An Analysis of Bicyclists and Bicycling Characteristics:
Who, Why, and How Much are they Bicycling?

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ABSTRACT

The objective of this paper is to explore and unravel the factors influencing the decision to bicycle, with a view to inform the development of appropriate and effective strategies to increase bicycling use and promote the health of individuals as well as the environment. The data used in the analysis are drawn from a survey of Texas bicyclists, and the study includes a comprehensive explanatory analysis of bicyclists and their bicycling habits. Further, different econometric models are employed to evaluate the determinants of bicyclists' perception, in terms of safety and quality issues, and the frequency of bicycling for commute and non-commute purposes. In general, the results of the study indicate that the perceptions of the quality of bicycle facilities and safety from traffic crashes show significant variation based on bicyclists' demographic and work characteristics, and bicycle amenities/facilities on the commute route and at the work place. Also, bicyclist demographics (gender, age, education level, and commute distance), household demographics (number of automobiles, number of bicycles, and number of children), residential location and season, bicycle amenities at work (bicycle racks and showers), bicyclist perceptions of the overall quality of bicycle facilities, and bicycle use characteristics impact commute and non-commute bicycling frequency. These study results can assist in the development of informed policies to increase commute and non-commute bicycling, and also highlight the continuing need for detailed surveys to understand bicycling behavior.

1. INTRODUCTION

In recent years, there has been an increasing interest in encouraging bicycling as a mode of transportation, or simply as a pure recreational activity, among transportation planning agencies and public health organizations. This is because of the awareness of the numerous societal and environmental benefits of bicycling. From a transportation perspective, bicycling can help alleviate the negative consequences of automobile use, including growing traffic congestion, air quality degradation, increased energy consumption, and high dependency on foreign fuel supplies (see *1-6*). In addition, as suggested by the Pedestrian and Bicycle Information Center (*7*), bikeable communities will ensure a more equitable provision (across individuals in society) of access to activities, because bicycling presents an inexpensive choice of transportation that is affordable to all citizens. From a public health perspective, bicycling can provide several benefits by promoting physically active life styles, especially at a time when the problems caused by physical inactivity have become a threatening public health concern (*8,9*). For instance, the World Health Organization (WHO) has identified obesity as one of the top ten health risks in the world, and the Center for Disease Control and Prevention (CDC) (*10*) recently indicated that there has been a dramatic increase in obesity during the past two decades in the U.S.

The benefits of bicycling are well-acknowledged in the transportation and public health fields, as just discussed. However, the percentage of individuals who bicycle continues to be low in the U.S. For instance, the 2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors revealed that only 27.3% of the driving age public (aged 16 and older) in the U.S. rides a bicycle even once during the summer period. Obviously, the percentage of regular bicyclists is much smaller. Specifically, only 0.9% of all trips in the U.S. are undertaken by bicycle, and the percentage drops even further to 0.4% for commute trips. This low bicycling mode share is despite the fact that a significant fraction of trips in the U.S. are short-distance trips that can be undertaken using a bicycle. For example, a study of the 2001 National Household Travel Survey (NHTS) observed that 41% of all trips in 2001 were shorter than 2 miles, and 28% were shorter than 1 mile.

There may be several reasons for the low bicycling use in the U.S. [see Dill and Voros (*11*)]. The objective of this paper is to explore and unravel these reasons by examining the factors influencing the decision to bicycle. The intent of the research effort is to inform the development of appropriate and effective strategies to increase bicycling use and promote the health of individuals as well as the environment.

The remainder of the paper is organized as follows. The next section briefly discusses the earlier literature on bicycling determinants, and positions the current study within this broader context. Section 3 describes the data collection procedures as well as the sample used in the analysis. Section 4 presents the results of a descriptive analysis of bicyclist and bicycling characteristics. Section 5 outlines the modeling methodology employed for the empirical analysis of bicyclist perceptions of bicycle facilities and safety, as well as bicycling frequency of bicyclists. Section 6 presents empirical results. Finally, Section 7 summarizes the important findings from the study and concludes the paper with policy recommendations.

2. FACTORS INFLUENCING BICYCLING BEHAVIOR

An individual's decision to bicycle may be influenced by several factors, which may be broadly classified into three categories: (1) Individual and household demographics (such as age, gender, race, household vehicle ownership, and household income), (2) Individual attitudes and perceptions (such as perceptions of safety and security, perceived time/cost, and attitudes regarding physical activity participation), and (3) Neighborhood characteristics, bicycle facilities, and related amenities (such as land use, environmental factors, presence and types of bicycle facilities, presence of showers and lockers at the work place, *etc*.). In the current section, we briefly discuss earlier studies that have considered one or more of the above factors in examining bicycling behavior.

2.1 Individual and Household Demographics

Individual and household demographics play an important role in the bicycling decision. At the individual level, Baltes (*12*) found a high proportion of adults aged 16-29 in the pool of individuals who bicycle to work. The results of the study by Dill and Voros (*11*) also supported the finding that younger individuals are more likely to bicycle for utilitarian purposes. On the other hand, Moudon *et al.* (*13*) observed that individuals aged 25-45 years bicycled more than individuals aged 18-21. Also, according to their study, white and male respondents, and individuals who spend fewer hours at work, are more inclined to bicycle (see also Parkin *et al.*, (*14*) for similar conclusions in terms of ethnicity). However, the National Survey of Pedestrian and Bicyclist Attitudes and Behaviors Report (*15*) suggests a higher propensity of bicycling among Hispanics compared to non-Hispanic whites. On the other hand, the analysis of the 1995 Nationwide Personal Transportation Survey by Pucher *et al.* (*16*) reinforces the findings of Moudon *et al.* (*13*) that men are more likely to bicycle than women, an observation also supported by McClintock and Cleary (*17*) and Parkin *et al.* (*14*).

In addition to the individual factors mentioned above, previous studies have found that respondents in high income households are more likely to bicycle relative to those in low income households (see *11*, *14*). Dill and Voros (*11*) also observed an increased propensity to bicycle among individuals in households with fewer motorized vehicles. Similarly, Xing *et al.* (*18*) found that the frequency of bicycling decreases with an increase in auto ownership and household size.

2.2 Individual Attitudes and Perception

Individual attitudes and perception have been found to play a significant role in the decision to bicycle, and include perceptions of safety from crashes, perceptions of safety from crime, exercise habits, and an overall perception of bicycle facilities (see *19*). For instance, earlier studies have indicated the following: (1) The perceived presence of bicycle lanes and trails positively affects bicycling behavior (*13*), (2) Individuals who have not bicycled in the past 30 days are less satisfied with the state of bicycle facilities (*15*), and (3) Neighborhoods where individuals perceive a higher safety risk have lower physical activity levels and lower bicycling levels (*20*). While there is evidence from earlier bicycling-related studies of the influence of individual attitudes and perceptions on bicycling use, there have been relatively few studies examining the role of these factors.

2.3 Neighborhood Characteristics, Bicycle Facilities, and Related Amenities

The recognition of the importance of neighborhood characteristics, as well as bicycle facilities and amenities, on bicycling has motivated a number of earlier studies to investigate the effects of these determinants. The variables in this category include topography, land-use patterns, climate, bicycle facilities and facility quality, and bicycle amenities (such as showers at work sites and bicycle racks on buses).

