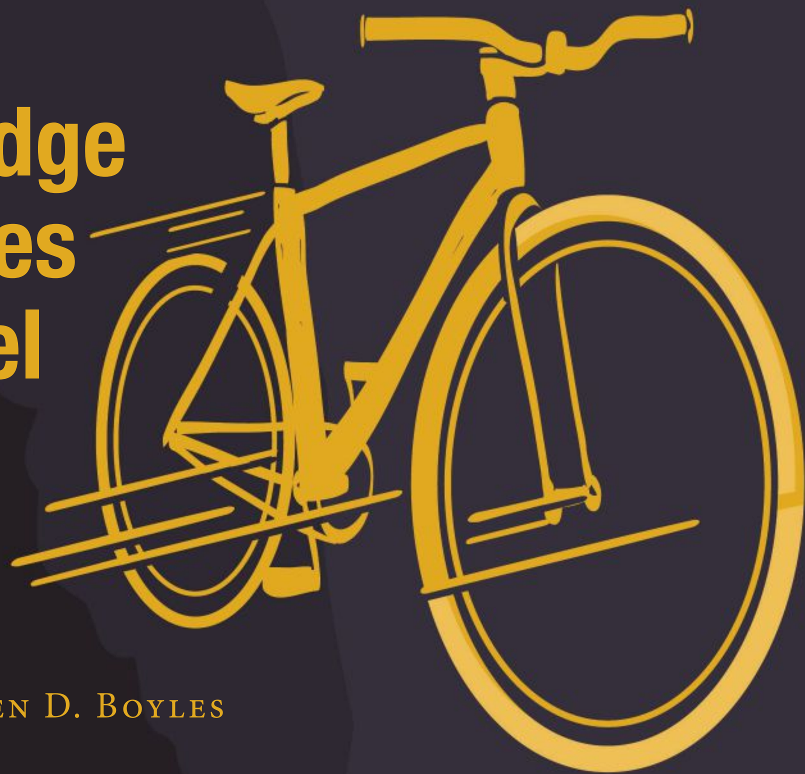
2013 Award Winner **DANIEL B. FAMBRO STUDENT PAPER AWARD**

Influence of Bridge Facility Attributes on Bicycle Travel Behavior



By Christopher L. Melson, Jennifer C. Duthie, and Stephen D. Boyles

An unlabeled multinomial logit model is developed to estimate the impact bridge facility attributes have on bicycle travel behavior. Data were collected in Austin, Texas, via a GPS-based smartphone application. Three attributes are analyzed and interacted with varied demographic and trip purpose information: bridge accessibility, vehicular volume, and traffic separation.

Due to the significant investment in bicycle facilities at the local, state, and federal levels and the increase in urban bicycle use, it is imperative that agencies fully understand the behavioral elements underlying bicycle travel patterns. Transportation planners cannot assume bicyclists are solely focused on minimizing travel time or distance—standard practice assumptions for vehicular modes. This paper focuses on the analysis of bridge characteristics that are attractive to bicyclists. While several others have looked at bicycle facility preferences, this is the first paper to focus exclusively on bridges. Bridge facilities are fundamentally different from the rest of the bicycle infrastructure network; they act as funneling systems, where paths are constrained to a small handful of options. Bridge facilities are crucial in bicycle route choice, since any improvements or additions can have wide-ranging and wide-reaching effects on travel behavior. Construction of bridges is also significantly more costly than at-grade facilities, making retrofit difficult. The objectives of this study are threefold:

1. Contribute to bicycle route choice research using revealed preference data.
2. Use detailed GPS data to gain insights while avoiding complications and potential errors of matching data to the full network and developing a network-based route choice model.
3. Identify bridge attributes that are necessary in making a bridge friendly to bicyclists, considering variations across gender, age, and experience.

To these ends, the authors developed an unlabeled multinomial logit model of bridge choice with data collected in Austin, Texas, using a GPS-based smartphone application. Attributes of the bridges are interacted with trip purpose and demographic factors to determine important infrastructure characteristics that influence bicyclists' trip behavior.

