A Comparison of the Route Preferences of Experienced and Inexperienced Bicycle Commuters

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ABSTRACT

This paper examines differences in bicycle route preferences across individuals with different levels of experience in bicycle commuting to work (or school). Individuals are categorized as follows: those who are experienced in bicycle commuting, those who are inexperienced in bicycle commuting but who are interested in trying it, and those who are inexperienced and not interested in trying it. Data gathered from an original stated preference survey administered over the Internet by the authors are used to estimate binary logit models of route choice for each class of respondents. The results quantitatively demonstrate the differential importance of each route factor to individuals of each level of experience. In general, experienced commuter bicyclists are far more sensitive to factors related to travel time and far less sensitive to factors related to separation from automobiles than the inexperienced individuals.

1. INTRODUCTION

The need to examine bicyclist route preferences as a function of bicycling experience level is well recognized in the literature. Studies that shed light on this issue allow bicyclist planners and engineers to design routes that serve and accommodate bicyclists with a range of bicycling experience levels. Our current research adds to the existing body of literature on bicyclist route choice by examining the route preferences of several types of potential facility users, including those who have little or no experience in commuting by bicycle. Our emphasis on commuting as a trip purpose is motivated by the fact that increasing bicycle use for commuting can help alleviate peak-period traffic congestion and air quality problems.

The variables in this study that are used to characterize bicycle routes and bicyclist preferences for routes are categorized as *link-level* and *route-level* factors (*1*). *Link-level factors* are attributes that generally are best measured at the link level because they frequently are different from one link to the next. The link-level factors included in this analysis are: (1) roadway class (defined by traffic speed and volume), (2) presence of parallel parking, (3) bicycle facility type (none, wide right-hand lane, bicycle lane, separate path), (4) bridge type (no bicycle facility, bicycle lane, barrier separation from motorized traffic, no motorized traffic permitted), (5) terrain (flat, hilly, mountainous), and (6) pavement type (rough pavement, smooth pavement, coarse sand surface).

Route-level factors, in contrast to *link-level factors*, are best measured at the route level because their accumulated effects are most meaningful to consider over the route (for example, the travel time on a bicycle path would constitute a route-level factor). The route-level factors included in this study are: (1) travel time, (2) continuity of the bicycle facility, (3) delays (number of red lights on the route, stop signs per mile), and (4) number of major cross streets.

The paper uses binary logit models to estimate the impact of each of the link-level and route-level variables on individuals' selection of a route for commuting by bicycle to work (or school). We classify an individual into one of three categories based on their reported experience and interest level in bicycle commuting, and estimate separate binary logit models for each category. The three categories are: (1) experienced bicycle commuters, (2) inexperienced bicycle commuters who nevertheless have an interest in considering commuting by bicycle in the future, and (3) inexperienced bicycle commuters who have no interest in commuting by bicycle.

The data used in the estimation were gathered by the authors during an original Internet-based survey effort conducted in 2002. The survey asked several questions about the respondent's commute patterns in addition to a series of stated preference route choice questions which gathered information on the respondent's route preferences in a hypothetical framework.

The rest of this paper is structured as follows. The next section discusses earlier research relevant to the topic of this paper. Section 3 discusses the data used and the methodology applied in the analysis. Section 4 presents the empirical results. The final section summarizes the important findings from the study and discusses policy implications.

2. EARLIER RESEARCH

This section provides an overview of earlier literature in the area of bicycle user preference regarding route choice. Section 2.1 discusses the bicyclist segment groups generally used in previous works about designing bicycle facilities. It also identifies the segment classification adopted in the current study. Section 2.2 describes earlier studies that have examined the impact of link-level characteristics on bicyclist route choice, while Section 2.3 presents earlier studies focusing on the influence of route-level factors on bicyclist route choice. Finally, Section 2.4 summarizes the literature synthesis and positions the current study in the context of earlier studies.

2.1 Bicyclist Segment Groups Used in Planning

There are numerous design manuals (*2-5*) available for assisting bicycle planners and engineers in designing bicycle facilities for different bicycle user classes. Because successful bicycle facility designs consider "the needs of all cyclists" (*2*), these manuals use some form of a classification scheme of bicycle commuters to recognize the heterogeneous route preferences of different groups of bicyclists.

