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Final Report

Tools for Predicting Usage and Benefits of Urban Bicycle Network Improvements

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16. Abstract (Limit: 200 words)

This report gives a brief overview of four related small research projects. The full papers resulting from the projects are included as appendices. The four projects were related by the theme of bicycling preferences and behavior with regard to bicycling facilities. The studies were also connected by the fact that they were all based on information from the Twin Cities of Minneapolis and St. Paul, Minnesota.

The four reports are:

- Effect of Trails on Cycling
- Value of Bicycle Facilities to Commuters
- Effect of Facilities on Commute Mode Share
- Cycling Behavior Near Facilities

Generally speaking, the results support the notion that people value bicycle facilities, in that they are willing to incur additional time costs in order to use higher quality facilities. The presence of facilities also appears to be associated with higher amounts of riding, although the precise nature of the impact is still unclear.

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Final Report

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EXECUTIVE SUMMARY

The amount of cycling, and the size and type of benefits gained from it, should depend on a number of factors including the quality of the cycling environment in an area. The amount of cycling will depend (among other things) on demographics, the presence of significant cycling destinations, and on facilities. Benefits will depend on factors such as the purpose and location of the trips, their number and duration, and who is making them. The critical question for planning purposes is how the cycling environment, as opposed to uncontrollable factors such as demographics, influences demand and the resulting benefits.

This project was part of a larger body of bicycling-related research that is ongoing at the Humphrey Institute at the University of Minnesota. This research has been funded by the Minnesota Department of Transportation (Mn/DOT), the National Cooperative Highway Research Program (NCHRP), and a variety of other sources. Because of the very broad nature of this research program, there was no single question guiding the research that is reported here. Rather, the project essentially consisted of four essentially independent research questions, under a broad unifying theme. This theme was bicycling preferences and behavior with regard to bicycling facilities. The studies were also connected by the fact that they were all based on information from the Twin Cities of Minneapolis and St. Paul, Minnesota.

The theme of bicycling preferences and behavior with regard to bicycling facilities could be understood as an attempt to develop answers to the following three questions:

1) In what way and to what extent does cycling demand depend on the environment?
2) How does the environment, through its influence on demand, impact the size and types of benefits gained from cycling?
3) How would specific changes to the environment be expected to change the amount of cycling and the benefits gained?

In addition to working toward finding answers to these questions, another major focus of this project was developing research methodologies by which the questions could be addressed rigorously. We hope that this will inspire other researchers to use these or similar methodologies to study other places; a robust understanding of how facilities affect bicycling behavior must rest on evidence from more than one location.

The four reports in brief are:

1. Effect of Trails on Cycling. This is based on the 2000 Travel Behavior Inventory (TBI) and analyzes reported cycling behavior based on the distance of a person's home from the nearest cycling facility.
2. Value of Bicycle Facilities to Commuters. This is based on an original data collection; a computer survey asking people to choose among commutes of

varying durations on bicycle facilities with different characteristics. The choices make it possible to deduce the value placed on various factors.

3. Effect of Facilities on Commute Mode Share. This study compared census bicycle commute-to-work mode shares in 1990 and 2000, and related changes to where new commuter-oriented bicycling facilities were constructed.
4. Cycling Behavior Near Facilities. This is based on an original data collection; a mail survey to residents of areas near the Midtown Greenway, Cedar Lake Trail, and Luce Line Trail. The objective was to better understand the relationship between cycling behaviors, trail access, and various demographic and lifestyle factors.

Generally speaking, the results support the notion that people value bicycle facilities, in that they are willing to incur additional time costs in order to use higher quality facilities. In particular, people value having striped bike lanes. The incremental value of this improvement is much greater than the incremental value of moving the facility off-road entirely. The presence of facilities also appears to be associated with higher amounts of riding, although the precise nature of the impact is still unclear. From this research, it appears that a facility can increase the amount of riding in an area even up to one and a half miles from the ends of the facility, but it is not clear whether the effect is larger for residents that are closer than this.

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CHAPTER 1: INTRODUCTION

Bicycling is a very popular recreational activity, and is an important commuting mode in some congested, limited parking areas and for those with limited incomes. Making cycling safer and facilitating additional cycling has the potential to provide substantial public benefits. However, funds for facilities are limited and historically there has been no systematic, quantitative way to evaluate which facilities would provide the greatest benefit, or would provide a specific desired result.

The amount of cycling, and the size and type of benefits gained from it, should depend on a number of factors including the quality of the cycling environment in an area. The amount of cycling will depend (among other things) on demographics, the presence of significant cycling destinations, and on facilities. Benefits will depend on factors such as the purpose and location of the trips, their number and duration, and who is making them. The critical question for planning purposes is how the cycling environment, as opposed to uncontrollable factors such as demographics, influences demand and the resulting benefits.

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The theme of bicycling preferences and behavior with regard to bicycling facilities could be understood as an attempt to develop answers to the following three questions:

4) In what way and to what extent does cycling demand depend on the environment?
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In addition to working toward finding answers to these questions, another major focus of this project was developing research methodologies by which the questions could be addressed rigorously. We hope that this will inspire other researchers to use these or similar methodologies to study other places; a robust understanding of how facilities affect bicycling behavior must rest on evidence from more than one location.