In terms of topography, Parkin *et al.* (*14*), Stinson and Bhat (*21*), Cervero and Duncan (*22*), and Sener *et al.* (*23*) found the presence of steep hills to be a major deterrent to bicycling, especially for women. Cervero and Duncan (*22*) examined land use effects and suggested an increase in bicycling levels in the presence of a rich land use mix. Dill and Carr (*24*), in their study, examined climate effects (among other effects) and suggested that rain has a negative effect on commute bicycling [see also Nankervis (*25*) and Parkin *et al.* (*14*) for similar results]. However, Cervero and Duncan's study did not find any such effect of rainfall on bicycling. Winters *et al.* (*26*) and Nankervis (*25*) observed a reduction in bicycling in cold weather.

The examination of bicycle facilities, facility quality, and bicycle amenities on bicycling propensity has received substantial attention in the literature. The results of these studies include the following: (1) Residents of neighborhoods with a high bicycle lane density and high population/employment density bicycle more (*14, 24, 27*), (2) A more integrated and connected transportation network encourages non-motorized travel (*28*), (3) Bicyclists prefer bicycle lanes that are separated from motorized traffic relative to shared roadways or wide outside lanes (*21, 29-31*), (4) There is an inverse relationship between the quality of the pavement surface and bicycling use (*14, 32*), and (5) The presence of secure parking and showers at the work place encourages bicycling to work (*33-35*).

2.4 The Current Paper in Context

The review of the existing literature underscores the potentially large number of factors affecting an individual's decision to bicycle and her/his bicycling frequency. Although there has been a growing interest in examining bicycling behavior, there has been relatively limited research on the effects of such potential determinants of bicycling as environmental factors, perceptions, and attitudes of bicyclists. In particular, most of the existing studies have focused on the effects of bicyclist demographics (for instance, age, gender, vehicle availability, *etc.*) and route-related factors (for instance, traffic conditions, bicycle facility design, lighting, *etc.*), but there is less focus on the influence of individuals' perception of safety, comfort, and satisfaction levels, as well as the influence of seasonal and locational variations (see *13*). In addition, since many earlier studies are based on univariate descriptive analyses, they are unable to provide a full multivariate picture of the trade-offs among factors influencing the decision to bicycle as well as the frequency of bicycling. Further, the few multivariate studies examining bicycling behavior [see for example, (*21, 23, 31, 35*)] have focused on bicycle route choice decisions rather than bicycle use and frequency decisions. In fact, this study, to our knowledge, is the first to comprehensively examine the underlying attitudes and perceptions that influence bicycling use and frequency.

To summarize, this paper contributes to the existing research by adopting a multi-level analysis, including (1) a detailed exploratory analysis of bicycle use and bicycling habits, and (2) a multivariate econometric modeling analysis to evaluate the determinants of bicyclists' perception and bicycling use/frequency. While the exploratory analysis provides general information on factors affecting bicycling propensity and bicycling characteristics at a univariate level, the econometric models allow us to control multiple determinants simultaneously to draw conclusions at a multivariate level. The current research aims to answer not only the question of "who is bicycling?" but also "why is s/he bicycling?" and "how much is s/he bicycling?". The empirical analysis is based on a sample of individuals who reside in the State of Texas, as discussed next.

3. DATA AND SAMPLE FORMATION

3.1 Data

The data used for the current study are obtained from a web-based survey of Texas bicyclists. A web-based survey approach is adopted for several reasons. First, such an approach is inexpensive to the researcher in the context of disseminating information about the survey, easier for respondents to answer, and is environmentally friendly. Second, a web-based survey has a quick turn-around time (in terms of receiving responses), and also saves considerable effort in processing since the data are directly obtained in electronic form. Third, question branching is straightforward to implement in web-based surveys based on an individual's response to earlier questions. That is, only the relevant questions are presented to a respondent.[1]

The survey was designed for the internet, using a combination of HTML, JavaScript and Java programs. After several iterations based on feedback gathered from pilot surveys, the survey was finalized with 45 questions (requiring about 15 minutes). The final version of the survey instrument is available at http://www.ce.utexas.edu/prof/bhat/bicyclesurvey/.

The survey was administered through a web site hosted by The University of Texas at Austin. The authors contacted the administrators of several bicycle groups and bicycle forums in Texas cities (such as Austin, Dallas, Houston, El Paso, Waco, Lubbock, Tyler, and College Station), and asked them to forward the information to their members. The survey link was also e-mailed to student groups in Texas universities. Further, we disseminated information about the survey to media outlets in Austin (including newspapers and television channels). Moreover, the survey information was also circulated with the help of metropolitan planning organizations and Texas Department of Transportation offices.

The final survey collected detailed information on bicyclist perceptions and bicycling characteristics from respondents aged 18 years or older, residing in more than 100 cities across Texas. The final sample employed for the current research includes 1605 bicyclists. Of the 1605 individuals, 810 (50.5%) respondents used their bicycle for commuting and are designated as commuter bicyclists in the current study (801 of these 810 commuter bicyclists also bicycle for non-commuting purposes such as running errands, exercising, visiting friends or family, recreation, and racing/stunt-riding). In the survey, commuter bicyclists were presented with questions confined to their commuting patterns to keep the survey length manageable. The remaining 795 individuals (49.5%) bicycled only for non-commuting purposes, and are designated as non-commuter bicyclists. These respondents were presented with questions pertaining to their non-commuting habits and levels.

3.2 Sample Formation and Analysis Context

The data from the completed web survey responses were downloaded in ASCII format, and then imported into SPSS. The records of respondents who provided incomplete information (about

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[1]The use of a web-based survey will not provide a representative sample of the population at large. Indeed, coverage bias is the primary limitation of the web-based surveys resulting from some population segments not having access to or not informed about the use of the internet (*36*). One possible solution to overcome this limitation is to implement a multi-method survey combining a variety of survey methods. But such a survey, in addition to its high-cost characteristics, can result in significant measurement error (*i.e.* the same question can be answered differently because of the different survey methods used) [(*37*); see also TCRP (*36*) for a detailed discussion of this point]. On the other hand, a web-based survey is a low-cost approach that is effective when targeting bicyclists, who tend to be quite well educated. Also, the focus of our effort here is on obtaining information from individuals who have had some experience in bicycling, since the objective is to obtain useful information for an objective assessment of bicycle facilities and an analysis of bicycling concerns/reasons.

5% of all responses received) were removed from the dataset. Next, several screening steps were undertaken to ensure the consistency of the respondent's survey, including checking the reported commute distance traveled, and reported bicycle travel times.

This paper undertakes two different types of analyses. The first analysis is exploratory in nature, and involves a descriptive analysis of bicyclist and bicycling characteristics. The second, econometric, analysis models bicyclists' travel perceptions and bicycling frequency. Two specific dimensions of bicyclists' travel perceptions are considered: 1) bicyclists' overall quality perception in terms of bicycle facilities, and 2) bicyclists' safety perception from the standpoint of traffic crashes. For the first dimension**,** bicyclists were asked to evaluate the quality of bicycle facilities in their community by providing a rating on a 4-point ordered scale - "very inadequate", "inadequate", "satisfactory" and "excellent". For the second dimension, respondents were asked to provide their responses on another 4-point ordered scale - "very dangerous", "somewhat dangerous", "somewhat safe" and "very safe". These ordered response ratings serve as the dependent variables for the perception models. The econometric analysis of bicycling frequency includes two separate models, one each for commuter and non-commuter bicyclists. In these models, the dependent variable is based on an ordered categorization –"never", "about once or twice a month (or less frequently)", "about once a week", "about 2-3 days a week" and "about 4-5 (or more) days a week". The time period used for the frequency analysis is 3 months, corresponding to each of the four seasons of the year – winter, spring, summer, and fall.

