else, it may be true that the spatial structure of the neighborhood can impose constraints on individual behavior. But for the most people who have a car, their behavior may not be restricted by neighborhood environment. Their behavior may be better explained by attitudes and perceptions, and the degree to which different attitudes play out in different circumstances. Thus, the question remains ambiguous regarding the relationship between the built environment and bicycle use, and the extent to which individual characteristics (e.g.
socio-demographic factors and personal attitudes) have on this relationship.

## III. Conceptual Framework

To better understand the relationship between the built environment and bicycle commuting, I made two hypotheses regarding the relationship between the built environment and bicycling. I also included additional hypothesis to examine any moderating role of attitudes on this relationship. Figure 1 illustrates these hypotheses including the moderating role of attitudes.


〈Figure 1〉 Moderating role of attitudes on the built environment and bicycle commuting

First, I hypothesized that people who live close to work are more likely to commute by bicycle than those who live far from work. Bicycling is good for a short-distance trip, but few studies have explored the relationship between distance and bicycle travel. Second, I hypothesized that urban residents are more likely to bicycle than rural residents. Urban areas are generally more supportive of bicycling because distance between major destinations is closer than rural areas, and more amenities are located within a bicycling distance. Because most bicycle-friendly cities are concentrated in the Northeast and West region of the U.S. (e.g. Portland, San Francisco, Philadelphia, Boston), I included geographic region as a controlling factor (Northrop, 2011). Lastly, I hypothesized that attitudes
about transportation environment would either promote or discourage people from bicycling. In addition, I incorporated several interaction terms between attitudinal factors and the built environment factors in order to examine the potential interactions between them.

## IV. Data and Methodology

The data source is 2009 National Household Travel Survey (NHTS), a nationally representative survey that asks participants to detail their travel for one full day ( $N=114,664$ ). The analysis uses all bicycle commuting trips made by the entire population in the survey. The total bicycle commuters record 656 persons, representing only a small fraction of the entire sample.

Based on the conceptual framework, I developed a binary logistic regression to determine the probability of choosing a bicycle mode for commuting. A binary logistic regression was chosen because the dependent variable was a dummy variable indicating whether a survey respondent commuted by bicycle or not. The following equations show the general form of logistic regression used in this study.

Logistic regression function,

$$
P(Y)=
$$

The linear regression equation, $z=\beta_{0}+\beta_{1} \mathrm{X}_{1}+\beta_{2} \mathrm{X}_{2}+\beta_{3} \mathrm{X}_{3}+\cdots+\beta_{k} \mathrm{X}_{k}$

Where,
$P(Y)=$ Probability of predicting dependent variable (bicycle commuting), $\mathrm{z}=$ Linear function of independent variables,
$\beta_{0}=$ Regression constant,
$\beta_{1,2, \cdots k}=$ Regression coefficients,
$\mathrm{X}_{1,2, \cdots} \quad{ }_{k}=$ Independent variables (socioeconomic/demographic factors, household characteristics, built environmental factors, attitudinal factors)

The dependent variable is a dummy variable indicating whether a person
commuted by a bicycle or not. For the independent variables, I developed four models, starting with the basic model with only socioeconomic and demographic variables, and incrementally adding household characteristics, built environment factors, and attitudinal factors. More detail specification of the variables used in the models is described in the results section.

To provide a brief summary of the models, Model 1 and 2 include socioeconomic, demographic, and household variables, commonly found in general social science literature. Model 3 builds on Model 2 by adding the built environment factors. The built environmental factors include three variables: commute distance, urban type, and geographic region. Commute distance is a one-way distance (miles) from home to work. Urban type was derived from the census classification code for describing common urban type (Table 1). Geographic region also followed the census code for regional classification. Census regions are groupings of states and the District of Columbia that subdivide the United States for the census data (U.S. Census Bureau, 2011).