In 1994, the Federal Highway Administration (*6*) created and standardized a classification system of bicycle users as follows: (a) Group A (advanced bicyclists): experienced riders who operate under most traffic conditions, (b) Group B (basic bicyclists): casual or new adult and teenage riders who are less confident of their ability to operate in traffic without specific provisions for bicycles, and (c) Group C (children). The bicycle user classification we use in the current study corresponds closely to the Federal Highway Administration (FHWA) classification. However, because of our Internet-based survey collection procedure, our sample is confined to adults (over 18 years of age). We classify adults into experienced and inexperienced users, based on experience in bicycle commuting. These categories correspond closely to the Group A and Group B FHWA categories. In addition, within the inexperienced category, we further consider two segments based on whether the user has an interest in considering bicycle commuting in the future (inexperienced, but interested group) or not (inexperienced and uninterested group).

2.2 Preferences Associated with Link-Level Characteristics

A substantial amount of previous research on bicycle facilities has focused on examining the impact of link-level factors (such as bicycle facility presence, motor vehicle traffic characteristics, parking characteristics, riding surface quality and hilliness) on route choice decisions (*7-19*). In addition, (*4*) and (*20-22*) have established general guidelines for designing bicycle facilities on links that form part of a bicycle route.

Most of the research studies and guidelines identified above provide a broad and qualitative sense of the effect of link-level factors on route preferences and/or provide broad and qualitative guidelines for bicycle facility design. Some studies, however, have quantitatively developed measures of safety, comfort, and level-of-service preferences of bicyclists based on link-level attributes (*10*, *13*, *15-17*, and *23-25*).

Some of these indices (e.g., *15*) have developed a rating scheme for categorizing network links according to suitability for bicyclists of different levels of ability or experience. However, other earlier studies typically do not assess preferences of bicycle users of varying bicycling experience levels. Furthermore, the construction of these indices and measures, in general, relies on qualitative weightings of link-level attributes rather than a comprehensive quantitative analysis of the individual link-level attributes.

2.3 Preferences Toward Route-Level Characteristics

The measures described in the above section do not include *route-level factors* such as total travel time, delays incurred over the route due to stop signs and red lights, and continuity of the bicycle facility[1]. It is important for bicycle planners and engineers to consider route-level factors, in addition to link-level factors, when deciding where to locate bicycle facilities. For example, if a city agency is hoping to increase bicycle mode share during the work commute, route planners should try to create routes that are desirable to potential bicycle commuters from an overall route standpoint.

Several studies of commuter bicyclists consider route-level variables concurrently with link-level variables, allowing planners to assess the trade-offs between link- and route-level attributes. Revealed preference (*11*, *26-28*) and stated preference studies (*18*, *29*, *1*) have generally shown that commuter bicyclists prioritize directness as a factor in commute route choice, although they will deviate somewhat from the most direct path to use bicycle facilities and avoid undesirable attributes such as turns, hills, major roads, and earthen riding surfaces.

Clearly, there are differences between the route-level studies discussed above and the link-level studies discussed in the previous section. First, the route-level studies have relied more on quantitative analysis and less on qualitative judgment. Second, the route-level studies have included both route-level and link-level factors in the analysis, while the link-level studies do not consider route-level factors. However, one common limitation in previous studies that simultaneously examine link- and route-level preferences is that they do not focus on preferential differences among different bicycle user groups.

2.4 Summary and Scope of Current Study

Earlier link-level and route-level analyses of bicycle commuter preferences have provided valuable insights into the factors affecting route evaluation and route choice. However, while these design procedures recognize the need to serve different populations of bicycle users, they generally do not comprehensively analyze the breadth of link-level and route-level factors when providing guidelines to design facilities suitable for different user groups.

The current study uses an SP survey to obtain information from a large sample of individuals with different bicycling experience levels. Additionally, it focuses on understanding the varying sensitivities to link and route-level factors of different bicycle user groups based on experience and interest in considering bicycling as a commuting mode.

3. DATA SOURCE AND METHODOLOGY

This section discusses the design and administration procedures of our internet survey (Section 3.1), presents sample statistics (Section 3.2), and discusses the model structure used in the study (Section 3.3).

3.1 Data Source

The authors designed and administered an original survey on the Internet in February-April, 2002. The University of Texas College of Engineering (COE) permitted the authors to place the survey on the COE server. Respondents were then solicited from bicycle-related listserves and websites and directed to the survey website. In addition, respondents were solicited from non-bicycle-related listserves in an effort to include casual and non-bicyclists as well as avid bicyclists in the sample. The survey notice consisted of an e-mail to the listserves that announced

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[1] This paper describes *continuous* bicycle facilities as facilities that are present for the entirety of the route (except on cross-streets) and *discontinuous* facilities as facilities that are present for only 75% of the route, with 25% of the route having no bicycle facility.

the address of the survey website, described the purpose of the research, and asked volunteers to participate in the survey.

