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Two Approaches to Valuing Some of Bicycle Facilities' Presumed Benefits

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This article reports the results of two different approaches to valuing some of what are thought to be benefits of bicycle trails and lanes. First, an adaptive stated preference survey is used to measure how much travel time individuals are willing to spend to obtain particular features of on- and off-street bicycle facilities. These findings indicate that bicycle commuters in Minneapolis and St. Paul prefer bicycle lanes on existing streets over off-street bicycle trails, and also prefer them over streets that have no onstreet parking but lack designated bicycle lanes. Second, I used home sales data to learn the effect of bicycle trail proximity on home value. Though proximity to bicycle facilities is valued differently for different types, it actually significantly reduced home value in suburban locations. Suburban home values were most reduced by proximity to roadside trails, which also reduced home values significantly in the cities. Proximity to other types of bicycle facilities in the cities did not significantly affect home values.

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Procedures for valuing benefits of highway or transit-related investments for planning purposes are relatively well established, but this is not the case for projects to accommodate nonmotorized modes. The value of investing in cycling facilities is often questioned, given that cycling in North America accounts only for approximately 0.8% of all trips (U.S. Department of Transportation, Bureau of Transportation Statistics, n.d.) causing some to term it a "fringe" mode (Gordon & Richardson, 1998). Opponents of bicycle projects bombard decision makers with cost information because data on costs are relatively easy to obtain. Benefits, however, are considerably more difficult to estimate, and though the bicycle planning community makes many advocacy-based claims, methodologies for valuing cycling facilities' benefits are in short supply.

Bicycle facilities presumably provide benefits to those who actually use them, and potentially to others, who are affected indirectly. Such consequences may be measured by asking people their opinions (i.e., their "stated" preferences, Brookshire, Thayer, Schulze, & D'Arge, 1982; Diamond & Hausman, 1994; Hanemann, 1994) or by attempting to identify how they influence markets (i.e., discovering people's "revealed" preferences, Freeman, 1979; Rosen, 1974). This research describes a stated-preference approach to measuring how much bicycle commuters value various facility characteristics, and a revealed-preference approach to measuring how much homeowners value proximity to bicycle facilities. Finally, I discuss the significance of this research, its shortcomings, and its policy relevance. I have reviewed the literature on other proposed methods elsewhere (Krizek, in press) and the research report from a project involving multiple collaborators is also available (Krizek et al., 2006).

The investigations reported here took place in the Minneapolis–St. Paul, Minnesota, metropolitan area, which boasts a system of off-street bike paths unparalleled among major metropolitan areas in the United States, totaling over 2,722 kilometers (1,692 miles). While not nearly as extensive, striped on-street bike lanes are common as well. The network of on- and off-street trails is accessible to most residents, with 90% of homes within 1,600 meters (one mile) of an off-street trail. Twin Cities residents cherish their bicycle trails, especially in the summer months. The metropolitan area has high rates of cycling use (Barnes & Krizek, 2005; Dill & Carr, 2003), suggesting a relatively high proportion of residents are sensitive to aspects of cycling-related infrastructure.

Adaptive Stated-Preference Survey Valuing Bicycle Facility Features

This first section describes a method used to measure how much additional travel time individual commuters are willing to spend in order to use enhanced cycling facilities during a typical commute. Tilahun administered the survey and performed the analysis (Tilahun, 2005), which we then incorporated into the larger research project (Krizek et al., 2006).

The literature on cyclists' preferences for various types of facilities mostly relies on surveys that ask cyclists to state preferences by making route choices. Bovy and Bradley (1985) and Abraham, McMillan, Brownlee, and Hunt (2002) analyzed bicyclists' route choices in order to gauge how they valued different facility types, surface qualities, traffic levels, and travel times in, respectively, Delft and Amsterdam in the Netherlands, and Calgary in Canada. Hopkinson and Wardman (1996) also asked about route choice to investigate the demand for cycling facilities generally. Stinson and Bhat (2003) administered an Internet-based stated-preference survey and used the data to estimate a logit model of how facility attributes affected commuter route choice. While their model showed that the most important variable affecting route preference was travel time, the facility type was also significant. In particular, they found that cyclists are willing to tolerate about 10% longer travel times in order to use routes on residential streets and routes with dedicated bicycle lanes on bridges rather than routes on minor and major arterials with no bicycle lanes on bridges. Another study (Taylor & Mahmassani, 1996) found that inexperienced cyclists had stronger preferences for bicycle lanes than did more experienced cyclists, who did not show a significant preference for bike lanes over wide curb lanes.

At least two studies explored similar themes using revealed preferences. Shafizadeh and Niemeier (1997) used intercept surveys along a well-known bicycle trail in Seattle to investigate how proximity to an off-road bicycle trail affects route choice decisions. They found that as the distance between the trip origin and the off-road trail increases, travel time increases to a point and then decreases. This led them to conclude that a 0.5 to 0.75 mile "bike shed" could exist around an off-road bike path, within which individuals will be willing to increase their travel time to access that facility and outside of which individuals preferred a more direct route. In another revealed-preference investigation, Aultmann-Hall, Hall, & Baetz (1997) used GIS to investigate bicycle commuter routes in Guelph, Canada. They compared participants' shortest paths to their actual paths, learning that people diverge very little from the shortest path, and that most bicycle commuters use major road routes. However, these studies' results may be flawed by several factors: a lack of comparable facilities connecting common origins and destinations, inability to provide realistic scenarios for comparison, and/or potentially biased samples of respondents (e.g., the sampled bicyclists were tolerant of environments too risky to be acceptable to the larger population).