Literature Review

The majority of bicycle route research has come in the form of stated preference surveys. These studies have included such variables as bicycle facility type, age, gender, roadway characteristics, traffic volume, and bicycling experience. Stinson and Bhat conducted a nationwide survey with more than 3,000 respondents, finding facility type, traffic volume, and presence of a bicycle facility on a bridge to be significant factors for bicyclists when choosing a route.[1] Several studies have found similar results.[2, 3, 4] Despite the advantage of efficient data collection, problems with stated preference surveys are well documented: There is not always a direct correspondence between one's stated and one's actual preference.[5, 6]

There is limited revealed preference research regarding bicycle travel behavior. The authors know of only three studies that have used GPS data. Menghini et al. analyzed 73,493 bicycle trips made in Zurich, Switzerland, collected via GPS units.[7] Shortest path alternative routes were generated for the purpose of building a route choice model. Bicyclists were found to prefer direct and marked routes and to avoid steep gradients. Broach et al. also used bicycle-mounted GPS units to collect data from 164 bicyclists in Portland, Oregon.[8] Key results include the following: Commuters were more sensitive to distance and less sensitive to other variables, bicycle boulevards and off-street paths were preferable to bicycle lanes, and half of all trips were less than 10 percent longer than the shortest path distance. Hood collected GPS data via the smartphone application CycleTracks.[9] 2,777 routes were collected by 366 users. Key results indicate that bicyclists prefer routes with fewer turns, women and commuters desire to avoid hills, and infrequent bicyclists have a stronger preference for bicycle lanes. The current study will build on the previous literature by examining the impacts of distance, bridge characteristics, and user characteristics (gender, age, and cycling frequency) on bicycle travel behavior. The study will contribute to the fairly new literature on GPS-based data collection by using the CycleTracks application.

Methodology

To analyze the influence of bridge attributes on bicycle behavior, data were collected, sample statistics examined, attributes defined, model structure determined, and explanatory variables created.

Data Collection

Real-time GPS data were collected in the Austin region May–October 2011 via the CycleTracks smartphone application. A comprehensive marketing campaign was conducted to bring awareness of the study to the bicycle community. The collection process relied solely on volunteers. CycleTracks allows the user to input their age, gender, bicycling frequency (less than monthly, monthly, weekly, or daily), and trip purpose (commute, work-related, school, exercise, shopping, social, errand, or other). The application records the position of the bicyclists and the time via their smartphone GPS capabilities. GPS data are recorded when the user indicates the trip start, with stop being recorded when the user signifies the trip end. More information regarding CycleTracks is provided by Hood.[9]

Trips were created from GPS data points recorded every few seconds. Points were deleted when (1) GPS satellite accuracy was low, (2) calculated travel speed (based on the current and directly preceding points) was greater than 30 mph, or (3) speed was less than 2 mph. Trips were completely removed when less than 5 points were collected. In total 3,615 trips were recorded by 317 users. Using ArcGIS and map matching, trips using the downtown bridges were extracted from the rest of the data, resulting in 550 total bridge trips by 81 users. After data cleaning (mainly due to incomplete demographic information), the final sample included 505 trips by 71 users.

Sample Statistics

Three time-related explanatory variables were created from the GPS data: whether the trip occurred on a weekday or weekend, during the peak period, or during sunlight hours. These variables along with the other collected data are summarized in Table 1. When speaking of bicycling for transportation versus recreation, one could combine trip purposes. Commute, errand, work-related, shopping, social, and school could be defined as transportation-related trips. About 90 percent of the trips recorded were for reasons of transportation, which can be explained by the close proximity of the bridges to the central business district.

While the study targeted all bicycling adults (due to restrictions on human subject research, only adults could participate), users are typically younger; most are ages 20–40. A 2012 Pew Research study showed significant smartphone usage across all income levels and races; however, the CycleTracks application did not collect income or race information, so it is not certain that the study is unbiased across these categories.[10]

Based on the methods of marketing the study, one might hypothesize that participants are more likely to be enthusiastic about bicycling and may be more comfortable bicycling in traffic. If cycling frequency is truly a proxy for level of expertise, then the study targeted expert bicyclists. This is important to consider when analyzing the results, since the routes selected by novice bicyclists (those who do not cycle frequently) may differ from the routes selected by more experienced bicyclists. Overall, the sample statistics compare well with state and national bicyclist data.[11, 12]

Characteristic	Count	Percentage
Departure Time		
Weekend	80	16
Weekday	425	84
Peak	170	34
Off-Peak	335	66
Dark	72	14
Light	433	86
Trip Purpose		
Shopping[a]	35	7
Exercise	42	8
Social	64	13
Work-Related[a]	16	3
Commute	299	59
School[a]	4	1
Errand[a]	41	8
Other[a]	4	1
Gender		
Males	52	73
Females	19	27
Cycle Frequency		
Less than once per month[a]	1	1
Several times per month[a]	8	11
Several times per week	29	41
Daily	33	47
Age		
20–30	28	39
> 30–40	24	34
> 40	19	27

[a]*Trip purposes and cycle frequencies with a limited number of observations and similar characteristics were modeled together; this is discussed in later sections.*

Table 1. Summary of sample statistics.