Due to the sampling methodology, most of the respondents were avid bicyclists with good access to Internet technology and an interest in Internet-based communities. This non-random sampling approach introduces some self-selection bias into the research. However, while a majority of respondents were avid bicyclists, approximately 300 casual bicyclists and non-bicyclists also completed the survey, alleviating some of the sampling bias concerns. Further, there is reason to believe that the bias introduced by having good access to internet technology and being interested in internet-based communities has negligible effects on the overall analysis of route choice preference. Specifically, earlier bicycle route choice models that have included socio-demographic variables such as income, sex, and age have indicated that these factors have only minor effects on individual route choice (*1*, *30*). It is important to note, however, that sampling bias does affect the basic sample statistics (such as income distribution and perhaps percentage of females in the sample).

The SP survey conducted in this research was designed to obtain information on commuter bicyclist route preferences using a series of hypothetical route choice questions. A base route option with certain route attributes was first presented to respondents for their commute by bicycling to work. Next, the respondents were asked to compare several other hypothetical route options with this base route option. Definitions of route attributes were clearly specified in the survey (further details of the web survey and self-selection issues are available in *30*, *31*).

In addition to route choice preferences in the SP experiments, our survey also collected data on individual socio-demographic characteristics such as sex, age, and income, as well as information on respondents' bicycle commuting experience, current use, and interest. Information on the latter set of characteristics was obtained by asking respondents to choose the statement that best described their situation from the following statements: (1) I bicycle to work regularly (or at least when I can tolerate the weather), (2) I have experience in bicycling to work, but currently do not bicycle to work, (3) I am not very experienced in bicycling to work, but I might bicycle to work in the future, and (4) I am not very experienced in bicycling to work, and I am not interested in trying it. For our analysis, we combined individuals from categories (1) and (2) into an experienced commuter category, and retained the two other categories as separate segments[2]. For convenience, we will refer to the three segments used in the current study as (1) Experienced group, (2) Inexperienced, but interested group, and (3) Inexperienced and uninterested group. As noted earlier in Section 2, the first group in our classification corresponds roughly to FHWA's Group A (advanced) bicyclists, and the next two groups together correspond roughly to Group B (basic) bicyclists.

The overall survey included nine different instruments, distinguished based on the attributes characterizing routes in the SP experiments. Each instrument considered only three or four attributes so that respondents could easily comprehend and evaluate the scenarios presented to them. The hypothetical route choice scenarios within each instrument were generated by varying the levels of the attributes specific to that instrument. For example, one question in the survey instrument asked the respondent to choose between a route with a wide outside lane, stop

[2] We grouped the first and second categories—(1) experienced and currently commuting and (2) experienced and not currently commuting—because of our emphasis on understanding the impact of experience level on route choice. On the other hand, we wanted to test if interest level in bicycle commuting within the group of inexperienced users has an impact on route preferences, and so retained these as separate segments.

signs every ½-mile, and 3 red lights, and another route with a narrow outside lane, stop signs every ½-mile, and no red lights. Also, by varying the attributes among the nine instruments in a carefully designed experimental procedure, we are able to obtain data to estimate the effects of the full range of attributes affecting route choice.

The completed on-line surveys were downloaded from the online software into Microsoft Excel and then imported into SPSS to code the variables numerically. Finally, the data were imported into LIMDEP to perform discrete choice modeling estimations.

3.2 Sample Description

Over 3,000 respondents completed the survey, creating approximately 35,000 route choice observations. In the sample, 22% are female and 78% are male. The age distribution is fairly typical, with most respondents aged between 25 and 54 years. Reported annual household incomes are high compared to the U.S. population, perhaps because of the computerized survey administration method (2000 U.S. Census figures are in parentheses): 19% (47%) of respondents' households earn less than $40,000 (USD), 20% (18%) earn $40,000-$60,000, 14% (10%) earn $60,000-$75,000, 21% (11%) earn $75,000-$100,000, and 26% (14%) earn over $100,000. However, previous analyses have shown that income has no measurable effect on route choice preferences (*1*). The data set includes individuals from various residential and geographic locations: 52% live in suburbs, 39% in an urban area, and 9% in a rural area. Furthermore, about 26% live in the Northeast U.S. or Alaska (grouped together for weather reasons), 20% in the Midwest, 14% in the Northwest, 22% in the Southwest, 11% in the South or Hawaii, and 7% in a non-U.S. location.