Survey Approach and Administration

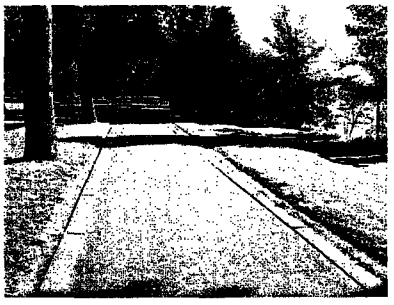
The approach employs an adaptive stated-preference (ASP) survey to understand how bicycle commuters value five different travel environments. Table 1 shows (A) an off-street facility, (B) an on-street facility with no parking, (C) an on-street facility with parking, (D) a roadway without a bicycle facility and no parking, and (E) a roadway without a bicycle facility with parking. Many municipalities would consider an off-street facility (A) a Class I facility, and the on-street facilities (B and C) to be Class II facilities. A roadway without a bike facility and no parking is similar to a wide curb lane.

The data come from a computer-based ASP survey developed specifically for this investigation. I videotaped 10-second clips taken from a bicyclist's perspective to accurately represent the conditions along each type of facility. All survey respondents watched nine presentations that asked them to simultaneously compare two facilities (see Figure 1 for a sample computer interface). The respondent was prompted to consider a typical 20-minute commute, choose among a set of travel times, and select a preferred facility. ASP is advantageous because the experimenter has dynamic control of the choice set, and presents the respondent with information based on their previous choices. While the choices portrayed in the survey do not have real consequences for the individual respondents, the videos help them make direct comparisons of alternatives.

The respondent compares each facility with all other facilities (e.g., A with B, then C, D, and E). The adaptive element of the survey allows us to determine the additional minutes each individual says he or she would be willing to bicycle over the 20 minutes they are told the commute would take using the base facility.

For each respondent, the choice set narrows or widens four times. For example, if the subject first chooses the longer option, then the next choice set assigns a higher travel time to the higher quality path (raised from 40 minutes to 50 minutes). If the respondent still chooses the longer option, the travel time for that choice increases to 55 minutes and the choice is posed again. If, on the other hand, the 50-minute option is rejected and the respondent chooses the 20-minute route, a bisection algorithm calcu-

Table 1. The five types of facilities examined in the stated preference analysis.



(A)
Off-street facility

(B)
On-street facility
(no parking)

(C)
On-street facility
(with parking)

(D)
No bicycle facility
(no parking)

(E)
No bicycle facility
(with parking)

lates the travel time that is between the now rejected option and the previously accepted one, which in this case is 45 minutes (see Table 2). By the time the respondent makes a fourth choice, the survey will have either narrowed the respondent's preference to within 2 minutes or reached the maximum travel time that can be assigned to the longer trip (58.5 minutes).

Average values for each pair of facilities compared are shown in Table 3. On average, individuals were willing to travel for a longer time on an alternate facility (i.e., the alternate facility was preferred) when the base facility was C, D, or E. For example, individuals were willing to travel further in environment B when the base environment is E, as opposed to C or D.

The survey was administered in two waves (winter and summer), showing the same five locations for each facility type in both seasons. All of the locations shown were in the western portion of St. Paul, Minnesota. Invitations were sent out to 2,500 randomly selected University of Minnesota employees, excluding faculty and teaching staff,[1] asking them participate in a computer-based survey about their commute to work and offering $15 as compensation. Participants were required to come to a central testing station on campus where the survey was being administered. A total of 90 people participated in the winter survey and another 91 participated in the summer survey, for a total of 181 participants. We omitted 14 of these cases due to incomplete information, leaving 167 respondents. (See Table 4 for sample characteristics.) Of these 167, 68 indicated they had bicycled to work at least once in the past year. Of these 68, 38 identified themselves as regular bicycle commuters, at least during the summer. Of the 167 respondents, 127 said they had bicycled somewhere, including to work, in the past year. We also collected demographic, socioeconomic, household, and current travel mode information from each participant to better understand if the value that people attach to attributes of facilities is systematically related to individual and social characteristics.

Model Specification

We used an empirical model to evaluate relationships between a variety of independent variables and the additional travel time respondents were willing to expend in order to commute on cycling facilities with particular attributes. This approach assumes that given a choice between two different routes and a time estimate for each, individuals choose options that provide them with the greatest utility,[2] depending on the features of the facility and the expected travel time for that route. The model accounts for three features of the five types of facilities in Table 1: whether a facility (1) has a designated on-street