〈Table 1〉 Census definition of urban size/type

| $\begin{aligned} & \text { Urban } \\ & \text { type } \end{aligned}$ | Definition |
| :---: | :---: |
| Urban | - Urban areas have highest population density scores based on density centiles <br> - $94 \%$ of block groups designated Urban have a density centile score between 75 and 99 <br> - Downtown areas of major cities and surrounding neighborhoods are usually classified as urban |
| $\begin{aligned} & \text { Suburba } \\ & \mathrm{n} \end{aligned}$ | - Suburban areas are not population centers of their surrounding communities <br> - $99 \%$ of block groups designated Suburban have a density centile score between 40 and 90 <br> - Areas surrounding urban areas are usually classified as suburban |
| Second City | - Second Cities are population centers of their surrounding communities <br> - $96 \%$ of block groups designated Second City have a density centile score between 40 and 90 <br> - Satellite cities surrounding major metropolitan areas are frequently classified as Second Cities |


| Town／ <br> Rural | －Town／Rural areas include exurbs，farming communities， and various rural areas <br> － $100 \%$ of block groups designated Rural have a density centile between 0 and 20 <br> － $98 \%$ of block groups designated Town have a density centile between 20 and 40 <br> －Exurban towns have slightly denser populations than rural areas |
| :---: | :---: |
|  |  |

Source：Claritas， 2004

Model 4 includes several attitudinal factors derived from the extended survey questionnaires asking respondent＇s views on transportation－related issues．Of the six questions concerning the respondent＇s attitudes，there were no bicycle related questions（Table 2）．However，I made an assumption that questions related to alternative transportation，such as transit or walking condition would be good proxies for assessing people＇s concern for bicycling condition．Under this assumption，two questions（b \＆c）were indirectly related with bicycling，and three other questions were also broadly related（a，d，f）．In the final model，each of the answers was coded as a dummy variable，and entered into the regression equation．

〈Table 2〉Attitudinal question regarding the respondent＇s views on transportation
Of the following issues，please tell me which one is the most important to you．Would you say．．．

A．Highway congestion
B．Access to or availability of public transit
C．Lack of walkways or sidewalks
D．The price of travel including things like transit fees，tolls and the cost of gasoline

E．Aggressive or distracted drivers
F．Safety concerns，like worrying about being in a traffic accident？
Source： 2009 National Household Travel Survey

## V. Results

Table 3 is summary statistics comparing the difference between bicycle commuters and overall commuters. Independent samples t-test was carried out to determine the significance of this difference. Bicycle commuters were significantly different from typical commuters across almost all dimensions. Bicyclists tend to be younger, and have higher income and education. Median household income of bicycle commuters is $\$ 49,434$ compared to $\$ 48,211$ for typical commuters, and $31 \%$ of bicycle commuters have a graduate degree compared to only $15 \%$ for typical commuters. Most bicycle commuters are white, healthy, and have driver's license. Fewer bicyclists own homes and cars compared to average commuters. Bicycle commuters travel significantly less than average commuters, and their built environment is evenly distributed across different urban types.

In terms of geographic distribution, bicyclists are mainly concentrated in the West and South, which was not expected in the initial hypothesis. This is partly because the geographic coverage of West and South region was arbitrarily defined by the Census (U.S. Census Bureau, 2011). Attitudinal factors show that bicycle commuters are less concerned with highway congestion and travel cost, but more concerned about lack of public transit and sidewalk, and aggressive drivers. Based on this descriptive result, it appears that bicyclists are more concerned about public transit, walking environment, and aggressive driving, all of which can be used as reasonable proxies for estimating bicyclists' attitudes.

〈Table $3-1$ 〉 Summary statistics of all commuters vs. bicycle commuters:
NHTS 2009


| Graduate school（\％） | 15 | 31 | $* * *$ |
| :---: | :---: | :---: | :---: |
| Age | $49(22)$ | 42 | $(14)$ |
| Gender |  |  | $* * *$ |
| Male（\％） | 46 | 75 | $* * *$ |
| Female（\％） | 54 | 25 | $* * *$ |
| Race |  |  |  |
| White（\％） | 86 | 4 | $*$ |
| Black（\％） | 6 | 2 | 4 |
| Asian（\％） | 2 | 86 | $* * *$ |
| Hispanic（\％） | 3 | 98 |  |
| Driver＇s license（\％） | 81 | 77 |  |
| Healthy to travel（\％） |  |  |  |