Table 1 presents the distribution of respondents by the three categories of bicycle user groups identified earlier (see first row of Table 1). The total number of respondents in our sample is 3,126, of whom about 91.1% belong to the "experienced" group, 6.3% are in the "inexperienced, but interested" group, and 2.6% are in the "inexperienced and uninterested" group. Clearly, most survey respondents are experienced bicyclists.

The subsequent rows in Table 1 provide descriptive statistics on the demographic composition of each group. Within each user group, the cells provide the percentages for each value of a demographic variable. One can examine the profiles of each group by comparing the cell percentages across the columns. The results show that experienced bicycle commuters are mostly males of 25-54 years from households with fewer cars. Experienced bicycle commuters also tend not to live very close to their workplaces (many commuters living within a mile of work reported walking as the most convenient mode). The profile of the "inexperienced, but interested" group indicates that individuals in this group tend to be males distributed across all age and car ownership groups, and live relatively close to their workplace. Finally, respondents in the "inexperienced and uninterested" group are mostly female, are older than respondents in the other groups, own many cars, and live very close or very far away from their workplace (relative to the other groups). Overall, the results in Table 1 indicate the following: (1) women are less experienced in bicycle commuting than men, (2) middle-aged individuals are more experienced in bicycle commuting than younger or older individuals, (3) individuals in households with fewer cars are more likely to be experienced bicyclists, and (4) individuals residing three to ten miles from work tend to be more experienced bicyclists than individual living very close or very far away from their workplace.

3.3 Methodology

A binary logit model is used to estimate the importance of each link-level and route-level factor on bicycle route choice decisions. The model system is as follows:

$$U_{in} = \beta X_{in} + \varepsilon_{in} \quad (1)$$

where i is an index for route (i = 1 or 2, since each choice scenario presents two routes), n is an index for individuals, X_{in} represents a vector of explanatory variables specific to individual i and route n, β represents a corresponding vector of parameters to be estimated, and U_{in} is the utility associated with route i by individual n. The random error term, ε_{in}, is assumed to be identically and independently distributed across routes and observations according to the Gumbel[3] distribution (also called the Extreme Value Type I distribution). The probability that a person n chooses route i is:

$$\text{Prob (Individual } n \text{ selects route } i) = \text{Prob}(U_{in} > U_{jn}) = e^{\beta X in} / (e^{\beta X in} + e^{\beta X jn}). \quad (2)$$

The above model was estimated using a maximum likelihood procedure for each of the three bicycle user groups. Coefficients for route-and link-level factors were estimated simultaneously.

The model specification process was undertaken in several steps to systematically estimate the effects of variables on route choice. First, all variables were included in each model segment. Next, statistically insignificant variables were eliminated. This iterative process was repeated for each segment of bicycle users. Finally, log-likelihood ratio tests were used to test whether different bicycle user groups have different preferences for route- and link-level attributes.

4. EMPIRICAL RESULTS

This section presents the empirical results of the route choice utility model for each group of respondents. As noted above, respondents are categorized according to level of bicycle commuting experience and interest in commuting.

The rest of this section is organized as follows. First, we discuss the statistical results of the tests for different route choice preferences among the three groups of bicycle users (Section 4.1). Next, focusing on the segments which are statistically unique, we discuss the effects of variables (Section 4.2). Finally, the relative magnitudes of impact of all the variables are described (Section 4.3).

4.1 Tests for Segmentation

To test for the presence of different route preference profiles among the three segments of bicycle users, we first estimated separate models for each segment. All link-level and route-level variables were found to be statistically highly significant or marginally significant in each segment and so the full specification was retained in each segment in the statistical testing (the full specification includes six link-level factors contributing 13 variables because of multiple

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[3] The Gumbel distribution is an asymmetric distribution with a long right tail. The density function of the standard Gumbel distribution is as follows: $f(\varepsilon_{in}) = e^{-e^{-\varepsilon_{in}}} \cdot e^{-\varepsilon_{in}}$.

variable levels within each factor, and four link-level factors contributing five variables, for a total of 18 variables in the full specification for each segment).