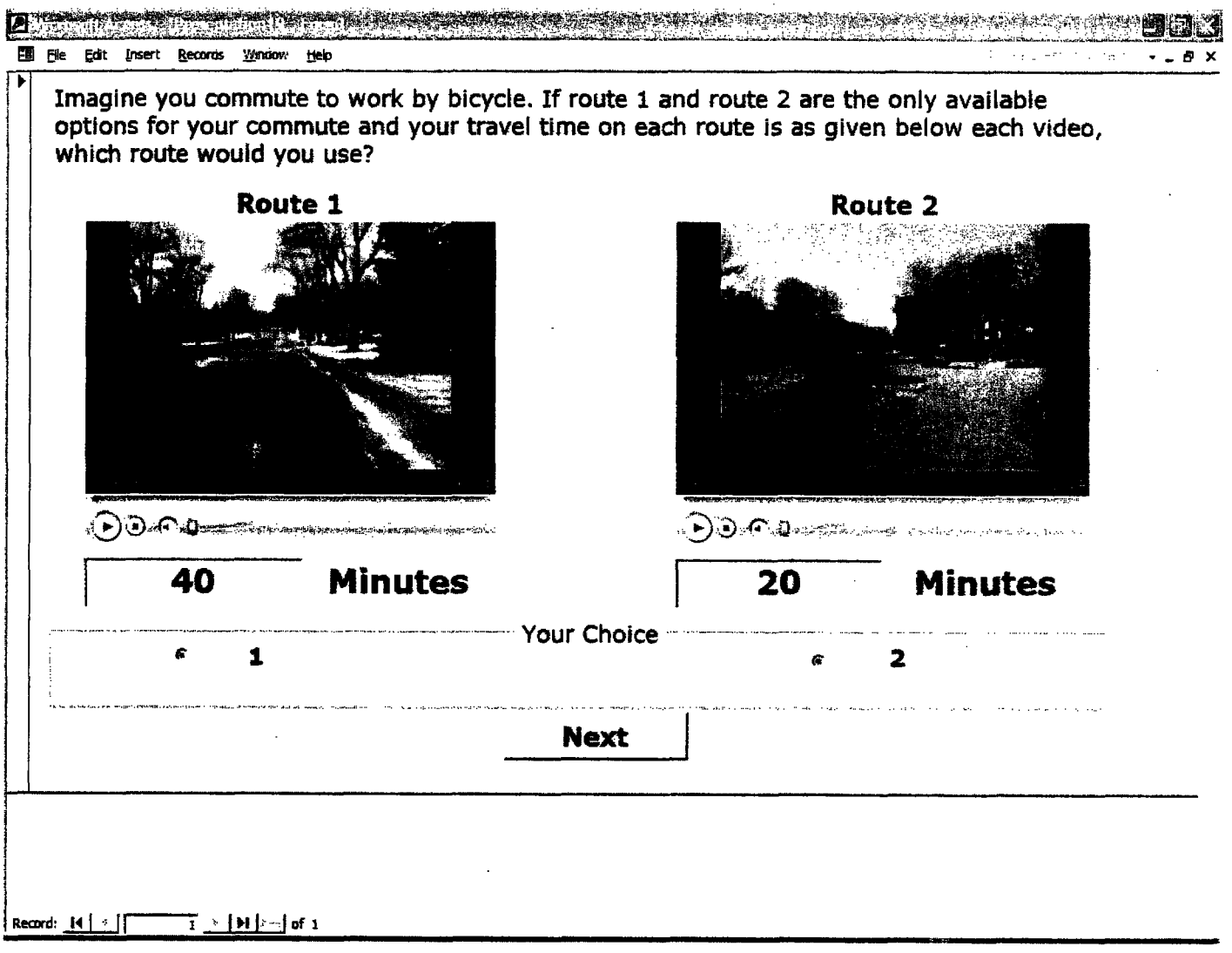


Figure 1. Survey instrument comparing designated bicycle lanes (with no parking) with in-traffic bicycling (with no parking).

bicycle lane, (2) is off-road, and (3) has parking adjacent to it.[3] We aim to know how each feature contributed to the individual's choice. Choices may also be affected by individual characteristics such as income, sex, age, or whether the individual considers him/herself to be a cyclist and whether it is summer or winter. Thus, the model's linear utility component is a function of the attributes of the facility, travel time, season, and the person's individual attributes.[4]

Results

Table 5 shows the results of the generalized mixed logit regression model, indicating the odds of selecting a facility worth extra travel time, meaning it would be preferred if travel times were the same. Thus the model indicates the odds that each independent variable contributes to a preference for "higher quality" bicycle facilities. Table 5 shows that the signs of the estimated parameters are as expected. The effect of travel time is negative, showing that people prefer shorter trips. The attributes theorized to be desirable (e.g., being off-road, having a designated bicycle lane, having no parking) all influence respondents positively and significantly toward more time-consuming trips, but at different magnitudes. Of these three, the presence of an on-street bicycle lane increases the odds of selecting a more time-consuming route more than do the absence of parking or being an off-road facility.

The season variable is negative and significant, indicating higher odds of choosing a longer route in summer. Neither income nor sex were significant at the 0.05 level,

Table 2. Hypothetical travel time choices facing a respondent to the ASP survey and result.

	Alternatives		
	Route 1	Route 2	Choice
Choice set 1	40 min.	20 min.	Route 2
Choice set 2	30 min.	20 min.	Route 1
Choice set 3	35 min.	20 min.	Route 1
Choice set 4	37 min.	20 min.	Route 2
Ti = Average acceptable travel time of the preferred alternative (Route 1)	36 min.		

Table 3. Average value of the additional travel time required by alternate over base routes.