4. EXPLORATORY ANALYSIS

The following sections present demographic/work-related characteristics and bicycling characteristics of the survey respondents.

4.1 Demographic and Work-Related Characteristics

Table 1a provides descriptive statistics on bicyclist and household demographic characteristics, as well as the residential location of bicyclists. As can be observed from the table, 29% of respondents are female and 71% are male [these gender shares are somewhat skewed toward males compared to the national bicycling shares of 37% and 63% for females and males, respectively; see (*15*)]. Among the female respondents, 45% are commuter bicyclists, while the corresponding figure for male respondents is 53% (this statistic is not presented in the table). That is, men are more likely to bicycle to work relative to women. In terms of age, 87% of those in the 18-24 year age group, 61% of those in the 25-34 year age group, 49% of those in the 35-44 year age group, 35% of those in the 45-64 year age group, and 19% of those at or above the age of 65 years bicycle to work. The implication is very clear - younger bicyclists are more likely to bicycle to work than are older bicyclists, perhaps because younger individuals are more environmentally conscious and use the bicycle for all purposes, not just for exercising/recreational purposes.

About two-thirds of the respondents are between the ages of 35 and 64 years, as shown under "Age" in Table 1a. Respondents also have high education levels, which is to be expected since bicyclists tend to be in the higher education/income groups (*38*). Also, a web-based survey may contribute to the bias toward highly educated individuals. Finally, among the bicyclist demographics, all respondents possess a driver's license.

The household demographic characteristics show that about half of the respondents live in the Austin area. This over-representation of Austin respondents is a direct consequence of our media efforts, which were heavily focused in the Austin area. In terms of motorized vehicle ownership, the vast majority of bicyclists' households own at least one automobile, with 71% owning two or more vehicles. Further, all bicyclists own at least one bicycle, with 87% having at least two bicycles in their households. About 20% of respondents live alone, while almost three-fourths of the bicyclist households have no children. This latter result is perhaps a reflection of exclusive motorized vehicle use when children are present in the household.

Table 1b presents the descriptive statistics on the work-related characteristics of commuter bicyclists. Among these respondents, the commute distance ranges from a quarter of a mile to 35 miles, with an average of about 6.5 miles and a median value of 5 miles. 57% of the commuter bicyclists live within 5 miles from their work place, with about half of them living within 2 miles or less. The high representation of commuter bicyclists in the short commute distance categories may be because individuals who are bicycling-inclined choose their home and work places to be in close proximity of one another, or because compact land-use development indeed triggers higher bicycle use, or a combination of both of these [see Bhat and Guo (*39*)]. Interestingly, however, the results also reveal a sizeable fraction of commuters (20%) residing beyond 10 miles from their work place.

The work start time and work end time distributions of commuter bicyclists are shown in the second and third columns of Table 1b, respectively. The majority of the commuter bicyclists start work between 8 and 11 AM, with over four-fifths of respondents starting their workday after 9 AM and about a fifth of respondents starting their workday after 11 AM. The high level of bicycling among "late work-start" commuters is potentially a manifestation of flexible work schedules, which may help avoid dangerous (from the standpoint of traffic crashes) peak period traffic conditions. With respect to work end time distributions, Table 1b shows that 62% of bicyclists end their work day after 5 PM, with a significant fraction ending their workday before 3 PM (21%) and after 7 PM (17%). Similar to the positive impact of off-peak work start time on commute bicycling, off-peak work end times also appear to encourage bicycling to work.

In addition to examining the work start and end time distribution of commuter bicyclists, we also examined work schedule flexibility effects directly in terms of whether the respondent believes it would be easy for her/him to arrive at work 30 minutes late and/or leave 30 minutes early from a work schedule point of view. By this definition, more than half of the commuter bicyclists have flexible arrival times, and close to half of them (44% to be precise) have flexible departure times (see last column of Table 1b). This reinforces the discussion above about the positive relationship between flexible work schedules and the use of the bicycle as the commute mode.

4.2 Bicycling Characteristics

The bicycling characteristics elicited in the survey may be categorized into three groups: (1) Bicyclists' travel perceptions, (2) Bicycle use characteristics, and (3) Bicycle commute-related characteristics.

4.2.1 Bicyclists' Travel Perceptions

The bicyclists' travel perceptions indicate that about 69% of respondents feel bicycling is "somewhat dangerous" or "very dangerous" from the standpoint of traffic crashes. In contrast, only 21% of respondents feel bicycling is "somewhat dangerous" or "very dangerous" in the context of crime. Obviously, safety from traffic crashes is more of a concern than safety from crime. Further, 79% of the respondents characterized the overall quality of bicycle facilities in their respective communities as "inadequate" or "very inadequate". These results highlight the need to improve bicycle facility infrastructure (or at least the perception of bicycle facility infrastructure).

4.2.2 Bicycle Use Characteristics

Table 2a provides information regarding the distribution of bicycle use characteristics, including the bicycling purpose, duration and season of bicycling for both commuting and non-commuting, and bicycling frequency for commuting and non-commuting during different time periods of the year. Exercising is the most common reason provided for bicycling, followed by recreation (such as parades, riding with family around the block, *etc*.), and running errands (see the top panel of Table 2a).[2] Clearly, bicyclists value health-related benefits, and perceive bicycling as a means of physical activity participation. The statistics corresponding to bicycling duration (*i.e*., the time period that the respondent has been bicycling on a regular basis for commuting and/or non-commuting purposes) in Table 2a reveal that a little more than 70% of those who bicycle to work have been doing so regularly for more than a year (see left panel in the middle of the table). In comparison, respondents have been bicycling longer for non-commuting purposes, with 88% of commuter bicyclists (*i.e.*, those who use the bicycle for both commuting and non-commuting purposes) and 90% of non-commuter bicyclists (*i.e.*, those who use the bicycle for only non-commuting purposes) doing so for over a year. In general, these results suggest that bicycling for non-commuting precedes bicycling for commuting, if respondents ever decide to commute by bicycle. Perhaps individuals like to get comfortable with bicycling around their neighborhood in relatively safe environments before evaluating whether or not to bicycle to work in dense traffic conditions. Alternatively, health conscious individuals may start off bicycling solely for exercise, and realize over time that they can extend health benefits and contribute less to environmental pollution by also bicycling to work.

Table 2a also provides information on the seasons of the year when the bicycle is used for commuting by commuter bicyclists and when the bicycle is used for non-commuting by commuter and non-commuter bicyclists. The fall and spring seasons are the periods during which bicycling to work is most prevalent, while the winter season is the most unpopular period for bicycling to work, perhaps due to inclement weather conditions. There is much less variation across seasons in bicycling tendency for those who bicycle for non-commuting reasons, though the winter period is still the one when bicycling is the least prevalent, especially for those who bicycle only for non-commuting reasons (*i.e.*, the non-commuter bicyclist sample in the table).