In the two segments of inexperienced bicycle users (inexperienced and interested in bicycle commuting, and inexperienced and uninterested in bicycle commuting), the coefficients on each of the 18 variables were very close to one another (relative to the standard error of the coefficient) and of the same sign. The log-likelihood values at convergence for the two groups were α_1 = –1284.0 and α_2 = –488.0. The log-likelihood value at convergence for a pooled model on both sets of inexperienced individuals was α_{12} = –1785.0 (this pooled model constrains all coefficients to be the same across the two segments). The log-likelihood ratio test value for the hypothesis that the two segments have identical route choice preference profiles may be computed as $-2[\alpha_1 + \alpha_2 - \alpha_{12}]$, which is 26.0. Comparing this with the chi-squared table value with 18 degrees of freedom (corresponding to the number of equality restrictions imposed on the segment-level models to obtain the pooled model), we find the log-likelihood ratio test value to be nearly equal to the table value at the 90% confidence level ($\chi^2_{18,0.90} \approx 26.0$). Thus, we cannot reject the hypothesis that both the "inexperienced and interested" bicycle users and the "inexperienced and uninterested" bicycle users have identical preferences toward link-level and route-level characteristics. So, we group these two segments together because respondents in the two groups have very similar route preferences.

At this point, there remain two route choice segments: experienced users and inexperienced users. We next examine whether segmentation into these two groups is warranted. That is, we conduct a second likelihood ratio test after estimating a pooled model across all respondents to test whether experienced and inexperienced users have different route choice preferences. The likelihood ratio test value is 188, which is much larger than the threshold chi-squared value of 26. Thus, the results strongly indicate that experienced and inexperienced bicycle users are systematically different in their sensitivity to link-level and route-level factors.

Our results lend support to the FHWA classification of bicycle users into "advanced" (Group A) and "basic" (Group B) bicyclists, and indicate that there is no need for further classification of the latter group based on interest level for bicycle commuting. In the next section, we pursue a more detailed analysis of the differences in preferences between the experienced and inexperienced user groups.

4.2 Variable Effects

This section presents the empirical results of the route choice utility model. The coefficient estimates, represented by the β vector in Equation (1), presented here demonstrate the effect of variables on the utility or preference for a route.

For link-level factors, one of the variable levels is used as the base and the sign on the other variable levels indicate the preference for these other levels relative to the base level. For example, consider roadway class, which this study defines as residential, minor arterial, and major arterial. Let us introduce minor arterials and major arterials as variables with residential streets being the base level. Then a negative sign on the coefficients on minor and major arterials would indicate that bicyclists prefer the base category, or residential streets, on their route rather than minor or major arterials. In contrast, a positive sign on these two variables would suggest that bicyclists prefer minor or major arterials on their routes relative to residential roads.

For route-level factors, the interpretation is more straightforward because these are introduced "as is" in the utility functions. For example, a positive sign on travel time would indicate that individuals prefer routes with longer travel times to their workplace.

The results of the estimates in each of the experienced and inexperienced groups are provided in Table 2. In addition to the coefficient estimates and t-statistics within each group, we also provide t-statistics for the hypothesis that each coefficient is the same across both groups (see last column of the Table). If this t-statistic is greater than 1.645 for a coefficient (the table t-statistic value for a two-tailed test at a 90% confidence level), then we consider the corresponding variable to have different effects in the two groups[4].

4.2.1 Link-Level Variable Effects

Six link-level factors were considered in our analysis. All of these factors have a statistically significant effect on route choice in both the experienced and inexperienced groups.

The effect of roadway class is introduced with the residential street class as the base. The negative signs on the non-residential street classes indicate that commuter bicyclists prefer residential streets to non-residential streets, and minor arterials to major arterials. Overall, bicyclists prefer routes with low-volume motorized traffic. A comparison of the magnitude of the coefficients between the experienced and inexperienced groups indicates that individuals in the inexperienced group perceive major and minor arterials as much greater deterrents to choosing a route than individuals who are experienced bicycle commuters (note from the last column that the difference in sensitivity between experienced and inexperienced users is statistically significant for both the roadway class variables). The cause of this difference is perhaps attributable to the higher level of experience and/or skill in riding alongside busy automobile traffic within the group of experienced bicyclists. Alternatively, experienced bicycle commuters may simply be more willing to take risks compared to inexperienced individuals.

The negative sign on the parallel parking variable indicates that bicyclists avoid routes with links on which parallel parking is permitted, presumably because parked cars can pose a safety threat to bicyclists with car doors swinging open or cars pulling out in front of the bicyclist's path. This threat is perceived about equally by inexperienced and experienced users, since we cannot reject the hypothesis that the coefficients on this variable is the same across the two groups.