Because the four parts of this project were basically independent, and because the resulting reports are in some cases very technical, this report is organized in a somewhat unconventional way. That is, the main body of the report is relatively short and provides

in essence a long executive summary of each of the four reports, as well as a general overview of the project and its findings. The reports themselves are then included as appendices for those who wish to view the detail.
The four reports in brief are:

1. Effect of Trails on Cycling. This is based on the 2000 Travel Behavior Inventory (TBI) and analyzes reported cycling behavior based on the distance of a person's home from the nearest cycling facility.
2. Value of Bicycle Facilities to Commuters. This is based on an original data collection; a computer survey asking people to choose between commutes of varying durations on bicycle facilities with different characteristics. The choices make it possible to deduce the value placed on various factors.
3. Effect of Facilities on Commute Mode Share. This study compared census bicycle commute-to-work mode shares in 1990 and 2000, and related changes to where new commuter-oriented bicycling facilities were constructed.
4. Cycling Behavior Near Three Minneapolis-Area Facilities. This is based on an original data collection; a mail survey to residents of areas near the Midtown Greenway, Cedar Lake Trail, and Luce Line Trail. The objective was to better understand the relationship between cycling behaviors, trail access, and various demographic and lifestyle factors.

These four studies are summarized in the next four sections; the full reports are contained as appendices.

CHAPTER 2: EFFECT OF TRAILS ON CYCLING

This study focuses on two modes of active transportation—walking and cycling—and two different elements of the physical environment that are often discussed in policy circles. The work aims to answer the following questions: (a) does having a bicycle lane/path close to home increase the propensity to complete a cycling trip, and (b) does having neighborhood retail within walking distance increase the propensity to complete a walk trip from home? The primary advantage of this work is that it carefully analyzes these relationships for an urban population employing detailed GIS/urban form data and a robust revealed-preference survey. The study uses multivariate modeling techniques to estimate the effect of features of the built environment on outcomes related to bicycling and walking.

The results suggest that distance to these facilities is statistically significant; however, the relationship is not linear. The most important point is that close proximity matters, which challenges conventional wisdom that people are willing to walk up to a quarter mile as well as analogous cycling-specific hypotheses. These results are not overly promising for planners and advocates; but this work raises a number of important data, measurement, and methodological issues for future researchers endeavoring to predict levels of walking or bicycle use for entire cities or metropolitan areas.

Our knowledge of who walked and cycled is derived from a home interview survey known as the 2000 Twin Cities Metropolitan Area Travel Behavior Inventory (TBI). This survey captures household travel behavior and socio-demographic characteristics of individuals and households across the seven-county metropolitan area.

Our exposures of interest vary for each mode and are based on distance, which is often mentioned as a suitable measure of impedance. For cycling, our exposure is the proximity of bicycle facilities in the form of on- and off-street bicycle lanes and trails. Three continuous distance measures were calculated using GIS layers furnished by the Minnesota Department of Transportation. Combining this data with precise household locations, we calculated the distance in meters to the nearest on-street bicycle lane, the nearest off-street trail, and the nearest bike facility of either type. Four distinct categories represent the distance from one's home to the nearest bicycle trail as < 400 meters (one-quarter mile), 400 – 799 meters, 800 – 1599 meters, and 1600 meters or greater (greater than one mile).

We identify several covariates to represent individual, household, and other characteristics. These covariates represent factors that may differ across exposure levels and thus could potentially confound our effect estimates. To help free our estimates from confounding explanations we use these covariates to statistically equate subjects on observed characteristics across exposure groups; therefore, the only measured difference between them is the proximity to each of the exposure levels.

For individual characteristics, we use age, gender, educational attainment (college degree or not), and employment status (employed or not). For household characteristics, we use household income (five categories), household size, and whether the household had any children less than 18 years old. We also use two other measures: household bikes per capita and household vehicles per capita. We calculate these by dividing the total number of bicycles by household size and dividing the total number of vehicles by household size.

The specific outcomes of interest in this application are twofold; both were operationalized in a dichotomous manner. The first is whether the respondent completed a bicycle trip as documented in the 24-hour travel behavior diary. A total of 5.2% reported doing so. This rate is higher than both the larger TBI sample and national averages, which tend to hover around 2% of the population. The second outcome of interest was if they had a walking trip from home, which comprised 12.4% of our sample.

Our first models explore the odds of bicycle use and proximity to any type of bicycle facility. From the simple logistic regression model to the fully adjusted model, the odds of bike use did not differ significantly by proximity to any bike facility. Our model suggests that there is no effect of proximity to any bike facility on bike use. We therefore used a separate model to estimate the effect of proximity to off-street facilities on the odds of bike use. Examining the simple logistic regression model to the fully adjusted model for off-street bicycle facilities, the odds of bike use did not differ significantly by proximity to a trail. We detected no effect of proximity to off-street bike facilities on bicycle use.

Finally, we examined the effect of proximity to on-street bike facilities on the odds of bike use. In the simple logistic regression model (Model 1a in Table 1), subjects living within 400 meters of an on-street bicycle facility had significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility. As expected, those that lived within 400 to 799 meters of an on-street bike facility also had significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility, although the odds of bike use were slightly lower than for those living closest to an on-street facility.

After adjusting for individual and household characteristics, the effects were somewhat attenuated. Subjects living in close proximity to an on-street facility (< 400 meters) still had statistically significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility. However, subjects within 400 to 799 meters still tended toward increased odds of bike use, however this failed to reach the level of statistical significance.

Somewhat to the chagrin of many officials excited about the prospects of using community design to induce physical activity, this analysis suggests an uphill battle lies ahead. First, our results underscore the fact that we are addressing fringe modes and rare behavior. Even among the urban population, only five percent cycled and twelve percent walked. And, the criteria for satisfying this measure were generous—any cycling or walking trip from home that was reported by the individual over a 24 hour period.