The bicycling frequency statistics for each season are shown in Table 2b.[3] In general, the results show that, for all seasons, respondents are more likely to bicycle once or more for non-commuting than for commuting (see the higher percentages for commuting compared to non-commuting for the “never” row of Table 2b). However, those who bicycle to work once or more in any given season do so much more regularly across days of the week (see the higher numbers for each season in the last row of the table for commuter bicyclists compared to non-commuter bicyclists). Thus, there is a significant fraction of commuter bicyclists who are very bicycle-

[2] The percentages across purposes sum to greater than 100 because respondents can choose multiple reasons for bicycling.

[3] There are no statistics corresponding to non-commuting bicycling frequency for commuter bicyclists in the table, even though almost all commuter bicyclists also use the bicycle for non-commuting purposes. This is because we presented season-specific frequency questions relevant only to the commute for commuter bicyclists, to keep the survey length manageable. However, based on the results of Table 2a that do not show substantial variation in bicycle use between commuter and non-commuter bicyclists for non-commuting reasons, it is quite likely that there will also be no substantial differences in frequency of use across these two bicyclist groups for non-commuting.

loyal, and who ride to work almost every day. These individuals tend to be younger than their peers, which reinforces the notion that they are the "environmentally conscious younger generation" of our time. Across seasons, while the summer season (May to August) is one of the two periods when individuals are most likely never to use the bicycle to work (the other period being the winter season), it is the period when bicycling for non-commuting is most frequent. This is intuitive, given the hot summers in Texas, and the perceived lack of bicycle amenities (such as clothing lockers and showers) at or during travel to the work place/school (as discussed later in this section). However, the summer period is also the time when there is likely to be more recreational/leisure bicycle riding with children and friends.

Table 3 provides the distribution of the leading reasons for, and deterrents to, bicycling. Fitness and heath concerns, followed by pleasure/enjoyment (or leisure), are the most compelling reasons for commuting as well as non-commuting. Also, those who bicycle to work identify being "environmental friendly" as an important reason for bicycling to work, while this is not an important reason for bicycling for non-commuting purposes (a further analysis indicated that young individuals are more likely to identify environmental friendliness as the reason for bicycling to work). This supports the notion discussed earlier that those who bicycle to work are young and more eco-friendly, and see their act of bicycling to work as a way of contributing less to environmental degradation. In addition to environmental considerations, those who bicycle to work are also driven by the convenience/speed of bicycling, a desire to avoid driving a car in congested traffic conditions, financial considerations, and limited auto parking. Interestingly, commuter bicyclists also identify these issues more often than non-commuter bicyclists as reasons for bicycling for non-commuting. Overall, those who bicycle to work have a more diverse set of reasons to bicycle (for both commuting and non-commuting purposes) than those who bicycle only for non-commuting reasons. Finally, Table 3 suggests that, regardless of the reason for bicycling (*i.e.,* commuting or non-commuting), and whether an individual is a commuter bicyclist or a non-commuter bicyclist, the biggest deterrent to bicycling is inclement weather conditions.

4.2.3 Bicycle Commute-Related Characteristics

As illustrated in Table 4, most commuter bicyclists (72%) have to travel unsigned shared roadways (*i.e., roadways without bike signage or pavement marking*) on their commute route. The results also show that a significant percentage of commuters use bicycle lanes (*designated portions of the roadway striped for bicycle use*), or a combination of bicycle lanes/unsigned shared roadways, or signed shared roadways (*shared roadways designated by signing as a preferred route for bicycle use*). In terms of bicycle amenities, a relatively sizeable fraction of commuter bicyclists (68%) indicate the existence of bicycle racks at their work place/school, while a reasonable percentage also indicate the presence of showers and bicycle racks on buses. Unfortunately, the presence of other amenities is less common. As we will see later in Section 6, the high prevalence of unsigned shared roadways on the commute route and the lack of bicycle lockers or safe storage rooms, in particular, contribute to the negative perceptions relating to the overall quality of bicycle facilities.

Finally, the survey data indicate that about 4% of respondents have been involved, during their bicycling experience, in a crash with a parked vehicle or vehicle being parked. About half of the crashes occurred when the driver of the parked vehicle was moving the car into or out of a parking spot, while about one third of them occurred when the driver of the parked vehicle opened the door.

5. MODEL STRUCTURE

As indicated earlier in Section 3.2, the dependent variables in the perception models and the frequency models take an ordinal discrete form. Further, for the frequency models, there are multiple responses from the same individual, corresponding to bicycling frequency in each of four different seasons. In this section, we present the model structure for the frequency models, because they take a more general mixed ordered response form compared to the perception models that take a simple ordered response form (because there is only one response per individual in these perception models).

Let q (q = 1, 2, …, Q) be an index to represent individuals, and k (k = 1, 2, 3, …, K) be an index to represent the ordered categories of bicycle frequency. Further, let t (t = 1, 2, 3, …, T) be an index of seasons, with T = 4 in the current empirical context. Then, the equation for modeling the ordinal variable may be written as follows:

$$y^*_{qt} = (\alpha' + \delta'_q)\, x_{qt} + \varepsilon_{qt}\,, \quad y_{qt} = k \text{ if } \psi_{k-1} < y^*_{qt} < \psi_k \tag{1}$$

The equation is associated with the latent bicycling propensity y^*_{qt} of individual q in season t. This latent propensity y^*_{qt} is mapped to the actual ordinal frequency variable y_{qt} by the ψ thresholds ($\psi_0 = -\infty\,, \psi_1 = 0$, and $\psi_k = \infty$) in the usual ordered-response fashion. x_{qt} is a (M x 1)-column vector of attributes that influences the propensity associated with the individual q in season t, and includes a constant. α is a corresponding (M x 1)-column vector of mean effects, and δ_q is another (M x 1)-column vector of unobserved individual factors moderating the influence of attributes in x_{qt}. For instance, a particular individual may be generically more bicycle-inclined, even after controlling for all the observed independent variables. This generic unobserved propensity will increase bicycle propensity for the individual across all seasons t, which can be captured by introducing an unobserved term in the δ_q vector corresponding to the constant term in x_{qt}. ε_{qt} in Equation (1) is an idiosyncratic random error, assumed identically and independently standard logistic distributed across individuals q and seasons t .

To complete the model structure of the system in Equation (1), we need to specify the structure for the unobserved vector δ_q. In the current paper, we assume that the δ_q elements are independent realizations from normal population distributions; $\delta_{qm} \sim N(0, \omega_m^2)$, where δ_{qm} is the m^{th} element of δ_q (m = 1, 2, …., M). With these assumptions, the probability expression for individual q choosing ordered category k in season t, conditional on δ_q, is given by:

$$P_{qkt}\left|\delta_q\right. = G\left[\psi_k - \left\{\left(\alpha' + \delta_q'\right) x_{qt}\right\}\right] - G\left[\psi_{k-1} - \left\{\left(\alpha' + \delta_q'\right) x_{qt}\right\}\right] \tag{2}$$

where $G(.)$ is the cumulative distribution of the standard logistic distribution.