Bridge Attributes

Three bridge attributes were included in the model: accessibility, vehicular volume, and traffic separation.

Accessibility. The purpose of the accessibility attribute is to measure how easily (in terms of distance and comfort) bicyclists can enter and exit from each bridge. The city of Austin categorizes its bicycle infrastructure with ease-of-use ratings: high, moderate, and low. High ease of use segments contain bicycle lanes or wide curbs on higher volume streets. Paved trails and low-volume residential streets also have high ease of use. Moderate ease of use corresponds to low- and moderate-traffic volume streets or high volume streets with wide outer lanes/shoulders. High traffic volume streets with narrow lanes or streets that function as a barrier to bicyclists have low ease of use. Accessibility was measured by determining the total amount of connected moderate and high ease of use network segments within 0.5 mi (0.80 km) of each bridge access point. Accessibility is measured in miles of moderate or higher ease of use segments. Figure 1 shows an example of how accessibility was calculated using ArcGIS.

Vehicular Volume. Previous studies have determined vehicular volume to be an important factor in bicycle travel behavior. The volume attribute is measured as the average hourly, directional volume during the time period of each observed bicycle trip. Time of day was divided into four periods: AM peak, mid-day off-peak, PM peak, and night. Hourly volumes were based on data collected during the AM and PM peaks, then aggregated to each time period using weighted diurnal factors. Traffic was assumed to be equally split in each direction during the off-peak periods.

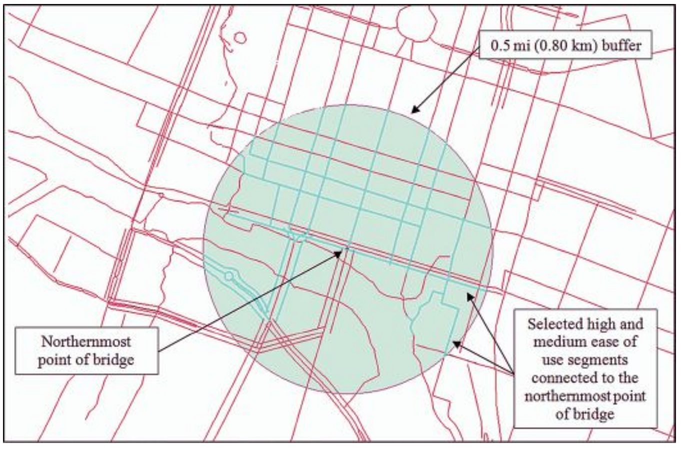


Figure 1. Calculating bicycle bridge accessibility using ArcGIS.

Traffic Separation. The third attribute in the multinomial logit model measures the degree to which bicycle users are separated from traffic and was taken as the bicycle/pedestrian pathway width. If a separate lane or bicycle facilities were not provided on the bridge, pedestrian sidewalk width was used. Bridge attributes are summarized in Table 2. Figure 2 shows the location of each bridge over Lady Bird Lake in downtown Austin.