The positive effects on the variables representing the presence of some type of a bicycle facility (compared to the base condition of no bicycle facility) indicate that bicyclists have a preference for routes designed for bicycle use, with a bicycle lane being the most preferred facility type, followed by a separate path. Clearly, bicyclists prefer routes that offer some or total

[4] There are two reasons why we are able to directly compare the coefficients from the two groups. First, the range of each exogenous variable is about the same in both segments, so it is appropriate to compare coefficients across the two segments. Second, it is possible that the coefficient differences are not just due to differential impacts of variables, but also due to differences in the level of preference uncertainty (associated with any particular route configuration) between experienced and inexperienced users. We tested for such a scale difference by constraining the coefficients on the parallel parking variable to be equal across the groups and estimated separate coefficients on all other variables in the two groups as well as a scale parameter that indicates the relative preference uncertainty in the second group compared to the first (the scale of utility of the first group is normalized to 1 for identification). In this estimation we could not reject the hypothesis that the scale parameter is equal to 1, which suggests that the level of unobserved preference heterogeneity is equal in the two groups. These points together allow us to compare the coefficients directly between the two groups and enable the interpretation of coefficient differences as systematic preference variations between the two groups.

lateral separation from motorized traffic. Interestingly, inexperienced users value a separate path or a bicycle lane more than experienced users. This could be attributed to the inexperienced user's lack of comfort, skill, or experience in riding with automobile traffic. This same reason could explain the higher valuation of experienced users to wide right-hand lanes. Inexperienced users in the sample do not value wide right-hand lanes as much as experienced users, perhaps because of the general reluctance of inexperienced users to travel with automobile traffic.

The parameter estimates on the bridge type variables in Table 2 indicate that bicyclists prefer an environment in which no motorized traffic is allowed on bridges, or bridges that feature a riding area separated completely or through a sturdy barrier from auto traffic. Again, inexperienced users value such partial or complete lateral separation from automobile traffic on bridges more so than experienced users.

The variables associated with the riding terrain indicate a preference for flat ground rather than a mountainous environment, with the preference for flat ground much more pronounced for the inexperienced group. Surprisingly, however, the results suggest a preference for hilly (moderately uphill and downhill) terrain compared to flat terrain for experienced users. Hilly terrain may be preferred to flat terrain for experienced users because they provide a higher level of exercise benefits compared to flat ground. There is no difference in sensitivity to hilly versus flat terrain for inexperienced users. This may be because the benefits of hills (for example, coasting downhill) may balance out the discomfort of riding uphill.

Finally, in the group of link-level factors, the impact of the pavement type variables clearly reveals a preference among bicyclists for a smooth pavement riding surface over a rough riding surface, and for a rough, paved surface over a coarse sand surface. Smooth pavement conditions have a smaller effect on route choice for inexperienced individuals, yet earthen riding surface conditions have a greater effect on route choice for inexperienced individuals. It is possible that the inexperienced individuals do not distinguish between rough and smooth pavement as much as experienced individuals do. At the same time, they also appear to have more negative perceptions about riding on coarse sand.

4.2.2 Route-Level Variable Effects

Four route-level factors were included in the analysis, as shown in Table 2. The coefficient on travel time for both the experienced and inexperienced groups show the expected negative sign; that is, individuals prefer routes with a faster travel time. This sensitivity to travel time is significantly higher for experienced users relative to inexperienced users. One possible reason could be a difference in priorities – *i.e.*, as evinced above, the inexperienced respondents place a higher priority on safety-related variables. Compared to route choices for the inexperienced group, the route choices made by experienced bicycle commuters are not as impacted by variables that reflect perceptions of safety from automobile traffic. Comfort with automobile traffic allows experienced bicycle commuters to place a higher premium on travel time.

Continuity of bicycle facility (when a bicycle facility is present along the route) positively impacts the route selection of both experienced and inexperienced individuals. Inexperienced riders appear to value continuity slightly higher than experienced riders, though this difference is not statistically significant.

More frequent stop signs along a bicycle route discourage the use of that route, with experienced individuals being more sensitive to this than inexperienced users. This is probably explained by bicycle commuters' experience with stop signs, which present a twofold obstacle to bicyclists. First, stopping incurs delay and may be perceived to be unnecessary for the personal safety of individuals who bicycle regularly. Second, accelerating from a stop requires significant exertion (*32*).