The parameters to be estimated in Equation (1) are the α vector and the ω_m scalars for each m. Let Ω represent a vector that includes all these parameters to be estimated, and let ω be a (M x 1)-column vector that vertically stacks the ω_m parameters. Then, the likelihood function, for a given value of the vector ω, may be written for individual q as:

$$L_q(\alpha \mid \delta_q) = \prod_{k=1}^{K} \prod_{t=1}^{T} \left[P_{qkt} \mid \delta_q \right]^{d_{qkt}} \tag{3}$$

where d_{qkt} is a dummy variable taking the value '1' if individual q chooses alternative k on the t^{th} choice occasion, and '0' otherwise. Finally, the unconditional likelihood function can be computed for individual q as:

$$L_q(\Omega) = \int_{\delta_q} (L_q(\alpha \mid \delta_q)\, dF(\delta_q \mid \omega)\,, \tag{4}$$

where F is the multidimensional cumulative normal distribution. The log-likelihood function is

$$\log L(\Omega) = \sum_q \log L_q(\Omega)\,. \tag{5}$$

The likelihood function in Equation (4), in its general form, involves the evaluation of an M-dimensional integral. We apply simulation techniques to approximate this multidimensional integral and maximize the logarithm of the resulting simulated likelihood function across individuals with respect to Ω. Specifically, we use the Halton method for discrete choice models [see Bhat (*40*)] to draw realizations for δ_q from its population multivariate distribution.

The framework for the perception models is similar to that presented above except that T=1, since we have only one observation per individual in the perception models. Thus, we set $\omega_m = 0$ for all m. The result is that the above mixed ordered-response logit model collapses to the standard ordered-response logit model.

6. EMPIRICAL ANALYSIS

In this section, we present an empirical analysis of bicyclist perceptions of bicycle facilities and safety, as well as bicycling frequency of bicyclists. Several different variable specifications (including demographic, work-related and bicycling characteristics as discussed in Section 4) and functional forms of variables were explored. The final variable specification for each model was obtained based on a systematic process of eliminating variables found to be statistically insignificant, parsimony in representing variable effects, as well as intuitive considerations and results from earlier studies. In addition to the direct variable effects, several interaction variables that may have an impact on the travel perception of bicyclists' as well as on the frequency of bicycling were examined.

6.1 Estimation Results of Bicyclists' Travel Perceptions

Table 5 presents the empirical results of bicyclists' travel perception associated with (1) overall quality of bicycle facilities in the community (second main column of the table), and (2) safety from traffic crashes (third main column of the table). The parameter estimates indicate the effects of independent variables on the underlying latent continuous perception intensity characterizing the ordered discrete perception categories.

6.1.1 Overall Quality of Bicycle Facilities in the Community

The effects of bicyclists' demographics/work-related characteristics in Table 5 indicate that male bicyclists and young bicyclists perceive the bicycle facilities in their community to be better than do female bicyclists and older bicyclists, respectively. The perception difference based on age is perhaps because older bicyclists are more comfort and convenience conscious, while younger individuals may be more accommodative and accepting of currently available facilities.

The impact of the household residence location variables reveal that individuals residing in Austin, Bryan, and Fort Worth are more satisfied with the quality of bicycle facilities than are bicyclists residing in the rest of the Texas.

The final set of variables relates to bicycle facilities/amenities at work and along the commute route. These effects are applicable only for commuter bicyclists. The results show, as expected, an improved perception of bicycle facilities among commuter bicyclists in the presence of bicycle lockers or safe storage rooms at the work place, and in the presence of a bicycle lane (*a designated portion of the roadway striped for bicycle use*) or a signed shared roadway (*a shared roadway designated by signing as a preferred route for bicycle use*) on the commute route. On the other hand, commuter bicyclists' perception of overall bicycle facilities drops when there is only an unsigned shared roadway (*roadway without bike signage or pavement marking*) for bicycling to work. These results clearly reflect the importance of work and commute route-related bicycle facilities in enhancing the overall perception of bicycle facilities in the community, an important point to recognize in devising informed policy strategies to encourage bicycling. In particular, and as discussed in Section 4.2.3, only about 14% of commuter bicyclists report the presence of bicycle lockers or safe storage rooms at their work place and 72% of commuter bicyclists indicate that they travel on unsigned roadways during their commute.

The constant and thresholds do not have any substantive behavioral interpretation. They simply map the latent quality perception index to the reported ordinal perception categories. The model statistics at the end of the table indicate a nested likelihood ratio value of -361.82 relative to the model with only the constant and thresholds. This value is much higher than the corresponding chi-squared table values with 12 degrees of freedom at any reasonable level of significance, indicating the value of the independent variables in explaining quality perceptions. These same computations can be done for each subsequent model based on the statistics provided at the end of the corresponding model, and the result is always the same. Hence, we dispense with such a discussion for the rest of the models.

6.1.2 Safety from Traffic Crashes

The effects of bicyclists' demographics/work-related attributes indicate that young bicyclists (aged 18-24 years of age) have the most positive perception of safety from traffic crashes, perhaps because they have better reflexes than their older peers and also a sense of "invincibility". Interestingly, there is no statistically significant difference in safety perception among individuals of different ages beyond 24 years.

As expected, commuter bicyclists with long commutes are more likely to be concerned about safety from traffic crashes. On the other hand, commuter bicyclists who have flexibility in their work start/end times have a more positive perception of safety from traffic crashes than those who do not have such flexibility. This is perhaps related to the ability of commuters with flexible work schedules to avoid congested and dangerous peak period traffic conditions during bicycling, as already discussed in Section 4.1. Given the high percentage of bicyclists who believe bicycling is dangerous from the standpoint of traffic crashes, one way to encourage bicycling use may be to offer flexible work schedules.

The household residence location variable effects reveal that individuals residing in the Fort Worth area have a much more positive perception of safety from traffic crashes relative to bicyclists in other parts of Texas. On the other hand, bicyclists in Dallas, Houston, and San Antonio have the most negative perception of safety from traffic crashes. The latter result is intuitive, given the high levels of traffic congestion in Houston, Dallas and San Antonio. Indeed, Houston and Dallas are listed among the 10 most dangerous urban areas in terms of overall traffic congestion in the U.S. (see *41*).

The effects of bicycle facilities along the commute route reflect a substantial improvement in perception of safety from traffic crashes in the presence of bicycle lanes, particularly for individuals who are 65 years of age or older. Further, the results indicate that individuals find it dangerous to bicycle in the presence of an unsigned shared roadway on their commute path. Thus, the type of bicycle facility on the commute route has a significant impact on commuter bicyclists' perceptions of both the quality of bicycle facilities as well as safety from traffic crashes. Furthermore, as one would expect, individuals who have experienced a crash involving a parked vehicle or a vehicle being parked on the roadway during their commute have a particularly poor perception of safety from traffic crashes.

6.2 Estimation Results of Frequency of Bicycling

Table 6 presents the empirical results of bicycling frequency for commuting (second main column of the table), and non-commuting (third main column of the table). The parameters indicate the effects of the independent variables on the bicycling propensity y^*_{qt} for individual q in season t (these are the α parameters in Equation (1), with the standard deviation parameters in the table corresponding to the ω_m scalars).