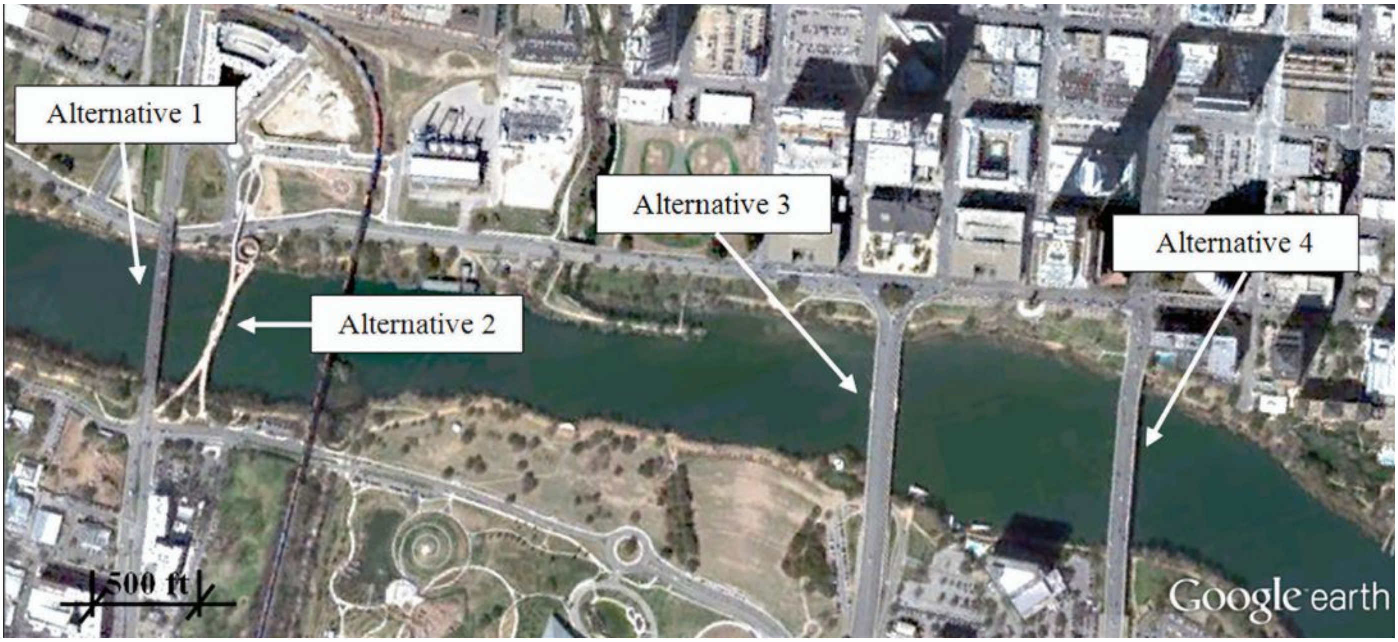


Figure 2. Bridge locations.

Model Structure and Explanatory Variables

The multinomial logit (MNL) model was chosen for its simplicity and common use. The authors feel that the assumption of independent error terms across individuals and alternatives is tolerable for modeling bridge choice decisions. Typical MNL utility functions are in the form $U_{in}= \beta X_{in}+\varepsilon_{in}$ where i is the index representing bridge choice, and n is the index for the individual. ε_{in} is the error term assumed to be of standard Gumbel distribution. β is the vector of parameters to be estimated. X_{in} contains the bridge attributes and all other individual/trip-specific explanatory variables interacted with these attributes. A distance variable was included in the model

Attribute	Attribute Description	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Accessibility	Total miles (kilometers) of high/medium ranked bicycle infrastructure within 0.5 mi (0.80 km) of bridge access points.	10.39 (16.72)	12.38 (19.92)	10.11 (16.27)	9.16 (14.74)
Vehicular Volume					
AM Peak—Northbound	Average directional, hourly vehicular volume within the specified time periods: AM peak, mid-day off-peak, PM peak, or night.	1087	0	1198	1130
AM Peak—Southbound		433	0	340	272
Mid-day Off-Peak—North/Southbound		424	0	407	379
PM Peak—Northbound		900	0	549	578
PM Peak—Southbound		1011	0	1208	1086
Night—North/Southbound		76	0	73	68
Traffic Separation	Average width of bicycle/pedestrian path in feet (meters).	3.5 (1.1)	20 (6.1)	15 (4.6)	8 (2.4)

Table 2. Bridge attributes.

and interacted with individual/trip-specific variables. Distance was measured as the Euclidean distance from the trip origin to the center of each bridge and from the center of each bridge to the destination. Since we are using a generic alternative approach, there is no "base case" or alternative-specific constants.

Several variables were grouped together due to limited data. Bicyclists who rode less than a month were grouped with bicyclists who rode several times a month. Shopping, errand, and other trip purposes were grouped into a single variable. School- and work-related trips were also grouped together. The following explanatory variables were included in the model: distance, bicycling frequency (*monthly as the base*), age, gender (*male as the base*), trip purpose (*commute trips as the base*), whether the trip occurred on the weekend, whether the trip occurred during the peak period, and whether the trip occurred during dark lighting conditions. Parameters were estimated using the BIOGEME software program.[13]

Results

This section examines the importance of each bridge attribute and its interaction with demographic and trip purpose data.