The effect of the number of red lights shows that experienced users dislike routes with many red lights. This is consistent with the notion that such users feel confident in their ability to handle intersections without the need for any kind of control, and so view stops or red lights as a pure nuisance (this conjecture seems reinforced by anecdotal evidence). On the other hand, inexperienced users appear to prefer routes with many red lights, presumably because it provides them with an added perception of safety.

Finally, both experienced and inexperienced users prefer routes with fewer major cross-streets, with inexperienced individuals more negatively affected than experienced individuals. This result also appears to demonstrate heightened safety concerns of inexperienced bicycle commuters.

4.3 Relative Impacts of Variable

In addition to comparing the parameter effects in Table 2, one can also compare the relative magnitudes of the coefficients on the link-level dummy variables within each segment. However, one cannot compare the coefficients on the link-level dummy variables with the coefficients on the route-level continuous variables within a segment. One simple approach to assess the relative importance of each variable within each segment is to compute the contribution to utility of each variable at its average value when the feature represented by the variable is present in a route. The results of such an exercise are presented in Table 3.

The results in Table 3 show that, for both experienced and inexperienced users, separation from motorized traffic through separate bicycle paths or clearly designated bicycle lanes, bicycle routes that are not along major arterial corridors, and a paved bike path, are among the most important attributes in route choice decisions. All these attributes are clearly related to safety and/or riding quality. As discussed already, all of these safety-related link-level variables are of more importance in the route choice decisions of inexperienced users than experienced users. Furthermore, for inexperienced users, the presence of a non-motorized lane along bridges on the route is also very important and is one of the top five variables, while for experienced users, travel time on the route is of paramount importance.

5. SUMMARY, CONCLUSIONS, AND POLICY IMPLICATIONS

This paper has presented a series of discrete choice models that estimate the impact of bicycle commuting experience on an individual's preference for different route characteristics. In general, bicycle commuters of all levels place the most emphasis keeping travel time low while minimizing interaction with motorized traffic. The most important variables for all respondents in the sample are roadway type, presence and type of bicycle facility, travel time, and whether or not the route is paved. However, there are important differences in preferences between experienced and inexperienced respondents. Experienced bicyclists have a strong bias for routes that minimize travel time and delays. They also have less of a disinclination for mountainous terrain. While safety-related attributes are also clearly important to experienced bicyclists, they are much less influential in the route choice selections of experienced bicyclists compared to inexperienced bicyclists. On the other hand, travel times and delays are not as influential for the inexperienced group as for the experienced group.

These results have important policy implications. First, they demonstrate conclusively that developing attractive routes for all levels of bicycle commuters involves minimizing travel time while maximizing separation from motorized traffic. (In fact, many non-bicycle commuters who responded to the survey indicate that motorized traffic and/or lack of bicycle facilities is a major reason for not commuting by bicycle to work.) Due to contemporary urban travel network patterns, meeting both goals is a challenging task for most planners. However, the results also indicate where planners might compromise in areas with transportation networks that pose extreme challenges. For instance, while bicycle commuters prefer a bicycle facility to be present for the entire route, the route is still relatively attractive if the facility disappears for part of the route. Such compromises must be used with caution, though. If, for example, a city creates several bicycle routes from residential areas to downtown, their efforts in encouraging bicycling to work will be much more successful if at least some of these routes provide safe or comfortable navigation into and throughout downtown. For home-to-downtown bicycle commuters, the provision of several bicycle lanes that abruptly vanish at the most precarious part of the commute is little better than the provision of no bicycle lanes at all. Second, the results show that numerous link-level and route-level factors that have a significant effect on route attractiveness. Bicycle planners should attempt to consider all of these factors (and more) when planning routes. Similarly, the results show that planning bicycle routes is a complicated task. Public agencies should make sure to employ competent bicycle planners who comprehend the many factors that impact bicyclist route choice when designing and evaluating bicycle routes. Third, the differences in route choice preferences between experienced and inexperienced bicycle users can inform marketing strategies for promoting bicycle use. Specifically, planners and marketers might use the demographic and commute distance profiles (see Section 3.2) to effectively promote bicycle commuting to men, middle-aged individuals, and individuals with few vehicles in their households by emphasizing route design improvements that reduce travel time and delays, while they can appeal to women, very young or older individuals, and individuals with many cars in their households by emphasizing safety-related route improvements. Such customized bicycle use promotion campaign can lead to higher overall bicycle mode shares for the commute.