Second, the research supports the theory that the built environment matters; however, it suggests that one needs to live extremely close to such facilities to have an statistically significant effect (i.e., less than 400 meters to a bicycle trail for bicycling, and less than 200 meters to retail for walking—approximately the length of two football fields). While the odds-ratios for longer distances failed to reach levels of statistical significance, it is important to mention that in all model estimations, they were always in decreasing orders of magnitude and always in the assumed direction. Planners need to be aware of such distance considerations when designing mixed land use ordinances.

CHAPTER 3: VALUE OF BICYCLE FACILITIES TO COMMUTERS

In this study we explore and provide a quantitative evaluation of individual preferences for different cycling facility attributes. This understanding can be incorporated into an evaluation of what facilities are warranted for given conditions.

The facilities considered here are: A) Off-road facilities, B) In-traffic facilities with bike-lane and no on-street parking, C) In-traffic facilities with a bike-lane and on-street parking, D) In-traffic facilities with no bike-lane and no on-street parking, and E) In-traffic facilities with no bike-lane but with on-street parking. The aim is to understand what feature people desire by quantifying how many additional minutes of travel they would be willing to expend if these features were to be available. This added travel time is the price that individuals are willing to pay for the perceived safety and comfort the attributes provide.

A computer-based adaptive stated preference (ASP) survey was developed and administered to collect data for this study. To understand if the value that people attach to attributes of facilities is systematically related to different individual and social characteristics, the study also collected demographic, socioeconomic, household, and current travel mode information from each participant. This information was then used to build an empirical model to evaluate relationships between these independent variables and the additional travel time that people are willing to expend for different attributes of cycling facilities. In addition to giving a measure of the appeal of the attributes under discussion, the model also highlights the social and individual factors that are important to consider in evaluating what facilities to provide.

All respondents of the ASP survey were given nine presentations that compared two facilities at a time. Each presentation asked the respondent to choose between two bicycle facilities. The respondent was told that the trip was a work commute and the respective travel time they would experience for each facility was given. Each facility was presented using a 10 second video clip taken from the bicyclists' perspective. The clips looped three times and the respondent was able to replay the clip if they wished.

Each facility was compared with all other facilities that are theoretically of lesser quality. For example, an off-road facility (A) was compared with a bike-lane no on-street parking facility (B), a bike-lane with parking facility (C), a no bike-lane no parking facility (D) and a no bike-lane with parking facility (E). Similarly, the four other facilities (B, C, D and E) were each compared with those facilities that are theoretically deemed of a lesser quality. The less attractive of the two facilities was assigned a lower travel time and the alternate (higher quality) path was assigned a higher travel time.

The respondent went through four iterations per presentation with travel time for the more attractive facility being changed according to the previous choice. The first choice set within each presentation assigned the lesser quality facility a 20 minute travel time and the alternate (higher quality) path a 40 minute travel time. Travel time for the higher quality facility increased if the respondent chose that facility and decreased if the less attractive facility was selected. By the fourth iteration, the algorithm converges on the maximum time difference where the respondent will choose the better facility. This way the respondent's time value for a particular bicycling environment can be estimated by identifying the maximum time difference between the two route choices that they will still choose the more attractive facility.

The survey was administered in two waves, once during winter and once during summer. The winter and summer respondents were shown video clips that reflected the season at the time of the survey taken at approximately the same location. Our sample for both waves was comprised of employees from the University of Minnesota, excluding students and faculty. Invitations were sent out to 2500 employees, randomly selected from an employee database, indicating that we would like them to participate in a computer based survey about their commute to work and offering $15 for participation.

Participants were asked to come to a central testing station, where the survey was being administered. A total of 90 people participated in the winter survey and another 91 people participated in the summer survey, making a total of 181 people. Among these 13 people had to be removed due to incomplete information leaving 168 people. Of these 168 people, 68 indicated that they have bicycled to work at least once in the past year. Thirty-eight of these 68 identified themselves as regular bicycle commuters at least during the summer. Also, 127 of the 168 people said they have bicycled to somewhere including work in the past year.

The survey results indicate that on average, and compared to riding in a street with parked cars and no bike lane, a bike-lane improvement is valued at 16.3 minutes, a no-parking improvement is valued at 8.9 minutes and an off-road improvement is valued at 5.2 minutes. These are all extra value based on the next-worse option. This is to say, from a baseline of a street with parking and no bike lane, the average person would be willing to ride an extra 16.3 minutes if a bike lane were provided. Given a street with a bike lane, the average person would ride an extra 8.9 minutes to have a bike lane and no parked cars. Then given this, the average person would ride an extra 5.2 minutes if the facility were separated from the road entirely. This says that the most value is attached to having a designated bike lane. While having an off-road facility would certainly increase the utility of the individual, most of the gains of an off-road facility seem to be derived from the fact that such facilities provide a designated bike lane. The absence of parking is also valued more than taking the facility off-road.

The overall assessment of the models suggests that designated bike lanes seem to be desired the most. It is also important to consider that both the linear and logit models found no evidence against the possibility that preferences between cyclists and non-cyclists are the same. This is encouraging in many respects, because it avoids the dilemma of which interest to serve. The policy implication is that by addressing this common preference, we can ensure cyclists receive the facilities they prefer and non-cyclists get the facilities that they could at least consider as a viable alternative.

CHAPTER 4: EFFECT OF FACILITIES ON COMMUTE MODE SHARE

This paper uses a longitudinal method for determining the effect of bicycle facility construction in Minneapolis-St. Paul, MN, on journey-to-work bicycle mode share. During the 1990s a number of new facilities were created in the two central cities; many of them focused on the bicycle commuting hotspots of the University of Minnesota and nearby downtown Minneapolis, and on connection to existing facilities. The U.S. census in both 1990 and 2000 counted bicycle commuters; we believe that this is the first time that such comparable data from two different surveys has been available in this country. The analysis is fairly simple, comparing bicycling commute rates over various parts of the city, and between specific origins and destinations, depending on proximity to the new facilities.