〈Table 3－2〉 Summary statistics of all commuters vs．bicycle commuters：
NHTS 2009

| Variables | $\begin{gathered} \text { All Commuters }(N= \\ 147,252) \end{gathered}$ | Bike Commuters（ $N=$ 656） | Sig． |
| :---: | :---: | :---: | :---: |
|  | Mean（S．D．） | Mean（S．D．） |  |
| Household characteristics |  |  |  |
| Household size | 2.9 | 3 | ＊ |
| Number of cars | 2.3 | 1.9 | ＊＊＊ |
| Home ownership（\％） | 89 | 74 | ＊＊＊ |
| Have a child（\％） | 41 | 47 |  |
| The built environment factors |  |  |  |
| Commute distance（miles） | 14 （23） | 3.5 （3．8） | ＊＊＊ |
| Urban size（census） |  |  |  |
| Urban（\％） | 11 | 25 | ＊＊＊ |
| Second city（\％） | 17 | 27 | ＊＊＊ |
| Suburb（\％） | 24 | 23 |  |
| Town／rural（\％） | 48 | 25 | ＊＊＊ |
| Census region |  |  |  |
| Northeast（\％） | 14 | 17 |  |
| West（\％） | 21 | 44 | ＊＊＊ |
| South（\％） | 54 | 30 | ＊＊＊ |
| Midwest（\％） | 11 | 9 |  |
| Attitudinal factors |  |  |  |
| Highway congestion（\％） | 17 | 9 | ＊＊＊ |
| Public transit（\％） | 7 | 16 | ＊＊＊ |
| Sidewalk（\％） | 3 | 9 | ＊＊＊ |
| Travel cost（\％） | 36 | 25 | ＊＊＊ |
| Bad drivers（\％） | 18 | 24 | ＊＊ |
| Safety concern（\％） | 19 | 17 |  |

After the initial descriptive analysis, four logistic regression models were developed. The dependent variable was a dummy, indicating whether an individual will bicycle for commuting. Independent variables were incrementally added to the model to examine their contribution to the outcome based on the hypothesized relationship. Initial regression diagnostics suggest no serious issue of muticollinearity, except that there might be a correlation between household size and presence of child (Pearson's correlation: -0.687). To avoid this problem household size was dropped from the analysis.
Table 4 shows the results of the four logistic regression models. Model 1 and 2 show the effects of socioeconomic and personal characteristics on bicycle commuting. There is no radical difference between Model 1 and 2, but only Model 1 shows that median household income has a significant impact on bicycle commuting. However, the effect size is very small. Every additional $\$ 1,000$ household income only decreases the odds of bicycling by $0.3 \%$, everything else being equal. As the model adds more variables, the effect of household income quickly diminishes. Model 1 and 2 generally agree that having a graduate degree, being male and healthy, all increase the likelihood of commuting by bicycle. Being older, black, and having a driver's license also decreases the likelihood of bicycling. Being black and having a driver's license reduce the odds of bicycling by more than half while having a good health more than doubles the odds of bicycling, everything else being equal.

Taking into account the household characteristics, Model 2 shows, holding other things equal, every additional car in the household almost halves the odds of bicycling, and the similar negative effect is observed when someone owns a home and raises children. It should be noted that these household characteristics reduce the effects of graduate degree, black ethnicity, and driver's license. Intuitive, it makes sense that additional child in the household decreases the odds of bicycling. Each child adds a chauffeuring duty, adding more vehicle trips by parents in the household. However, as more variables are added in the model, household characteristics become insignificant, indicating that other variables are better predictors of
bicycling.
Model 3 adds the built environmental factors, which is one of the central hypotheses of this paper. As expected, every additional mile of commute distance reduces the odds of bicycling by almost $20 \%$, else being equal. Compared to rural residents, urban and second city residents are almost $50 \%$ more likely to commute by bicycle. Also, compared to people in the Mid-west, people in the West and the Northeast are more likely to bicycle (e.g. more than quadruple the odds of bicycling if she lives in the West). Contrary to the overwhelming number of bicyclists found in the South (Table 4), living in the South does not make any significant difference as opposed to living in the mid-west. When the built environmental factors are added, effects of almost all variables decrease, except for the gender effect. Taking into account the built environment factors in model 3, the effect of being male increases by almost $50 \%$ ( 1.09 to 1.24 ), suggesting that the gender effect on bicycle use might be underestimated if the built environment factors are not controlled for.
Model 4 shows the final model that includes the attitudinal factors. Interestingly, four out of five attitudinal factors are significant in the model, reporting relatively large effect sizes. Being concerned with lack of sidewalk more than quadruples the odds of bicycling, controlling for other variables in the model. Being concerned with lack of transit service, bad drivers, and safety almost doubles the likelihood of bicycling, else being equal. Note that attitudinal variables further increase the effect of gender on bicycling ( 1.24 to 1.32 ) while reducing the effects of other variables. Inclusion of attitudinal factors reduces the effects of urban types, making them almost insignificant in Model 4.