6.2.1 Effects of Bicyclists' Individual Demographics and Work-Related Characteristics

The effects of bicyclists' demographics indicate that male bicyclists are more likely to bicycle than female bicyclists, regardless of the purpose of the bicycle trip. This gender difference in bicycling tendency has also been observed in previous studies [see, for instance, (*13*, *26*, *42*)]. The frequency of bicycling for non-commute purposes is found to be the highest for bicyclists aged 45 years or more, probably because of higher participation levels in recreational pursuits among older individuals.[4]

Interestingly, the results reveal a lower bicycling propensity among commuter bicyclists who have a bachelor's degree or higher education level relative to those with a lower education level. This is in contrast to Winters *et al.* (*26*), but may be a reflection of higher income levels among highly educated individuals, who can then more afford to commute by car (see *14*). On the other hand, there is no mean effect of education level on non-commuting bicycling frequency, though there is a highly statistically significant unobserved variation in the sensitivity to education level. The final two variable effects under individual demographics show that experienced bicyclists and those with short commute distances bicycle more frequently to work.

6.2.2 Effect of Bicyclists' Household Demographics

Bicyclists with more automobiles in their household are less likely to bicycle, for both commuting and non-commuting purposes (see also *14*). On the other hand, the more the number

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[4] It may seem odd that age does not appear to impact frequency of bicycling to work, given our finding earlier that those who have used a bicycle to get to work at least once in the previous year tend to be drawn from the young age groups. As we will see later, the age effect gets manifested indirectly through the impact of the perception of the quality of bicycle facilities on bicycling frequency to work.

of bicycles in the household, the more often individuals choose to bicycle for both commuting and non-commuting (see *13*). These results are quite intuitive, although the direction of the relationship needs more careful scrutiny. That is, it is unclear whether owning more cars (bicycles) discourage (encourage) individuals to bicycle, or whether individuals who are bicycle-inclined decide to have few cars (more bicycles) (see *11, 42*). The effect of the final household demographics variable - number of children - suggests, on average, a decrease in bicycling propensity as the number of children (less than 16 years of age) in the household increases. One possible reason for this may be the increased number of serve-passenger activities in households with children (such as, a working mother dropping off her child at school before proceeding to work). However, the results also suggest a significant variation of the effect of this variable due to unobserved factors. For instance, adults in some families with children may prefer to participate in non-bicycle forms of physical activities, such as playing soccer, while others may be more bicycle-oriented and ride with the family around the block.

6.2.3 Effect of Bicyclists' Household Residence Location and Season of Bicycling

According to the results in the table, individuals residing in Austin and Houston are less likely to use a bicycle for non-commuting purposes. Also, as revealed in the exploratory analysis, the winter season is the most unlikely season to bicycle to work.

6.2.4 Effect of the Perception of Overall Quality of Bicycle Facilities in the Community and Bicycle Amenities at Work

We estimated a continuous measure of the perception intensity of the overall quality of bicycle facilities, using the results of Table 5 (note that the ordered-response model essentially assumes that such a perception intensity underlies the observed ordered response perception ratings provided by respondents; thus, after estimation, one can construct this continuous perception intensity variable using a linear combination of the estimated coefficients and corresponding variables for each respondent). A higher perception intensity implies a better perception of the quality of bicycle facilities. We also constructed a similar perception intensity related to safety from traffic crashes, but this variable did not turn out to be statistically significant in the bicycling frequency models. This is not surprising, since there is a correlation between perception of bicycle facility quality and safety from traffic crashes.

The results in Table 5 indicate, as expected, that individuals who have a more positive perception of the quality of bicycle facilities have a higher propensity to bicycle to work. This shows that improvements to bicycle facilities not only will improve quality perceptions (*i.e.* perception of overall quality of bicycle facilities), but will also lead to an increase in bicycle use to work through the quality perception improvement. The effect of the quality perception is not that important for non-commuting (see the statistically insignificant coefficient for the non-commuting purpose), because of the recreational focus of such trips.

In addition to the perception of the overall quality of bicycle facilities, the presence of bicycle racks and showers at work also increase bicycling use and frequency to work. It is interesting that these amenities do not directly influence overall quality perceptions of bicycle facilities, but do have a direct impact on bicycle use to work.

6.2.5 Effects of Bicycle Use Characteristics

The final set of variables in Table 6 pertains to bicycle use characteristics. Respondents who bicycle for visiting friends/family bicycle frequently for non-commuting purposes, perhaps because many of these trips are within their neighborhoods. The effects of the next few variables indicate that individuals who identify “environment friendliness”, “convenience/speed of bicycling”, “avoiding driving a car in congested conditions”, and “financial considerations” as the reasons for bicycling have a high frequency of bicycling to work, reinforcing the exploratory analysis findings in Section 4.2.2. Finally, individuals who bicycle for fitness/health concerns are the ones who clearly are likely to bicycle frequently for non-commuting reasons.

6.2.6 Effect of the Constant and Threshold Parameters
The constants and threshold parameters do not have any substantive behavioral interpretations. But it is interesting to note the highly statistically significant coefficient on the standard deviation on the constant for the commuting model, indicating that there is indeed substantial variation across individuals in bicycling propensity to work due to unobserved individual specific factors, as hypothesized in Section 5. That is, individuals who are generically bicycling-inclined have a high bicycling propensity to work across all seasons of the year, while those who are generically bicycling-averse (within the group of individuals who bicycle at least occasionally) have a low bicycling propensity to work across all seasons of the year.

7. SUMMARY AND CONCLUSIONS
Encouraging bicycle use for commuting and non-commuting purposes can be a part of a broader policy plan to alleviate traffic congestion and air pollution problems in metropolitan areas, as well as to stem health problems such as obesity caused by physically inactive lifestyles. However, to encourage bicycling use, it is important first to understand the factors that affect an individual’s decision to bicycle. Although there has been a growing interest in examining bicycling behavior, there has been relatively limited research on the effects of such potential bicycling propensity determinants as environmental factors, perceptions, and attitudes of bicyclists. Instead, most existing studies have focused on the effects of bicyclist demographics (for instance, age, gender, vehicle availability, *etc.*) and route-related factors (for instance, traffic conditions, bicycle facility design, lighting, *etc.*) by employing descriptive analyses. While such analyses provide general information on the factors influencing bicycling decision and/or frequency, they are not capable of capturing a multivariate picture of the trade-offs among factors influencing bicycling use/frequency. In this regard, the current paper contributes to the existing research by adopting a multi-level analysis framework to examine a comprehensive set of attributes associated with bicyclist demographics, bicycle facility quality and safety perceptions, bicycle use characteristics and bicycling habits, and bicycling frequency. The empirical analysis is based on a sample of individuals who reside in the State of Texas.