Seven new bicycle facilities in the cities of Minneapolis and St. Paul were selected for the analysis. Three are on-street bicycle lanes, and the remaining four are off-street bicycle paths. They do not necessarily represent a comprehensive list of all new facilities created during the 1990s, but they are of particular interest for this study because they all are located in areas where they could reasonably be expected to impact the rate of bicycle commuting through providing improved access to the major employment centers of downtown Minneapolis and the University of Minnesota, which are about one mile apart.

There were also a number of major bridge improvements during the 1990s. Both downtowns and the University are located on the Mississippi River. Two new bicycle bridges were constructed near the University, and wide bicycle lanes were added as part of the general rebuilding of several other road bridges in the area. Thus it could be expected that there would be more cross-river commuting by bicycle in 2000 than in 1990. We examine this possibility as part of our analysis, but without trying to define spheres of influence for specific bridges, as we do for linear facilities.

Two different buffering techniques were employed for paths and lanes. In the first technique, Traffic Analysis Zones (TAZs) were selected if their centroids lay within one mile (1.61 km) of the facility. This method assumes that the importance of a residential or employment location's proximity to the facility remains constant for the entire length of the facility. In the second technique, the endpoints of the facility were buffered to a distance of 1.5 miles (2.43 km), and if these two buffers did not intersect, the remainder of the facility was buffered to a distance of one mile. This method allows for the possibility that the ends of the facility attract riders from a greater distance. Again, TAZs were selected if their centroids lay within the buffer.

Our analysis examined various measures of bicycle commute shares in the central cities of Minneapolis and St. Paul. We focused on residential measures, that is, the bicycle commute rate for people who live in a given area. We looked also at the mode share for people who work in a given area, but the results were generally similar to the residential measures, with one exception noted in the bullets below. We considered a sequence of measures that represent different ways of specifying commuting patterns, in each case comparing 1990 to 2000:

- Overall mode shares for different parts of the metro region
- Shares for TAZs in facility buffers versus those that are not
- Point-to-point shares for trips that are within facility buffers
- Shares for the areas around individual facilities
- Share for trips that cross the Mississippi River
- Shares for trips terminating in downtown Minneapolis, downtown St. Paul, and the Minneapolis campus of the University of Minnesota.

The examination of river crossings was prompted by the observation, noted earlier, that there were many bridge improvements including the addition of bicycle lanes to existing road bridges. We looked at point-to-point data to determine whether trips crossing the river gained a significant number of bicycle commuters as a result. The study of the three trip destinations derived from the fact that many of the major improvements concentrated around providing access to the University of Minnesota and downtown Minneapolis, and in particular the connection between them, while there were few or no improvements of similar magnitude around downtown St. Paul.

While the results are not entirely unambiguous, the preponderance of evidence seems to support the hypothesis that the major bicycle facilities constructed in the Twin Cities during the 1990s did in fact significantly impact the level of bicycle commuting. The suburban parts of the region showed a decline in bicycle commuting, contrasted with a sharp increase in both central cities. Within the central cities, areas near bicycle facilities tended to show more of an increase in bicycle mode share than areas farther away, although this trend is less sharply defined. Trips that crossed the Mississippi River showed a much larger increase than trips that did not, seemingly demonstrating the impact of several major bridge improvements. Finally, trips into downtown Minneapolis and the University of Minnesota, where improvements were concentrated, showed substantial increases, while trips into downtown St. Paul, where few improvements were made, showed a slight decline.

The results also provide considerable support for the alternative hypothesis that facilities are the effect, rather than the cause, of high bicycle use. In the Twin Cities, the areas where major facilities were built already had bicycle mode shares that ranged from twice the regional average up to nearly 15 times the regional average. While the facilities did increase the bicycle mode share in their buffers by about 17.5% overall (from 1.7% to 2.0%), this is far from the factor of ten difference that is observed between the facility and non-facility areas when considering the year 2000 in isolation (2.0% compared to 0.2%). This highlights the risks inherent in trying to deduce the impact of facilities by trying to compare two different places.

CHAPTER 5: A SURVEY OF RESIDENTS NEAR BIKE TRAILS

This report describes the results of a survey that was sent to residents near three off-road bicycle trails in and west of Minneapolis. The survey was aimed at a number of complementary objectives centered on better understanding the relationships between various lifestyle preferences and behaviors, and access to recreational facilities and how they are used. This report focuses on the characteristics of those who reported riding bicycles versus those that did not. Because the survey explored a wide range of issues beyond the ordinary demographic descriptors, this adds a great deal to our understanding of the factors related to bicycling behaviors.

The trails were the Midtown Greenway, the Cedar Lake Trail, and the Luce Line Trail. These were selected to represent urban, inner suburban, and outer suburban contexts. Study areas were selected that surrounded these trails. The Greenway study area was in Minneapolis, the Cedar Lake area was in St. Louis Park, and the Luce Line area included parts of Plymouth, Orono, Wayzata, Minnetonka, and small parts of several other towns. One thousand surveys were sent to randomly selected households in each of the three study areas. The eight-page survey encompassed a wide variety of questions: the majority of questions pertained to trail access and use and residential attributes. Questions about household automobiles, consumer preferences and basic demographics were also included.