	Base routes			
Alternate routes	B	C	D	E
A	14.21 min.	16.00 min.	18.46 min.	23.14 min.
B		10.13 min.	13.73 min.	20.87 min.
C			11.52 min.	19.65 min.
D				18.25 min.

though the model indicates that both women and people with higher incomes have greater tendencies to choose the longer routes, which are also perceived as safer ($p = 0.07$ and 0.13 respectively). Whether the respondent uses bicycling as his or her main mode for commuting, at least during summer, is insignificant. Individuals whose household size is greater than two had lower odds of choosing the facility requiring more time. This may be because these individuals have greater constraints on their time than individuals who live in one- or two-person households.

The marginal value of these three features of cycling facilities (on a 20-minute base travel time) can be derived using the marginal rate of substitution between each of the facility features and travel time. An on-street bicycle lane is worth an additional 16.3 minutes, the absence of parking is worth an additional 8.9 minutes, and an off-road bicycle facility is worth an additional 5.2 minutes.

Revealed-Preference Survey Valuing Homeowners' Bicycle Trail Access

The second part of this investigation tests the degree to which bicycling-related infrastructure adds to a community's real value. To the extent access to facilities is valued, the dollar value people place on proximity to bicycle paths should be capitalized in the prices of homes that are nearby.

Using hedonic modeling techniques to value housing attributes dates back to Lancaster (1966) and Rosen (1974). In an extensive review of this literature Sirmans and Macpherson (2003) documented nearly 200 such investigations which estimated values for structural attributes (e.g., lot size, square footage, and number of bedrooms), internal and external features (e.g., fireplaces, air conditioning, garage spaces, and porches), natural environmental features such as scenic views or proximity to open space (Benson,

Table 4. Attributes of the stated preference analysis sample.

Sex	
Male	34.5%
Female	65.5%
Age (years)	
Mean (SD)	44.19 (10.99)
Usual mode for commute to work (year round)	
Car	69.7%
Bus	18.5%
Bicycle	9.2%
Walk	2.6%
Bicycle commuter	
In all seasons	9.2%
During summer months	22.6%
Household income	
<$30,000	8.3%
$30,000–$45,000	14.3%
$45,000–$60,000	19.6%
$60,000–$75,000	15.5%
$75,000–$100,000	20.2%
$100,000–$150,000	17.9%
>$150,000	4.2%
Household size	
1	25.0%
2	32.7%
3	16.7%
4	20.8%
>4	4.8%
N	167

Table 5. Stated preference analysis: Generalized mixed logit model predicting odds of selecting an alternative more time consuming than the base alternative.

	Coefficient	SE	t	Probability > |t|
Variable				
Intercept	0.166	0.284	0.580	0.562
Season (1 = winter)	−0.582	0.209	−2.790	0.006
Travel time	−0.052	0.004	−12.110	<0.0001
Off-street improvement?	0.260	0.060	4.330	<0.0001
Parking improvement?	0.474	0.065	7.340	<0.0001
Bicycle lane improvement?	0.838	0.067	12.510	<0.0001
Age	−0.001	0.001	−1.160	0.248
Sex (1 = male)	−0.405	0.225	−1.567	0.073
Income	0.005	0.003	2.510	0.129
HH size (1 if greater than 2, 0 otherwise)	−0.693	0.227	−3.060	0.003
Cyclist (1 = at least summer, 0 = No)	−0.094	0.257	−0.360	0.716
Random effects of subjects	1.271	0.088	14.507	<0.0001
Statistics of model fit				
−2 Log likelihood	7266.1			
Akaike (AIC)	7290.1			
Bayesian (BIC)	7327.4			
Observations	6,012			
Subjects	167			
Observations/subjects	36			

Hansen, Schwartz, & Smersh, 1998; Geoghegan, 2002; Irwin, 2002; Lutzenhiser & Netusil, 2001; Mahan, Polasky, & Adams, 2000; Quang Do & Grudnitski, 1995; Smith, Paulos, & Kim, 2002), neighborhood and location attributes (e.g., crime, golf courses, and trees), public services, school quality (Brasington, 1999), and different forms of accessibility (Franklin & Waddell, 2003).

I expect different types of bicycle facilities to have different amenity values depending on whether they are lanes on existing streets, separated from roadways by curbs or landscaping (hereafter roadside facilities), or more distant from roadways within open spaces (nonroadside facilities).[5] Anderson and West (in press), modeled the effect of proximity to different amounts of open space on home prices in the same setting. Comparing city and suburb, they found that urbanites and suburbanites value various types of open space differently.[6] The work by Lindsey, Man, Payton, and Dickson (2003, 2004) is the only analysis investigating the effect of multipurpose trails on property value using home sales prices. Their hedonic analysis of 9,348 home sales within a half-mile of 14 different greenways in Marion County, Indiana, found that some greenways have a significantly positive effect on property values, while others have no significant effect.

Theory and Data

One county commissioner in the Twin Cities claims that bike facilities, like libraries, are goods everyone appreciates (P. McLaughlin, personal communication, April 18, 2003), but Anderson and West's analysis (in press) suggests that open spaces (and bicycle facilities also, I maintain) may be perceived and valued differently depending on whether they are located in the city or suburbs. Thus I build a hedonic model that assumes the market price of a home reflects its own attributes and those of its location in the city or the suburbs.