〈Table 4〉Estimates (log-odds and odds) from selected logistic regression models of likelihood of commuting by bicycle ( $=1,0$ otherwise) : NTHS 2009 ( $\mathrm{N}=656$ )

| Independent Variables | Models |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 |  | 2 |  | 3 |  | 4 |  |
|  | $\beta$ | $\exp (\beta)$ | $\beta$ | $\exp (\beta)$ | $\beta$ | $\exp (\beta)$ | $\beta$ | $\exp (\beta)$ |
| Socioeconomic characteristics |  |  |  |  |  |  |  |  |
| Median HH income (\$) | -1E-05 *** | 1.00 | -9E-07 | 1.00 | 2E-06 | 1.00 | 5E-07 | 1.00 |
| Education (no HS reference) |  |  |  |  |  |  |  |  |
| High school diploma | -0.32 | 0.73 | -0.26 | 0.77 | -0.22 | 0.80 | -0.18 | 0.83 |
| College degree | 0.14 | 1.15 | 0.07 | 1.08 | 0.08 | 1.09 | 0.21 | 1.24 |
| Graduate degree | 1.05 *** | 2.87 | 0.77 ** | 2.16 | 0.67 *** | 1.96 | 0.70 * | 2.02 |
| Personal characteristics |  |  |  |  |  |  |  |  |
| Age (year) | -0.03 *** | 0.97 | -0.03 *** | 0.97 | -0.03 *** | 0.97 | -0.03 *** | 0.97 |
| Male (female reference) | 1.09 *** | 2.96 | 1.09 *** | 2.98 | 1.24 *** | 3.47 | 1.32 *** | 3.76 |
| Race (white reference) |  |  |  |  |  |  |  |  |
| Black | -0.81 ** | 0.44 | -1.05 *** | 0.35 | -0.79 *** | 0.45 | -0.85 * | 0.43 |
| Asian | -0.47 | 0.63 | -0.64 | 0.53 | -0.91 ** | 0.40 | -1.01* | 0.36 |
| Hispanic | -0.28 | 0.76 | -0.43 | 0.65 | -0.66 * | 0.51 | -0.51 | 0.60 |
| Multiple/other | 0.64 | 1.90 | 0.39 | 1.48 | -0.10 | 0.90 | 0.62 | 1.85 |
| Driver's license | -2.35 *** | 0.10 | -1.62 *** | 0.20 | -1.20 *** | 0.30 | -1.06 *** | 0.35 |
| Good health | 0.92 ** | 2.50 | 0.92 ** | 2.50 | 0.84 * | 2.32 | 1.04 * | 2.82 |
| Household characteristics |  |  |  |  |  |  |  |  |
| \# cars per household |  |  | -0.66 *** | 0.52 | -0.53 *** | 0.59 | -0.54 *** | 0.58 |
| Own a home |  |  | -0.47 *** | 0.62 | -0.08 | 0.92 | -0.04 | 0.96 |
| Have a child |  |  | -0.50 ** | 0.61 | -0.40 ** | 0.67 | -0.33 | 0.72 |
| Built environment factors |  |  |  |  |  |  |  |  |
| Commute distance (mile) |  |  |  |  | -0.24 *** | 0.79 | -0.22 *** | 0.80 |
| Urban type (rural reference) |  |  |  |  |  |  |  |  |
| Urban |  |  |  |  | $0.47{ }^{\text {*** }}$ | 1.60 | 0.44 * | 1.56 |
| Second city |  |  |  |  | 0.39 ** | 1.48 | 0.32 | 1.37 |
| Suburban |  |  |  |  | 0.15 | 1.16 | 0.13 | 1.14 |
| Census region (mid-west ref) |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Northeast |  |  |  |  | 0.50 * | 1.64 | 0.43 | 1.53 |
| West |  |  |  |  | 1.21 *** | 3.35 | 1.19 *** | 3.28 |
| South |  |  |  |  | 0.18 | 1.20 | 0.15 | 1.16 |
| Attitudinal factors (congestion ref) |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Transit issue |  |  |  |  |  |  | 0.92 *** | 2.52 |
| Sidewalk issue |  |  |  |  |  |  | 1.22 *** | 3.39 |
| Cost concern |  |  |  |  |  |  | 0.16 | 1.18 |
| Bad driver |  |  |  |  |  |  | 0.65 ** | 1.91 |
| Safety concern |  |  |  |  |  |  | 0.53 * | 1.70 |
| Constant | -2.90 *** | 0.06 | -2.17 *** | 0.11 | -2.60 *** | 0.07 | -3.41 *** | 0.03 |
| Chi-square | 442 |  | 618 |  | 1176 |  | 983 |  |
| df | 12 |  | 16 |  | 23 |  | 28 |  |
| BIC | -302 |  | -431 |  | -908 |  | -657 |  |