Many surveys have established some general facts with regard to the level of bicycling as well as some demographic patterns. This survey sought to further support this existing knowledge, as well as adding local (Twin Cities) specificity. There were also two other, more original objectives. One was to gather information, typically ignored in other surveys, regarding lifestyle and political (broadly defined) choices and preferences. We and others have hypothesized that pro-bicycling attitudes may typically be part of a package of attitudes and preferences that does not necessarily closely relate to standard demographic categories, but that may be more predictable by other information, such as political preferences or priorities in home location choice.

The other major objective was to better understand the role of bicycle-specific facilities in bicycling choices. Specifically, we wanted to know more about the extent to which the presence of high-quality off-road facilities would be associated with higher levels of bicycling, how the facilities were used, and again, the demographic and lifestyle factors associated with facility use in the different areas. This can ultimately help in better understanding the likely impacts of new facilities on cycling behavior in different types of residential environments.

The survey questions can be roughly divided into four categories:

- Bicycling, trail use, and other transportation information
- Home location and preferences
- Lifestyle and politics
- Demographic

The results of this survey generally support the findings of other surveys. Various demographic factors are associated with a higher likelihood of bicycling, for example, higher incomes and education, and being male. We found some expected attitudinal correlations, such as shopping at natural food stores, donating to environmental causes, and listening to National Public Radio. However, the impact of these factors was limited, and interestingly, political party affiliation was not at all correlated with bicycling behavior. Ultimately, about 50% of the population bikes at least sometimes, and this is a large enough number to encompass a wide range of opinions on other issues. And given that we found (as have others) that most cycling is recreational, perhaps it is natural that politics is not a major factor in predicting who will ride.

In terms of better understanding the relationship between facilities and frequency of cycling, our results here were somewhat consistent with the other studies described in this report. We generally found a relationship in that people who lived closer to facilities tended to ride more, but the difference between the closest and farthest groups (less than a quarter mile versus more than one mile) was not that big. However, most of our respondents lived within about a mile of a trail, so impacts at a larger scale than this would not have been captured by our survey. This indicates that perhaps the impacts of a trail are not confined to the short distances indicated by one of our other studies; and is more consistent with the commuting study, in which even people a mile and a half from a trail still seemed to show a higher likelihood of biking.

One concern with this survey is that there appears to be some bias in the characteristics of the respondents. Generally the people who filled out this somewhat long mail-in survey were older, better educated, and higher income than the general population in the areas where the survey was done. The differences between the survey sample and the general population of the areas from which they were drawn are especially significant in the Greenway area. In certain important ways, for example, race and education, the survey respondents in the Greenway were more similar to the survey respondents from the other areas than they were to the general population of the Greenway area. The very high rate of people who classified their occupation as "professional" also points to the conclusion that a certain type of person was more likely to fill out this survey. This need not render the results invalid, but some care must be taken to consider whether the nature of the sample might bias the results of particular findings. One key example is the frequency with which people ride bikes; this sample was strongly weighted toward the type of person that is more likely to ride. Thus the results here should not be taken as indicative of riding frequencies among the general public.

CHAPTER 6: CONCLUSIONS

In terms of understanding how bicycle facilities impact people's propensity to cycle, the four research projects described in this report provide a variety of perspectives. They can be summarized as follows.

The study of the 2000 TBI found little relationship between proximity to facilities and the likelihood of cycling. However, because this was based on a single-day travel diary, very few people were counted as cyclists. Infrequent recreational cyclists in particular were unlikely to be counted as such. Thus the sample of cyclists was small and probably heavily weighted toward the frequent "serious" cyclists for whom facilities may not be so important. Another problem was that this study was comparing different locations, and cyclists may concentrate in certain areas for reasons that have little to do with facilities, for example, proximity to the University, or being within walking distance of shops. In other words, it is impossible to separate the impact of facilities from exogenous variations in cycling rates. Our study of census commute rates addresses this problem.

The computerized stated preference survey was aimed at understanding the relative value that people place on different types of facilities. This was done through an iterative process to determine the additional time that a person would be willing to ride on one type of facility compared to another. This found that off-road facilities are valued the highest, on-road with no auto parking the next, then on-road with parking, with no facility at all ranking last. In terms of the relative valuations, the most important improvement was striping a bike lane where none previously existed. The next most important was eliminating parking. Given these two improvements, moving the facility off-road entirely added relatively little additional value. This survey method had the advantage of providing a very controlled testing environment. However, this controlled environment was in some ways also a disadvantage; the choices were being made in a setting that did not resemble the real options. It is easier to say you will ride ten extra minutes than it is to actually do it.

The study of commute rates in 1990 and 2000 had two major findings. The first was that the facilities that were created during the 1990s did have a measurable and consistent impact on cycling commute rates in their vicinity; and the relevant vicinity extended at least a mile and a half from the ends of the facilities. The second was that the areas in which the facilities were created already had very high bike commute rates even before the facilities were built. This supports the point that comparing different areas may be misleading in that differences in biking rates may have preceded differences in facility levels. The disadvantage of this study was that it considered only commuting, which is a small and possibly atypical subset of bicycling in general.

Finally, the mail survey of residents around three trails provided some insight into the behavior and preferences of people as a function of how much they bicycle. Generally there were no significant surprises here. So many people cycle at least occasionally that it is hard to develop a profile of a "stereotypical" cyclist. This is unfortunate from the standpoint of understanding and predicting the impacts of facilities and policies, but may be a good thing from the perspective of increasing acceptance of bikes as a vehicle on the roads: the people who ride bikes are no different in the aggregate from those that don't. In terms of facilities and their impact on biking frequency, this survey found only a small relationship between proximity to facilities and the likelihood of cycling, within a radius of a mile or so. This was consistent with the commuting study, which found that the effect of facilities extended at least a mile and a half from the ends of the facilities.