The Regional Multiple Listing Services (RMLS) of Minnesota, Inc. maintains home sale data from major real estate brokers in Minnesota. This database encompasses all home sales listed by the RMLS in the seven-county Twin Cities metro area in 2001, totaling 35,002 sales,[7] and includes the structural attributes of each home. The address of each home was mapped and married with GIS features for spatial analysis using ArcGIS. Table 6 lists each variable, its definition, and descriptive statistics. The variables include three location attributes: linear distance to the central business district of either Minneapolis or St. Paul, whichever is closer; linear distance to the nearest major highway; and whether the location is on an arterial street.

Neighborhood attributes include demographic variables from the 2000 U.S. Census[8] and the quality of the school district using standardized test scores.[9]

Measures of Distance to Bicycle Facility. Using detailed GIS data, we mapped all bike facilities in the region and identified each as either an on-street or an off-street facility, some in major open space corridors (e.g., along railway lines, rivers, and lakes, examples in Figure 2). We merged the RMLS data for every home sale with the locations of these facilities. We divided off-street facilities into roadside and nonroadside trails based on proximity to busy streets. For each home, we calculated the distance to the nearest roadside trail, nonroadside trail, and on-street bicycle lane. We also calculated the distance from each home to the nearest open space area, each classified as either active or passive. I defined active open spaces as those primarily used for recreation, including neighborhood parks and some regional parks. I defined passive open spaces to include golf courses, cemeteries, and large regional parks that are accessible only through designated entrance points and often only by car.

Interaction Terms. I expected many of the structural attributes of housing (e.g., home size, number of bathrooms) to be universally valued, but expected some other attributes to vary by whether the home was located in the city or the suburbs. Thus I calculated interaction terms to allow me to parsimoniously estimate a single model that preserves the potentially different city and suburban effects. The model's coefficients capture the effects of attributes common to both city and suburb, yet separate the effects

Table 6. Attributes of the revealed preference analysis sample of home sales.

Variable name	Variable description	Mean	Standard deviation	Median
Environmental amenities				
contrnr	CITY: distance to nearest on-street bicycle lane (meters)	1,276.31	947.90	1,023.55
cnrtrnr	CITY: distance to nearest nonroadside bicycle trail (meters)	799.42	517.82	711.29
crstrnr	CITY: distance to nearest roadside bicycle trail (meters)	1,293.81	716.20	1,219.16
sontrnr	SUBURBS: distance to nearest on-street bicycle lane (meters)	1,580.51	2,240.18	979.82
snrtrnr	SUBURBS: distance to nearest nonroadside bicycle trail (meters)	1,099.89	1,732.29	602.92
srstrnr	SUBURBS: distance to nearest roadside bicycle trail (meters)	1,359.35	1,728.01	911.83
cactive	CITY: distance to nearest active open space (meters)	340.15	203.41	315.35
cpassive	CITY: distance to nearest passive open space (meters)	683.10	396.64	633.76
sactive	SUBURB: distance to nearest active open space (meters)	569.92	1,176.45	290.07
spassive	SUBURB: distance to nearest passive open space (meters)	760.73	641.12	613.09
Structural attributes				
bedroom	Number of bedrooms	3.12	0.91	3.00
bathroom	Number of bathrooms	2.14	0.88	2.00
homestea	Homestead status	0.86	0.34	1.00
age	Age of house (years)	35.88	28.97	27.00
lotsize	Size of lot (square meters)	2,097.98	8,053.17	968.00
finished	Finished square feet of floor space	1,871.01	908.66	1,708.00
firepls	Number of fireplaces	0.70	0.76	1.00
garagest	Number of garage stalls	1.72	1.02	2.00
Location				
hwynear	Distance to nearest major highway (meters)	1,672.32	1,821.44	1,149.58
cbdnear	Distance to nearest central business district (meters)	17,558.59	10,409.61	16,374.75
busy	Home is on a busy street	0.05	0.21	0.00
Neighborhood attributes				
mca5_att	Standardized test score in school district	4,760.46	276.78	4,836.10
pctnonwt	Percent nonwhite in census tract	12.51	14.02	7.82
avghhsiz	Persons per household in census tract	2.67	0.40	2.66