The current study elicits information from a sample of current bicyclists from the overall population of interest. Although this approach has the limitation that it is confined to bicycle users (the group that is obviously bicycling-oriented in the first place!), it has the advantage of providing an objective evaluation of bicycle facilities and analysis of bicycling concerns/reasons. An alternative approach that elicits information from a sample of both bicyclists and non-bicyclists has the advantage that it provides useful information to understand why current non-bicyclists shy away from bicycling, how they are different from current bicyclists, and what can be done to entice non-bicyclists to take up bicycling. However, non-bicyclists may refrain from bicycling due to overall lifestyle considerations and general/pre-conceived notions about bicycle safety based on a cursory evaluation of the current bicycling infrastructure. To the extent that they choose not to expose themselves to bicycle routes, current non-bicyclists may not be able to provide an objective assessment of bicycle facilities and bicycling concerns. The approach adopted here, on the other hand, allows planners to provide effective and reliable policy strategies to design comfortable, convenient and safer bicycling options based on the concerns of current bicyclists. At the same time, the results might provide valuable insights to promote bicycling among non-bicyclists. However, it is also likely that non-bicyclists may have quite different bicycling-related concerns and issues relative to bicyclists, a research area that requires further investigation.

There are several important findings from the empirical analysis. First, bicycling is more common for non-commute reasons than for commuting. Specifically, while only half of the respondents bicycle to work, almost all respondents use their bicycle for non-commuting purposes. Those who bicycle to work are quite young, and these same individuals are more environmentally conscious, because of which they appear to use the bicycle for all purposes. Second, bicyclists have a rather negative opinion of bicycle facilities in their communities, and feel rather unsafe when bicycling due to the worry of being involved in traffic crashes. The negative opinion of bicycle facilities is particularly pronounced among older bicyclists. Further, individuals who report that there are no bicycle lockers or safe storage rooms at their work place, and who have to travel along unsigned shared roadways on their commute, are particularly likely to have a poor evaluation of bicycle facilities. Similarly, individuals with long commutes, inflexible work schedules, and who have to travel along unsigned shared roadways on their commute are likely to be particularly worried about traffic crashes. From a policy standpoint, the results suggest that the perception of the quality of bicycle facilities can be enhanced by having bicycle lockers or safe storage rooms at workplaces, and by having bicycle lanes or signed shared roadways on the commute. Also, the worry of traffic crashes can be reduced by having bicycle lanes or signed shared roadways on the commute, and by offering flexible work timings so that individuals can avoid the rush hours of travel.

Third, exercising is the most common reason for bicycling, followed by recreation (such as parades, riding with family around the block, *etc*.), and running errands. The fact that exercising tops the list of bicycling reasons is a clear indication that bicyclists value health-related benefits, and perceive bicycling as a means of physical activity participation. In addition to fitness and health considerations, other compelling reasons for bicycling among respondents are pleasure/enjoyment (or leisure), and being environmentally friendly. Also, regardless of the reason for bicycling (*i.e.* commuting or non-commuting), the biggest deterrent to bicycling is inclement weather. Fourth, a number of bicyclist demographics (gender, age, education level, and commute distance), household demographics (number of automobiles, number of bicycles, and number of children), residential location and season, bicycle amenities at work (bicycle racks and showers), and bicycle use characteristics impact commute and non-commute bicycling frequency. In addition, bicyclist demographics (age, gender), residential location, and bicycle facilities (bicycle lockers/safe storage rooms, and commute route characteristics) also influence bicycling frequency to work through the moderating effect of bicyclist perceptions of the quality of bicycle facilities. While bicyclist and household demographics, and season/weather related considerations, are not within the scope of policy control, the results point to the need to improve bicycle facilities at the work place and along bicycle routes to enhance bicycle facility quality and bicycling safety perceptions, as well as to increase bicycling frequency. Other viable and effective ways to increase bicycling use/frequency include (1) land-use strategies to encourage compact developments to reduce commute distances, and (2) education/information campaigns to highlight the environmental, financial, and fitness/health benefits of bicycling (particularly targeted toward young adults, at places such as high schools).

In conclusion, the results of the study highlight the importance of a good understanding of bicyclists' travel perceptions and reasons for bicycling, in addition to examining the demographic, work-related, and built environment correlates of bicycling use. Such a broad perspective in examining bicycling behavior can assist in the development of informed policies to increase commute and non-commute bicycling. The study also underscores the continuing need for detailed surveys aimed at collecting more extensive and higher quality data to better understand bicycling behavior of current bicyclists as well as the bicycling decision of potential bicyclists. For instance, the current paper does not explicitly accommodate weather-related effects and travel constraints imposed by household activity schedules (such as picking up/dropping off children and trip chaining) on bicycling use/frequency decisions.

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LIST OF TABLES

TABLE 1a Bicyclist' Demographic Characteristics

Bicyclist Demographics

Gender	%
Female	29
Male	71

Age	%
18-24 years	11
25-34 years	23
35-44 years	29
45-64 years	34
65 years or older	3

Highest level of education	%
High school or lower	5
Associate degree/Some college	20
Bachelors degree	42
Graduate degree or higher	33

Driver's license	%
Individual has driver's license	99

Household Demographics

Residential location of survey respondents	%
Austin	47
Bryan	2
Dallas	3
Fort Worth-Arlington	3
Houston	14
Plano	2
San Antonio	10
Others (each less than 1%)	19

Number of people (including respondent) in bicyclists' household	%
1	20
2	42
3	16
4 or more	22

Auto ownership	%
0	3
1	26
2	49
3	16
4 or more	6

Number of children (less than 16 years of age) in bicyclists' household	%
0	73
1	11
2	12
3 or more	4

Bicycle ownership	%
1	13
2	21
3 or more	66

TABLE 1b Bicyclists' Work-Related Characteristics

Commute distance	%	Work start time	%	Work end time	%	Work start/end time flexibility	%
2 miles or less	26	Before 6 AM	1	Before 3 PM	21	Flexible work start time	50
2.01 to 5 miles	31	Between 7-7:59 AM	4	Between 3-3:59 PM	4	Flexible work end time	44
5.01 to 7 miles	9	Between 8-8:59 AM	14	Between 4-4:59 PM	13	Flexible work start/end time	33
7.01 to 10 miles	14	Between 9-9:59 AM	37	Between 5-5:59 PM	30		
10.01 to 15 miles	12	Between 10-10:59 AM	27	Between 6-6:59 PM	15		
15.01 to 25 miles	7	Beyond 11 AM	17	Between 7-7:59 PM	7		
More than 25 miles	1			Beyond 8 PM	10		

TABLE 2a General Bicycle Use Characteristics

Purpose for bicycling (%) *"Sample Size= 1605 (all respondents)"*[**]	
Commuting to work or school	51
Running errands	55
Exercising (not including stationary exercise bicycles)	94
Visiting friends or family	46
Other recreation (such as parades)	61
Racing/Stunt riding	25
Other	18

Duration of bicycling for commuting (%) *"Sample Size= 810 (commuter bicyclists)"*	
Less than 6 months	12
6 months - 1 year	17
1 year – 5 years	40
More than 5 years	31

Duration of bicycling For non-commuting (%)	**Commuter Bicyclists** *"Sample Size=801"*	**Non-commuter bicyclists** *"Sample Size=795"*
Less than 6 months	5	4
6 months - 1 year	7	6
1 year – 5 years	23	32
More than 5 years	65	58

Season of bicycling for commuting (%) *"Sample Size= 810 (commuter bicyclists)"*	
May to August (summer)	76
September to November (fall)	85
December to February (winter)	62
March to April (spring)	86