Appendix A

Appendix A: The Effect of Neighborhood Trails and Retail on Cycling and Walking in an Urban Environment

Kevin Krizek
Pamela J. Johnson

Introduction

Urban planners and public health officials have been steadfast in encouraging active modes of transportation over the past decades. While the motives for doing so differ somewhat between professions—urban planning to mitigate congestion, public health to increase physical activity—both have ardently aimed to increase levels of walking and cycling among the U.S. population. Decisions to walk or bike tend to be the outcome of myriad factors. Conventional thinking suggests two dimensions are important: for cycling, this includes the proximity of cycling-specific infrastructure (i.e., bicycle lanes or off-street paths); for walking, this includes the proximity of neighborhood retail (i.e., places to walk).

This study focuses on two modes of active transportation—walking and cycling—and two different elements of the physical environment that are often discussed in policy circles. Our work aims to answer the following questions: (a) does having a bicycle lane/path close to home increase the propensity to complete a cycling trip, and (b) does having neighborhood retail within walking distance increase the propensity to complete a walk trip from home? The primary advantage of this work is that it carefully analyzes these relationships for an urban population, employing detailed GIS/urban form data and a robust revealed-preference survey. The study uses multivariate modeling techniques to estimate the effect of features of the built environment on outcomes related to bicycling and walking.

The results suggest that distance to these facilities is statistically significant; however, the relationship is not linear. The most important point is that close proximity matters, which challenges conventional wisdom that people are willing to walk up to a quarter mile as well as analogous cycling specific hypotheses. These results are not overly promising for planners and advocates; but this work raises a number of important data, measurement, and methodological issues for future researchers endeavoring to predict levels of walking or bicycle use for entire cities or metropolitan areas.

We first briefly review directly relevant literature to this pursuit and describe some issues that limit the utility of previous research. We explain the setting for this application, the travel data, and the detailed urban form data. We then report the results of our analysis in two different tracks: one for estimating the odds of cycling; another for estimating the odds of walking. The final section discusses these results and offers policy implications.

Existing Literature

Attempts to document correlations between active transportation and community design have been a focus of much of the recent urban planning and public health literature. Available literature underscores the importance of this research (Jackson 2003; Killingsworth 2003), establishes a common language for both disciplines (Handy 2002; Sallis 2003), helps refine approaches for future studies (Bauman 2002), and comprehensively reviews available work (Transportation Research Board 2005). Most of the research, however, varies in geographical scope, the manner in which it capture different dimensions of active transportation, and the varying strategies for measuring key features of the built environment. Specific work on the environmental determinants of bicycling and walking often dually consider both modes (Wendel-Vos, Schuit et al. 2004) or is conceptual in nature (Pikora, Giles-Corti et al. 2003). The following paragraphs provide a more specific context for the literature on walking and retail or cycling and facilities.

Early work on pedestrian travel underscores the importance of neighborhood retail in creating inviting pedestrian environments (Rapaport 1987; White 1988; Owens 1993). Some studies have offered detailed strategies for operationalizing these measures (Handy and Niemeier 1997; Krizek 2003b; Talen 2003). However, much of the available work on pedestrian behavior vis-à-vis retail tends to lack detailed spatial attributes or be very urban-design specific (Krizek 1995). Much of the empirical work matches measures of pedestrian behavior with assorted place-based destinations in their work (Brownson 2000b; Huston 2003) or even select measures of retail (Handy 1996; Moudon, Hess et al. 1997; Shriver 1997; Hess, Moudon et al. 1999; Handy and Clifton 2001; Cervero and Duncan 2003; Powell 2003). However, few available studies examine such behavior over an entire city with detailed measures of retail activity.

Similar concerns pervade available literature on cycling and the provision of cycling-specific infrastructure. There is considerable enthusiasm about the merits of bicycle trails and paths to induce use (Wardman 1998; Dill 2003; Librett 2003; Rietveld and Daniel 2004). Little work, however, has rigourously tested such claims. Existing studies have examined the use of relatively specific environments or trails (Troped 2001; Lindsey 2002; Merom 2003), cycling commute rates vis-à-vis bicycle lanes (Nelson and Allen 1997; Dill 2003) or their impact on route choice decisions (Hyodo, Suzuki et al. 2000).

Again, there exists a dearth of empirical knowledge about the merits of such cycling infrastructure using disaggregate data for individuals who may live across entire cities.

Setting and Data

To help fill such voids in the urban planning/public health research, the setting for our work is the Twin Cities of Minneapolis and St. Paul, Minnesota, which proves to be almost ideal for a variety of reasons. Both Minneapolis and St. Paul are well-endowed with both on-street and off-street bicycle paths (see Figure 1); furthermore, residents comprise a population who appear to cherish such trails, particularly in the summer months. Minneapolis ranks among the top in the country in percentage of workers commuting by bicycle (Dill 2003). For the walking query, each city also has a wide distribution of retail activity across the city (see the top half of Figure 2) and healthy number of homes with close proximity to neighborhood retail.[i]

Our knowledge of who walked and cycled is derived from a home interview survey known as the 2000 Twin Cities Metropolitan Area Travel Behavior Inventory (TBI). This survey captures household travel behavior and socio-demographic characteristics of individuals and households across the seven-county metropolitan area, encompassing primarily the urbanized and suburbanized parts of Twin Cities of Minneapolis and St. Paul metropolitan area. The TBI data were originally collected via travel diaries in concert with household telephone interviews.[ii] Participants were asked to record all travel behavior for a 24-hour period in which they documented each trip that was taken, including the origin and destination of the traveler, the mode of travel, the duration of the trip, and the primary activity at the destination, if one was involved.[iii] Household characteristics and household location were attributed to each individual. We additionally linked households with neighborhood spatial attributes relative to their reported home location. We selected all subjects from the TBI diary database that were residents of Minneapolis or St. Paul and 20 years of age or older (n = 1,653).[iv] A key feature of this investigation is that it applies to two entire central cities, rather than precise study areas or specific corridors of interest.