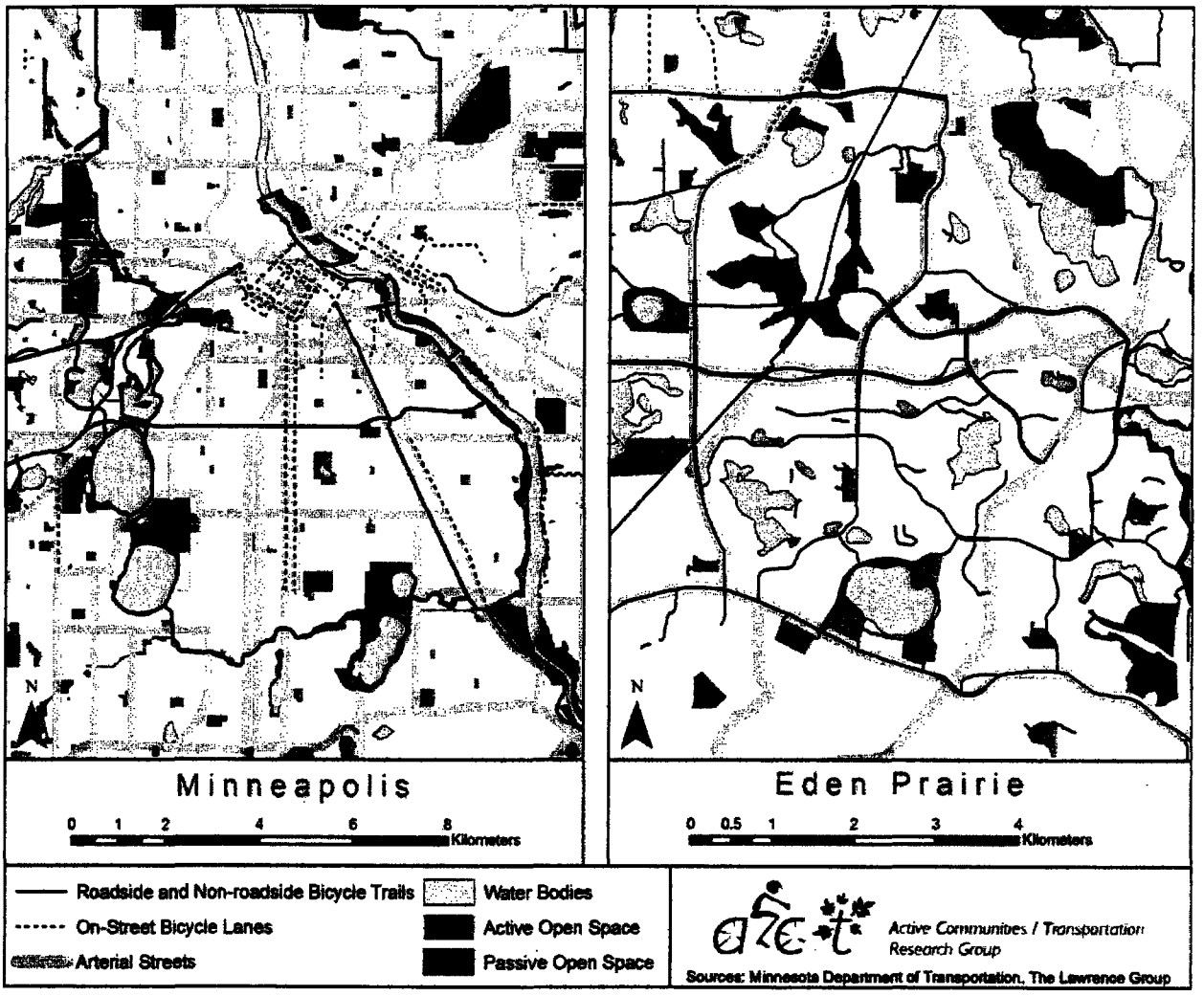


Figure 2. Examples of off-street bicycle trails, on-street bicycle lanes, and open space.

of city home sales (within the boundaries of Minneapolis and St. Paul) and suburb (elsewhere in the metropolitan area) on the bicycle facility type and open space variables.

Fixed Effects. The previously described measures may fail to capture other influences of the surrounding housing stock, neighborhood reputation, or unobserved local characteristics. To account for the bias introduced by potential omitted variables, I added a dummy variable for each of the 104 real estate market areas in the region.[10]

Revealed-Preference Results

Table 7 shows the ordinary least squares regression model predicting home sale prices. I employ a logged dependent variable and also log transformations of several continuous independent variables to better represent linear relationships. Home values increase with number of bedrooms, bathrooms, lot size, finished square feet, fireplaces, garage stalls, proximity to a central business district, and school quality. Home values decrease with age and percent non-Caucasian in the census tract. Similarly, proximity to a freeway has a negative effect on home value. Among the variables of special interest here, in the city, proximity to passive open space increases home values more than proximity to active recreational areas. In the suburbs, home values increase with proximity to passive open spaces such as lakes and golf courses, but proximity to active open space has the opposite effect.

Even after controlling for proximity to open space, city residents clearly value proximity to off-street bicycle facilities, but prefer to live at greater distance from roadside facilities, even after controlling for the negative effects of being close to the busy streets adjacent to these bicycle

facilities. On-street bicycle facilities have no significant effect on home prices in the city, though it is possible that this is a result of differing patterns in Minneapolis and St. Paul canceling each other out. In Minneapolis, bicycle lanes are found on several streets in the downtown core, on busy commuting arterials, and near the commercial area adjacent to the University of Minnesota, none of which are desirable residential areas. On-street lanes in St. Paul are located along a well maintained boulevard (Summit Avenue) and the Mississippi River.

Suburban homes near all types of bicycle facilities also sell for less than those further away, even though the model controls for proximity to busy streets. In the suburbs, even off-street bicycle facilities negatively influence home prices, unlike in the city.[11]

The last two columns in Table 7 show the effect of moving a median-priced home located at the median distance from the specified type of bicycle facility 400 meters closer to that facility, all else constant.[12] In the city, the effect of moving a median-priced home 400 meters closer to a roadside bicycle facility reduces the sale price by $2,272, while moving a home 400 meters closer to an off-street bicycle facility increases its value by $510. While proximity to any type of bicycle facilities in the suburbs reduces home sale prices, the negative effect of a roadside bicycle trail is $1,059, while a nonroadside facility has a negative effect of only $240.

Table 7. Revealed preference analysis: OLS regression model predicting home sale value.