Unlabeled Multinomial Logit Model

Table 3 shows the estimated parameters of the MNL model. Coefficient values represent the change of an individual's utility based on a unit change in the corresponding variable. For example, an accessibility value of 1.37 can be interpreted as the increase in utility a bicyclist experiences for every increase in mile of moderate/high ease of use segments near the bridge access points.

Accessibility. Accessibility is a significant factor in a bicyclist's bridge choice decision. As bridge accessibility increases, attractiveness of that bridge increases. As shown in Table 3, accessibility is a major factor for more comfort-value users (females and less experienced bicyclists). It is less important for time-stressed trips and trips during low volume periods.

Volume. Vehicular bridge volume has no influence on bicycle travel behavior during off-peak periods, after accounting for traffic separation and other factors. However, during peak periods, bicyclists are more attracted to low volume bridges. Also, bicyclists are more inclined toward higher traffic bridges when conducting shopping trips. The authors believe this is due to the distribution of major shopping centers in downtown Austin.

Traffic Separation. Separation from vehicular traffic significantly impacts a bicyclist's bridge choice; bicyclists are attracted to bridges with higher traffic separation. High frequency users are more inclined toward traffic separation than monthly users. This may be due to inexperienced bicyclists solely focusing on origin-to-destination travel (without deviating from standard routes to more separated routes with only marginal increases in travel time). Bicyclists traveling during night and early morning hours place less importance on traffic separation, since lower traffic volumes occur during those time periods.

Distance. Distance is the most significant factor in a bicyclist's trip decision, especially when trips are time-constrained; users comparatively place less importance on distance when conducting recreational-type and off-peak trips. Female bicyclists place less importance on distance than males, suggesting females choose more comfortable routes while sacrificing travel time.

Attribute and Interaction Terms	Value	t-value
Accessibility	**1.37000**	**6.22**
Peak Trips	-0.72700	-3.37
Weekend Trips	-0.39200	-2.74
Female Cyclists	0.44200	2.81
Daily Cyclists	-1.55000	-6.52
Weekly Cyclists	-1.25000	-5.15
Volume	**insignificant**	
Peak Trips	-0.00265	-4.91
Shopping Trips	0.00195	3.31
Traffic Separation	**0.33500**	**3.15**
Low-Light Trips	-0.17600	-4.91
Shopping Trips	0.07540	2.14
Daily Cyclists	0.11700	2.08
Weekly Cyclists	0.21900	3.64
Age	-0.00973	-4.88
Distance	**-19.10000**	**-7.84**
Peak Trips	-4.05000	-2.97
Exercise Trips	12.90000	7.59
Shopping/Social Trips	10.40000	6.98
Female Cyclists	2.03000	2.09
Daily Cyclists	2.61000	3.44
Age	0.15600	3.49
Log-likelihood at equal shares	-646.301	
Log-likelihood at convergence	-350.656	

Table 3. Estimated parameters.

Conclusion

This paper developed an unlabeled multinomial logit model for bicycle bridge choice decisions based on GPS data gathered in Austin, Texas. By limiting focus to bridge facilities, we avoided the difficult task and potential errors associated with generating feasible path sets for each observation. We also examined the impact of bridge facility attributes on bicyclists' behavior at a more detailed level than previous studies. Of the three inspected attributes, bridge accessibility and traffic separation were found to significantly influence bicycle travel behavior. Bicyclists, especially infrequent and female cyclists, are attracted to bridges that are easily and comfortably accessible via the current bicycle network. Bicyclists are also more inclined toward bridges with adequate traffic separation, particularly for daily and weekly users. Vehicular traffic was insignificant except during the peak period.

Bridge choice plays a significant role in bicyclists' route choice decisions. Bridge facilities act as funneling systems, constraining paths to limited network segments. Also, bridge facilities are difficult to modify once constructed, have a much longer design life than typical bicycle infrastructure, and are expensive. Therefore, integrating detailed bridge characteristics with true bicycle route choice models would be extremely beneficial to transportation planning agencies.

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