Exposure

Our exposures of interest vary for each mode and are based on distance which is often mentioned as a suitable measure of impedance (Untermann 1984). For cycling, our exposure is the proximity of bicycle facilities in the form of on- and off-street bicycle lanes and trails (Figure 3). Three continuous distance measures were calculated using GIS layers furnished by the Minnesota Department of Transportation, with separate map layers for on-street and off-street trails. Marrying this data with precise household locations, we calculated the distance in meters to the nearest on-street bicycle lane, the nearest off-street trail, and the nearest bike facility of either type. Four distinct categories represent the distance from one's home to the nearest bicycle trail as < 400 meters (one-quarter mile), 400 – 799 meters, 800 – 1599 meters, and 1600 meters or greater (greater than one mile).

For walking, we measure neighborhood retail in an extremely detailed and rigorous manner. We first obtained precise latitude and longitude information for each business using the North American Industrial Classification System (NAICS).[v] We focused on those businesses likely to attract walking trips, including establishments like general merchandise stores, grocery stores, food and drinking establishments, miscellaneous retail and the sort.[vi] We again married this information with household location data. Finally, we calculated the *network* distance between the home location and the closest retail satisfying the above criteria. For analysis, we used the distance variables to classify subjects into one of four categories. The four categories represent the distance from home to the nearest retail establishment as < 200 meters (one-eighth mile), 200 – 399 meters, 400 –599 meters, and 600 meters or greater.[vii] To provide the reader with visual representations of the retail "catchment" areas for varying distances, we provide Figure 4 showing a home location (in the center) and retail establishments within varying walking distances from the home.

When measuring each exposure variable, a four-level ordinal variable is advantageous over the continuous distance measure in two respects. First, the categorical measure allows us to relax the strong linearity assumption that underlies continuous measures [viii]. Second, the four-level categorical measure allows flexibility relative to ease of presentation and intuitive interpretation. Given that we used distance cut-points with relatively simple interpretation, it provides a compelling way to grasp the reported findings in terms of comparing individuals who live within 400 meters of a bike trail and those who live more that 1600 meters from a bike trail.[ix]

Covariates

We identify several covariates to represent individual, household, and other characteristics. These covariates represent factors that may differ across exposure levels and thus could potentially confound our effect estimates. To help free our estimates from confounding explanations we use these covariates to statistically equate subjects on observed characteristics across exposure groups; therefore, the only measured difference between them is the proximity to each of the exposure levels.

For individual characteristics, we use age, gender, educational attainment (college degree or not), and employment status (employed or not). For household characteristics, we use household income (five categories), household size, and whether the household had any children less than 18 years old. We also use two other measures: household bikes per capita and household vehicles per capita. We calculate these by dividing the total number of bicycles by household size and dividing the total number of vehicles by household size.

Spatial measures and other attributes of the built environment in this study are limited to the two different exposure variables. In many respects, limiting our sample to the central cities of Minneapolis and St. Paul effectively controls for other spatial measures via the research design. Our sample has little variation in density [x], regional accessibility, access to open space, and virtually no variation in topography or other commonly measured urban design features (e.g., every street in Minneapolis and St. Paul has sidewalks).

Results

Overall, our sample was nearly evenly split on gender (52% female vs. 48% male) and two-thirds (67%) were residents of Minneapolis (as opposed to St. Paul). Most subjects were employed (83%) and had at least a four-year college degree (63%). The majority lived in households with no children (80%) and reported household incomes less than $50,000 per year (36%).

We first used descriptive techniques (i.e., chi-square and t-tests) to characterize our sample by proximity to each type of facility. We explored the distributions of individual and household characteristics for subjects at each level of exposure. Subjects living within different proximity levels to bike facilities or retail differ somewhat with respect to many of the individual and household characteristics. For example, subjects living in close proximity to any bicycle facility are more likely to be 40 or older, have a college degree, and live in households with no children than subjects living farther away from a bike facility. Different covariate patterns emerge depending upon which proximity measure we examine.

The specific outcomes of interest in this application are twofold; both were operationalized in a dichotomous manner. The first is whether the respondent completed a bicycle trip as documented in the 24-hour travel behavior diary. A total of 86 individuals from our 1,653 individuals reported doing so (5.2%).[xi] This rate is higher than both the larger TBI sample and national averages, which tend to hover around 2% of the population (Barnes and Krizek 2005). The second outcome of interest was if they had a walking trip from home, which comprised 12.4% of our sample (n = 205).[xii]

Because our outcome measures are dichotomous we use multiple logistic regression models to examine the effect of our exposure measures on bicycling or walking. For each proximity measure (e.g., distance to any trail, distance to on-street trail, distance to off-street trail, distance to retail), we conduct a series of analyses; they build from a simple logistic regression of the exposure on the outcome to a multiple logistic regression fully adjusted for all subsets of covariates (Models 1 and 2 in Table 1).

Because our data are hierarchically structured—individuals are nested within households—we use robust standard errors to account for the effects of this clustering. Subjects who reside in the same household are more alike within a household than they are with subjects residing in other households. Accordingly, less independent information is contributed by individuals from the same household, which may artificially decrease the standard error of the estimate. This in turn can lead to an increase in the Type I error rate; that is, finding a statistically significant effect, when in fact there is none.