Variable name	Variable description	Coefficient	SE	t	Effect of locating home 400m closer to bicycle facility (dollars)
	Constant	11.314800	0.079957	141.51**	
contrln	CITY: distance to nearest on-street bicycle lane (ln)	0.003950	0.002689	1.47	
cnrtrln	CITY: distance to nearest nonroadside bicycle trail (ln)	−0.007851	0.003732	−2.09*	509.85
crstrln	CITY: distance to nearest roadside bicycle trail (ln)	0.022772	0.003777	6.03**	−2,271.63
sontrln	SUBURBS: distance to nearest on-street bicycle lane (ln)	0.003334	0.001272	2.62**	−364.02
snrtrln	SUBURBS: distance to nearest nonroadside bicycle trail (ln)	0.003858	0.001325	2.91**	−239.65
srstrln	SUBURBS: distance to nearest roadside bicycle trail (ln)	0.010230	0.001419	7.21**	−1,058.73
cactive	CITY: distance to nearest active open space (meters)	−0.000024	0.000012	−1.96*	1,425.36
cpassive	CITY: distance to nearest passive open space (meters)	−0.000065	0.000007	−9.08**	3,860.35
sactive	SUBURB: distance to nearest active open space (meters)	0.000006	0.000001	3.88**	−442.80
spassive	SUBURB: distance to nearest passive open space (meters)	−0.000028	0.000002	−12.86**	2,066.40
bedrooms	Number of bedrooms	0.033037	0.001570	21.05**	
bathroom	Number of bathrooms	0.079976	0.002018	39.63**	
homestea	Homestead status	−0.027259	0.003481	−7.83**	
ageln	Age of house (ln)	−0.092578	0.001759	−52.65**	
lotsize	Size of lot (square meters)	0.000003	0.000000	21.68**	
finished	Finished square feet of floor space	0.000168	0.000002	82.14**	
firepls	Number of fireplaces	0.068749	0.001768	38.89**	
garagest	Number of garage stalls	0.075257	0.001268	59.37**	
hwynear	Distance to nearest major highway (meters)	0.000009	0.000001	10.35**	−637.20
cbdnrln	Distance to nearest central business district (ln)	−0.056065	0.006926	−8.09**	9,861.10
busy	Home is on a busy street	−0.033351	0.005096	−6.54**	
mca5_att	Standardized test score in school district	0.000160	0.000010	15.34**	
pctnonwt	Percent nonwhite in census tract	−0.004014	0.000183	−21.99**	
avghhsiz	Persons per household in census tract	0.038961	0.004481	8.68**	
N	35,002				
Adjusted R^2	0.7920				

*$p < 0.05$ **$p < 0.01$

Discussion

The results of the adaptive stated-preference survey show an on-street bicycle lane is worth an additional 16.3 minutes of travel time on a 20-minute commute (an increase of more than 75%), while not having roadside parking is valued at 8.9 minutes, and an off-road improvement at only 5.2 minutes. This is much more concrete than the "less preferred facilities" defined in previous research (Aultman-Hall, Hall, & Baetz, 1997; Shafizadeh & Niemeier, 1997; Stinson & Bhat, 2003). Thus I conclude that of the three features considered, an on-street bicycle lane is most valued under the conditions of the survey.

The revealed-preference analysis of the effect of access to cycling-related infrastructure on home values showed (1) that the three types of bicycle facilities we defined are valued differently, (2) that bicycle facilities have different values in the city than they do in the suburbs, and (3) that bicycle facilities are not always considered an amenity. Such findings should not necessarily come as a surprise. Though relying on perceived impacts on property values, Crompton (2001) found predominant sentiment to be that the presence of a trail had a neutral impact on the saleability or value of property; in fact, some residents believed trails reduced property values. The only other work based on actual sale prices (Lindsey, Man, Payton, & Dickson, 2004) found that Marion County, Indiana, residents were willing to pay a slight premium to live within one quarter mile of the county's flagship multipurpose trail; however, proximity to other multiuse greenway trails had a statistically insignificant but negative effect on property values.

There are several possible explanations for these findings. First, suburbanites may not value access to trails simply because they have lower rates of bicycle use. It is also possible that they dislike greater access to their property and neighborhood by other cyclists. Stories in local newspapers describe how suburban residents oppose such trails (Bach & Singer, 2003; Kocian, 2004; Lenhart, 2001). A second possibility is that home values along suburban trails may be influenced by other phenomena. For example, since some of the suburban trails are in former railroad rights-of-way, if this lowered home values before the bicycle trail was developed, there may be a legacy effect. If there were uncertainty about the future uses of such corridors, such as for commuter rail, this could also reduce home values nearby. In Minnesota, such trails in exurban locations might also be used for snowmobiling, which could affect home values.

The findings reported here also need several caveats. First, the stated-preference analysis asked participants to respond in the context of commuting to work by bicycle, in order to limit sources of unexplained variance. Respondents might have valued features differently had they been asked about recreational use. Second, both analyses measured only the preferences of adults. Children, who often use off-street facilities, are likely to value trails much differently. Finally, the external validity of this research may not extend beyond the Twin Cities, where I expect people to be particularly aware of bicycle paths. Nonetheless, it does suggest the order of magnitude of such benefits. For example, if I apply the ASP results using the Minnesota Department of Transportation's value of $12 per hour for an average individual's time, this analysis implies that a bicycle commuter engaging in a typical 20-minute bicycle commute values an on-street facility at $3.26 each way, or $6.52 per round-trip. It seems likely that these values would likely have similar ranges in comparable settings.