Overall, Model 3 is the best model because it has the best model fit (indicated by smaller Bayesian Information Criterion and large chi-square value) with less parameters. However, Model 4 offers some important insights in understanding the role of attitudes on bicycling. Though the attitudinal variables did not improve the overall model fit, their contribution to the model outcome is significantly large, especially with regards to the attitudes toward sidewalk and transit. To further investigate this effect, I included several interaction terms between the attitudinal factors and the different urban types and geographic regions. I also tested the presence of interaction effects between gender and attitudes. No interaction terms were found significant in any combinations, and no single interaction contributed to the overall model fit. This finding may lend moderate support to hypotheses regarding attitudes and self-selection, suggesting that some aspect of attitudinal factors may have an independent effect on bicycle commuting. However, the relationship between broad attitudinal factors and bicycle commuting is tenuous at best, and the differences may be attributable to other unmeasured covariates.

## VI. Discussion and Implication

The results of the models estimated here indicate that urban residents are more likely to travel by bicycle than suburban or rural counterparts, and the likelihood of bicycling quickly drops as commuting distance increases. As shown in the predicted percentage of bicycle commuting (Figure 2a), the threshold distance is between 15 to 20 miles. Promoting bicycle commuting beyond that threshold is likely to fail, because of escalating physical challenge associated with longer bicycle commute. Figure 2b also shows that lower urban density reduces the likelihood of bicycling to work for typical male cyclists. In suburban and rural settings, it is possible that major destinations (i.e. work, shopping malls, post office, etc.) are spatially distributed across larger areas than in urban setting, making bicycle commuting a challenging task.


〈Figure 2〉Predicted percentage of bicycle commuting by distance to work and by urban types

In terms of the regional differences, living in the West region significantly increases the likelihood of bicycling. This regional influence carries on even after controlling for other variables including socio-demographic and attitudinal factors. However, the effects of urban type diminishes when the regional factors are controlled, indicating that some of the effects from urban density can be attributable to broader regional difference in bicycling levels. Evidently, most bicycle-friendly cities are concentrated in the West region (e.g. Portland, San Francisco, Seattle, and Boulder). Therefore, diminishing effect of urban density indicates that some parts of the country may have better bicycle facilities and street network configuration more conducive to bicycling. Still, the residual "density effect" represents a yet unexplained phenomenon, around which further hypotheses can be built (Transportation Research Board, 2005).
Finally, the model results provide some support for the hypothesis that unexplored attitudinal f may explain some of the differences in bicycling behavior. Figure 3 shows that while the attitudinal factors are more pronounced among urban residents, the proportion of their effects remain relatively similar across different urban types. This explains why no interaction terms were significant in the model, suggesting that bicycle commuters share the same attitudes towards their neighborhood environment regardless of the built environment. This also suggests that the expected moderating role of attitudes still remains uncertain, and further research is necessary to uncover underlying mechanism that can
explain the role of attitudes on bicycling behavior（Cao et al．，2009）．


〈Figure 3〉Predicted percentage of bicycle commuting by attitudinal factors stratified by urban／rural living

Despite some of the limited findings with the interaction terms，the general findings of this paper offer some important implications for future bicycle policy and planning．Currently，many existing bicycle programs focus on improving physical conditions of bicycling，by increasing urban density and building more bicycle infrastructure．While these efforts may benefit overall population，findings of this study suggest that certain population group may be more impacted than others．One of the most important factors that influence the likelihood of using bicycle was gender．Male population was significantly more likely to use bicycle than female population， regardless of the built environment conditions．The interaction between gender and safety concern was not significant in this study；however，other literature suggests that safety concern is one of the most important detriments to bicycling for women（Emond，Tang，\＆Handy，2009）．Given this difference in gender gap and attitudinal factors，more efforts should be dedicated to help female population help overcome their fears in riding a bicycle to work and school．Effective strategies may include improving safety conditions of the current bicycle facilities and providing more bicycle safety training programs to potential female riders．While the NHTS dataset is limited in answering some of the more challenging question，this research
suggests that soft policy may indeed help promote more bicycling. For a policy implication, it would be desirable to combine both soft and hard policy as much as possible in order to get the most desirable outcomes in promotion of bicycle commuting.

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