Season of bicycling For non-commuting (%)	**Commuter Bicyclists** *"Sample Size=801"*	**Non-commuter bicyclists** *"Sample Size=795"*
May to August (summer)	97	97
September to November (fall)	96	96
December to February (winter)	92	87
March to April (spring)	98	98

[**] The percentages across purposes do not sum to 100% because respondents could choose multiple reasons for bicycling

TABLE 2b Bicycle Use Characteristics Specific to Bicycling Frequency††

Bicycling frequency during different time periods of the year	**Commuting (%)** ***"Sample Size = 810 (commuter bicyclists)"***				**Non-Commuting (%)** ***"Sample Size = 795 (non-commuter bicyclists)"***			
	May to August (summer)	September to November (fall)	December to February (winter)	March to April	May to August	September to November	December to February	March To April
Never	25	15	39	14	8	14	15	10
About once or twice a month (or even less frequently)	11	12	8	13	7	8	7	8
About once a week	10	12	8	11	23	22	21	23
About 2-3 days a week	23	24	18	25	45	41	41	42
About 4-5 (or more) days per week	31	37	27	37	17	17	16	17

†† The numbers in the table sum to 100% across all rows for each column. Thus, the first entry of 25 indicates that 25% of commuter bicyclists never used the bicycle as the travel mode to work in the summer.

TABLE 3 Reasons for Bicycling and Not Bicycling

Reasons for bicycling (%)	Commuting *"Sample Size=810"*	Non-commuting: Commuter bicyclists *"Sample Size=801"*	Non-commuting: Non-commuter bicyclists *"Sample Size=795"*
Environment friendly	82	45	39
Convenience/speed	50	31	20
Avoid driving a car in congested conditions	61	23	11
Financial considerations	47	17	4
Fitness/heath concerns	88	88	97
Pleasure/enjoyment	87	90	92
Limited auto parking	29	13	5
Flexible work/school start-end times	26	-	-
Presence of a safe bicycle facility on the route traveled	10	9	6
Others	11	9	9
Reasons for not bicycling (%)			
Weather	85	90	92
Problems with the bicycle	25	32	15
Construction/repair of roadways	15	13	28
Felt too tired to ride a bike	29	-	-
Others	42	30	38

TABLE 4 Bicycle Facilities/Amenities at Work and Along the Commute Route

Existing bicycle facilities on commute route (%)		Existing bicycle amenities at (or during travel to) work place/school (%)	
Bicycle lane	45	Bicycle racks	68
Unsigned shared roadway	72	Bicycle lockers or safe storage rooms	14
Signed shared roadway	27	Showers	39
Off-road bikeway	18	Clothing lockers	24
Combination of bicycle lane and unsigned shared roadway	37	Bicycle racks on bus	39
Combination of unsigned roadway and signed shared roadway	21	Others	7
Other combinations	11		

TABLE 5 Ordered Response Model of Bicyclists Travel Perception
(Response categories for perception of overall quality of bicycle facilities: 1- very inadequate, 2- inadequate, 3- satisfactory, 4- excellent)
(Response categories for perception of safety from traffic crashes: 1- very dangerous, 2- somewhat dangerous, 3- somewhat safe, 4- very safe)

Variables	**Perception of overall quality of bicycle facilities in the community**		**Perception of safety from traffic crashes**	
	Coefficient	**t-stats**	**Coefficient**	**t-stats**
Bicyclists' Demographics				
Male	0.140	1.28	-	-
Age Variables (age between 18-24 years is base)				
Age 25-34 years	-1.066	-6.09	-0.449	-2.40
Age 35-44 years	-1.247	-6.99	-0.453	-2.43
Age 45-64 years	-1.325	-7.25	-0.413	-2.22
> 65 years	-1.439	-4.00	-0.413	-2.22
Commute distance (in miles)	-	-	-0.027	-2.00
Works start/end time flexibility	-	-	0.348	2.06
Residential Location				
Austin	1.148	9.81	-	-
Bryan	1.596	4.15	-	-
Dallas	-	-	-0.354	-1.20
Fort Worth	1.268	4.30	0.594	1.98
Houston	-	-	-0.353	-2.47
San Antonio	-	-	-0.467	-2.83
Bicycle Facilities/Amenities at Work and along the Commute Route				
Bicycle lockers or safe storage rooms	0.384	1.90	-	-
Bicycle lane	0.869	5.10	0.752	5.22
Bicycle lane-Age 65 years or more	-	-	3.130	2.15
Unsigned shared roadway	-0.539	-4.42	-0.303	-2.00
Signed shared roadway	0.346	1.84	-	-
Experienced traffic crash	-	-	-1.122	-2.56
Constant and Threshold Parameters				
Constant	1.581	8.43	1.961	10.30
Threshold 1	0.000	-	0.000	-
Threshold 2	2.754	14.49	2.480	13.57
Threshold 3	5.740	22.94	5.135	21.87
Log-likelihood at convergence	-1566.73		-1733.48	
Log-likelihood at thresholds	-1747.64		-1784.50	
Number of observations	1605		1605	

TABLE 6 Panel Ordered Response Model of Frequency of Bicycling
(Response categories: 1- never, 2- about once or twice a month (or less frequently), 3- about once a week, 4- about 2-3 days a week, 5- about 4-5 (or more) days a week)

Variables	Commuting		Non-commuting	
	Coefficient	t-statistic	Coefficient	t-statistic
Bicyclists' Demographics				
Male	0.628	2.96	0.979	12.23
Age Variables				
Age > 45 years	-	-	0.572	5.90
Bachelor's degree or higher education level	-0.538	-2.58	0.000	-
Standard deviation	-	-	4.314	23.50
Experienced (1 year or more)	0.633	1.78	-	-
Commute distance (in miles)	-0.066	-3.03	-	-
Household Demographics				
Number of automobiles	-0.500	-4.60	-0.766	-16.37
Number of bicycles	0.299	2.25	1.035	19.03
Number of children	-	-	-0.482	-2.44
Standard deviation	-	-	2.224	16.37
Residential Location and season				
Austin	-	-	-1.692	-11.55
Houston	-	-	-0.467	-4.58
December to February	-2.700	-2.38	-	-
Perception Intensity of Overall Quality of Bicycle Facilities in the Community	0.294	3.12	0.079	0.87
Bicycle Amenities at Work and along the Commute Route				
Bicycle racks	0.334	1.58	-	-
Showers	0.523	2.38	-	-
Bicycle Use Characteristics				
Purpose for bicycling				
Visiting friends or family	-	-	0.761	9.12
Reason for bicycling				
Environment friendly	0.605	2.41	-	-
Convenience/Speed	1.261	5.65	-	-
Avoid driving a car in congested conditions	0.557	2.73	-	-
Financial considerations	0.898	4.77	-	-
Fitness/heath concerns	-	-	3.394	18.07
Constant/Threshold Parameters				
Constant	0.340	0.61	0.795	3.06
Standard deviation	2.234	22.49	-	-
Threshold 1	0.000	-	0.000	-
Threshold 2	0.889	1.60	1.348	5.27
Threshold 3	1.758	3.16	4.356	16.54
Threshold 4	3.937	7.04	9.661	36.97
Log-likelihood at convergence	-4189.35		-3162.75	
Log-likelihood at thresholds	-4916.08		-4599.33	
Number of observations	3240		3180	