Although my results are interesting, I believe this research makes a greater contribution with its methods, which are applicable in any setting, though they allow valuing only two specific types of potential bicycle facility benefits. They form part of the basis for a tool for estimating economic benefits, induced demand, and bicycle facility cost available on the web at http://www.bicyclinginfo.org/bikecost/. This tool provides planners and project managers with an easy-to-use online framework for considering the preferences of both direct and indirect users of such facilities at various levels. A neighborhood group considering lobbying for a facility might input minimal specifications to obtain ballpark estimates; a professional planner could enter highly detailed information to obtain more accurate cost, demand, and benefit estimates.

Conclusion

This work demonstrates two methods for producing quantitative estimates of bicycle facility benefits, and in the process shows that the type of bicycle facility matters, as do the specific characteristics of the facility. For example, for commuting purposes, marked lanes appear to trump off-street trails. My results also show that on-street bicycle facilities and roadside trails may not be as universally appreciated as many think, and that not all homeowners consider bicycle facilities to be amenities at all. My results show that bicycle facilities that are assets in a city neighborhood may depress nearby home values when located in the suburbs.

One aim of this work is to help move the practice of transportation planning for bicycle facilities from anecdote to science by developing robust methodologies, analyzing the results, and translating the results into guidelines. I look

forward to others refining and adding to these methods, which should lead to sharper research results as well as better policy decisions on bicycle facility investment.

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Notes

1. We did not include faculty and teaching staff because we wanted to avoid oversampling people more highly educated and with higher earnings than the larger population.
2. For example, A and B are the alternative facilities and U is the utility function. Alternative A is selected if, after weighing its greater commute time against its preferred attributes, U_A is greater than U_B.
3. The logit model estimates the effects of the three facility attributes (being off-street, having a bicycling lane, and not having parking) coded as shown in the table below.

Bicycling environment	Off-street	Bicycle lane	No parking
(A) Off-street facility	1	1	1
(B) On-street facility (no parking)	0	1	1
(C) On-street facility (with parking)	0	1	0
(D) No bicycle facility (no parking)	0	0	1
(E) No bicycle facility (with parking)	0	0	0

4. The data report individual respondents making repeated choices, meaning the errors are not independently distributed. To overcome this problem, we employ a generalized linear mixed model, which estimates a random effect for the between-subject effect, thus separating the within-subject and between-subject errors. Both subject random effects are assumed to have a normal distribution with 0 mean and separate variances. The error term of the utility function's linear component is assumed to have a Gumbel distribution.
5. For the latter category, it is important to explain and control for the degree to which open space versus the bike trail contained within the open space contributes to a home's value. In many metropolitan areas, bike trails are located within open spaces and exhibit similar recreational qualities. On-street lanes or roadside trails are often on or near roadways ranging from collector streets or trunk highways to neighborhood arterial streets. Homebuyers tend to dislike proximity to busy roadways. Much of the attraction of these facilities therefore depends on the design speed of the roadway and the average daily traffic. Research aiming to estimate the value of bicycle trails themselves must account for all of these factors.
6. They found that proximity to golf courses, large parks, and lakes has a positive effect on home prices in the city, but no significant effect in the suburbs. The effects of open space on home prices also increased with the size of the open space. Proximity to small parks and cemeteries tended to reduce sale prices.
7. Our sample began with 42,750 records. Geocoding and removing records with missing or unreasonable data (e.g., homes with zero bathrooms, zero square feet, or built before 1800) reduced our sample to 35,002 home sales, which remained evenly distributed across the metro area.
8. We include the percentage of people in the census tract who do not classify themselves as Caucasian (*Pctnonwt*) and the average number of people in each household in the census tract (*Avghhsize*).
9. *Mca5_att* represents the sum of the average math and reading scores achieved by fifth grade students taking the Minnesota Comprehensive Assessment. Scores associated with suburban homes are measured at the school district level, while Minneapolis and St. Paul scores were calculated for elementary school attendance areas.
10. These boundaries mostly follow city limits in suburban areas. In the central cities the neighborhood boundaries define fairly homogenous real estate markets. By controlling for fixed effects, we are estimating the effect of proximity to a bicycle trail, assuming a household has already decided to locate in one of the 104 RMLS areas in the region. While this increases accuracy, it makes it difficult to identify the impact of bicycle trail proximity because it reduces variation in the variables of interest. Michaels and Smith (1990) demonstrated this, showing that dividing a market into submarkets results in less robust estimates of the effects of hazardous waste site proximity.
11. It is possible that the functional relationship between home value and distance to bicycle facilities is not linear. For example, it may be disadvantageous to live immediately adjacent to a trail, whereas living 200 yards away would be attractive. I tested for this possibility using dummy variables to represent different categories of distance to the facility. A categorical measure makes it possible to relax the strong linearity assumption underlying continuous measures though it prevents me from calculating point elasticities. I tested distances of 50, 100, and 200 meters from each kind of facility (while still controlling for type of facility, distance to open space, and distance to busy roads). In each case, the pattern of results was relatively stable, with the magnitude of the coefficients mirroring the order of the signs of the continuous measures as presented in Table 7. Nonroadside trails increased home values in the cities no matter how close they were, while home values in the suburbs were either unaffected or depressed by proximity to the trails.
12. The median sale prices in the city and suburbs for 2001 were $148,475 and $184,500, respectively.

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