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LIST OF TABLES

TABLE 1 Descriptive Statistics of Sample

Variable	Experienced Users	Inexperienced Users	
		Interested in bicycle commuting	Uninterested in bicycle commuting
Number of respondents and (percentage)	2,846 (91.1)	197 (6.3)	83 (2.6)
Sex (%)			
Male	80	62	43
Female	20	38	57
Age (years) (%)			
18-24	5	9	7
25-34	27	28	10
35-44	31	23	10
45-54	26	22	21
55-64	9	16	22
65+	2	2	30
Number of cars in household (%)			
0	9	5	2
1	33	29	28
2	42	50	45
3	11	10	12
4	5	6	13
Home-work distance (miles) (%)			
<1	3	4	8
1-3	2	10	10
3-5	20	17	10
5-10	30	25	21
10-20	23	29	22
>20	22	15	29

TABLE 2 Route Utility (Binary Logit) Models for Experienced and Inexperienced Bicycle Users

Variable Types	Variable Class (or Factors)	Variable Level	Experienced Users		Inexperienced Users		t-statistic for test of coefficient equality
			Coefficient	t-ratio	Coefficient	t-ratio	
Link-Level	Roadway Class (base: residential street)	Major arterial	-1.75	-32.18	-2.35	-12.92	3.16
		Minor arterial	-0.56	-15.64	-0.82	-6.86	2.08
	Parking (base: parking not permitted	Parallel parking permitted	-0.48	-12.67	-0.51	-4.07	0.23
	Bicycle Facility Type (base: no facility)	Separate path	1.56	30.37	1.99	11.59	2.50
		Bicycle lane	1.84	37.30	2.27	13.56	2.46
		Wide right-hand lane	1.11	30.45	0.89	7.71	1.82
	Bridge Type (base: no bicycle facility)	Bicycle lane	0.98	18.34	1.30	7.45	1.76
		Barrier separation	1.25	16.56	1.71	6.61	1.71
		Non-motorized bridge	1.42	20.60	1.91	8.31	2.04
	Terrain (base: flat ground)	Mountainous	-0.73	-10.56	-1.44	-7.58	3.52
		Hilly	0.21	4.32	--	--	4.32
	Pavement Type (base: rough pavement)	Smooth Pavement	1.40	30.85	1.12	7.55	1.81
		Coarse Sand Surface	-1.45	-21.48	-1.84	-8.31	1.70
Route-Level	Travel time	Travel time (minutes)	-0.12	-32.68	-0.08	-7.43	3.10
	Continuity	Continuous facility	0.70	17.81	0.89	6.26	1.29
	Delays	Stop signs per mile	-0.38	-19.21	-0.13	-1.81	3.36
		#Red lights	-0.12	-6.21	0.13	1.76	3.28
	Cross-streets	#Major cross streets	-0.43	-16.01	-0.64	-7.25	2.28
Log-likelihood value at equal shares			-22,042		-2,138		--
Log-likelihood value at convergence			-19,731.8		-1,785		
Number of parameters			18		17		
Number of route choice observations			31,861		3,096		

TABLE 3 Contribution of Variables to Utility (and rank order of impact)

Variable Class	Variable Level	Average Contribution to Utility	
		Experienced Users	Inexperienced Users
Travel Time	Travel time (minutes)	-2.47 (1)	-1.72 (6)
Bicycle Facility Type	Bicycle lane	1.84 (2)	2.27 (2)
Roadway Class	Major arterial	-1.75 (3)	-2.35 (1)
Bicycle Facility Type	Separate path	1.56 (4)	1.99 (3)
Pavement Type	Coarse sand surface	-1.45 (5)	-1.84 (5)
Bridge Type	Non-motorized bridge	1.42 (6)	1.91 (4)
Pavement Type	Smooth pavement	1.40 (7)	1.12 (11)
Bridge Type	Barrier separation	1.25 (8)	1.71 (7)
Bicycle Facility Type	Wide right-hand lane	1.11 (9)	0.89 (13)
Bridge Type	Bicycle lane	0.98 (10)	1.30 (9)
Cross Streets	#Major cross streets	-0.84 (11)	-1.24 (10)
Delays	Stop signs per mile	-0.83 (12)	-0.28 (17)
Terrain	Mountainous	-0.73 (13)	-1.44 (8)
Continuity	Continuous facility	0.70 (14)	0.89 (12)
Roadway Class	Minor arterial	-0.56 (15)	-0.82 (14)
Parking	Parallel parking permitted	-0.48 (16)	-0.51 (15)
Delays	#Red lights	-0.31 (17)	0.32 (16)
Terrain	Hilly	0.21 (18)	--