Bicycling

Our first models explore the odds of bicycle use and proximity to any type of bicycle facility. From the simple logistic regression model to the fully adjusted model, the odds of bike use did not differ significantly by proximity to *any* bike facility. Our model suggests that there is no effect of proximity to any bike facility on bike use. We therefore used a separate model to estimate the effect of proximity to off-street facilities on the odds of bike use. Examining the simple logistic regression model to the fully adjusted model for off-street bicycle facilities, the odds of bike use did not differ significantly by proximity to a trail. We detected no effect of proximity to off-street bike facilities on bicycle use.

Finally, we examined the effect of proximity to on-street bike facilities on the odds of bike use. In the simple logistic regression model (Model 1a in Table 1), subjects living within 400 meters of an on-street bicycle facility had significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility. As expected, those who lived within 400 to 799 meters of an on-street bike facility also had significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility, although the odds of bike use were slightly lower than for those living closest to an on-street facility.

After adjusting for individual and household characteristics, the effects were somewhat attenuated (see Models 1b and 1c). Subjects living in close proximity to an on-street facility (< 400 meters) still had statistically significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility. Subjects within 400 to 799 meters still tended toward increased odds of bike use; however, this failed to reach the level of statistical significance.

Walking

We employed a similar approach to examine walking behavior vis-à-vis retail and discovered similar results. In the simple logistic regression model (Model 2a in Table 1), subjects living within 200 meters of a retail establishment had significantly increased odds of making a walk trip compared with subjects living more than 600 meters away from retail. Households living between 200-400 meters and 400-600 meters of retail, however, failed to reach a level of statistical significance.

Again, after adjusting for individual and household characteristics, the effects were somewhat attenuated (see Models 2b and 2c). Subjects living in close proximity to retail (< 200 meters) still had statistically significantly increased odds of walking.

Interpretation and Conclusions

This research reports the results of individual level models predicting bicycling and walking behavior and correlations with proximity to bicycle paths and neighborhood retail, respectively. We do so by focusing on specific behavior—whether an individual biked or walked from home—and robustly measuring policy relevant dimensions of the built environment. The travel, bicycle facility, and the retail data we employed are the most precise among city-wide measures for a metropolitan area in the U.S. The primary merits of this exercise focus specifically on measuring the exposure measures, each of which have direct policy relevance. To our knowledge, this question has not previously been asked or answered across an entire city.

We separated facilities into two categories: off-street bicycle trails and on-street bicycle lanes. For the former group of facilities, there is no effect of proximity to off-street bike facilities on bicycle use. For on-street bicycle lanes, subjects living within 400 meters of a bike facility had significantly increased odds of bike use compared with subjects living more than 1600 meters from an on-street bike facility. Walking use increases if retail is within 200 meters. While not the focus of this analysis, our study reaffirmed that many of the socio-demographic and economic variables used in other studies are important.

Somewhat to the chagrin of many officials excited about the prospects of using community design to induce—or even enable—physical activity, this analysis suggests an uphill battle lies ahead. First, our results underscore the fact that we are addressing fringe modes and rare behavior (Gordon 1998). Even among the urban population, only 5% cycled and 12% walked. And, the criteria for satisfying this measure were generous—any cycling or walking trip from home that was reported by the individual over a 24-hour period.[xiii] Second, the research supports theory that the built environment matters; however, it suggests that one needs to live *extremely* close to such facilities to have an statistically significant effect (i.e., less than 400 meters to a bicycle trail for bicycling, and less than 200 meters to retail for walking—approximately the length of two football fields). While the odds-ratios for longer distances failed to reach levels of statistical significance, it is important to mention that in all model estimations, they were *always* in decreasing orders of magnitude and *always* in the assumed direction. Planners need to be aware of such distance considerations when designing mixed land use ordinances (Librett 2003).

The results, however, need to be viewed in the following light. The first consideration is that the analysis is reported for only an urban and adult population. Conventional wisdom suggests children (Krizek, Birnbaum et al. 2004), women (Brownson 2000a; Krizek, Johnson et al. 2004) or rural or suburban residents (Parks 2003) may value different features of the built environment. The second is that the original TBI survey was the result of a complex sampling design which needs to be taken into account.[xiv]

As they are based on cross-sectional analysis, these results cannot be used to infer causal relationships (Winship and Morgan 1999). We can conclude that respondents living very close to bicycle paths or retail bike or walk more than their counterparts farther away. However, consistent with emerging theories about travel behavior, the decision to live in close proximity to such features is likely endogenous (Boarnet and Sarmiento 1998). There are likely attitudes, preferences, or other attributes that are motivating such bicycling or walking behavior (Krizek 2003c; a). Such attributes are not directly captured in this analysis—and, strictly using the results from this research, we would be remiss to conclude that adding retail or bicycle paths would directly induce such behavior.

Given the dearth of studies on which to build, however, this investigation makes progress by using focused research and carefully measured variables. We make headway in learning that distance matters—particularly close distance. Relative to the larger picture of travel behavior, however, our understanding remains murky. The evidence suggests that features of the built environment matter, though it is hardly compelling. Statistical analysis like ours needs to be complemented with more direct sampling as well as qualitative modes of analysis to shed light on different factors and attitudes as well as sorting out the issue of residential self-selection. Further work will inevitably allow planners and modelers to better understand relationships between cycling and walking infrastructure and physical activity. Continued and thorough understanding will therefore assist policy makers in constructing better informed policies about using the built environment to induce physical activity, namely walking and cycling.

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Tables and Figures

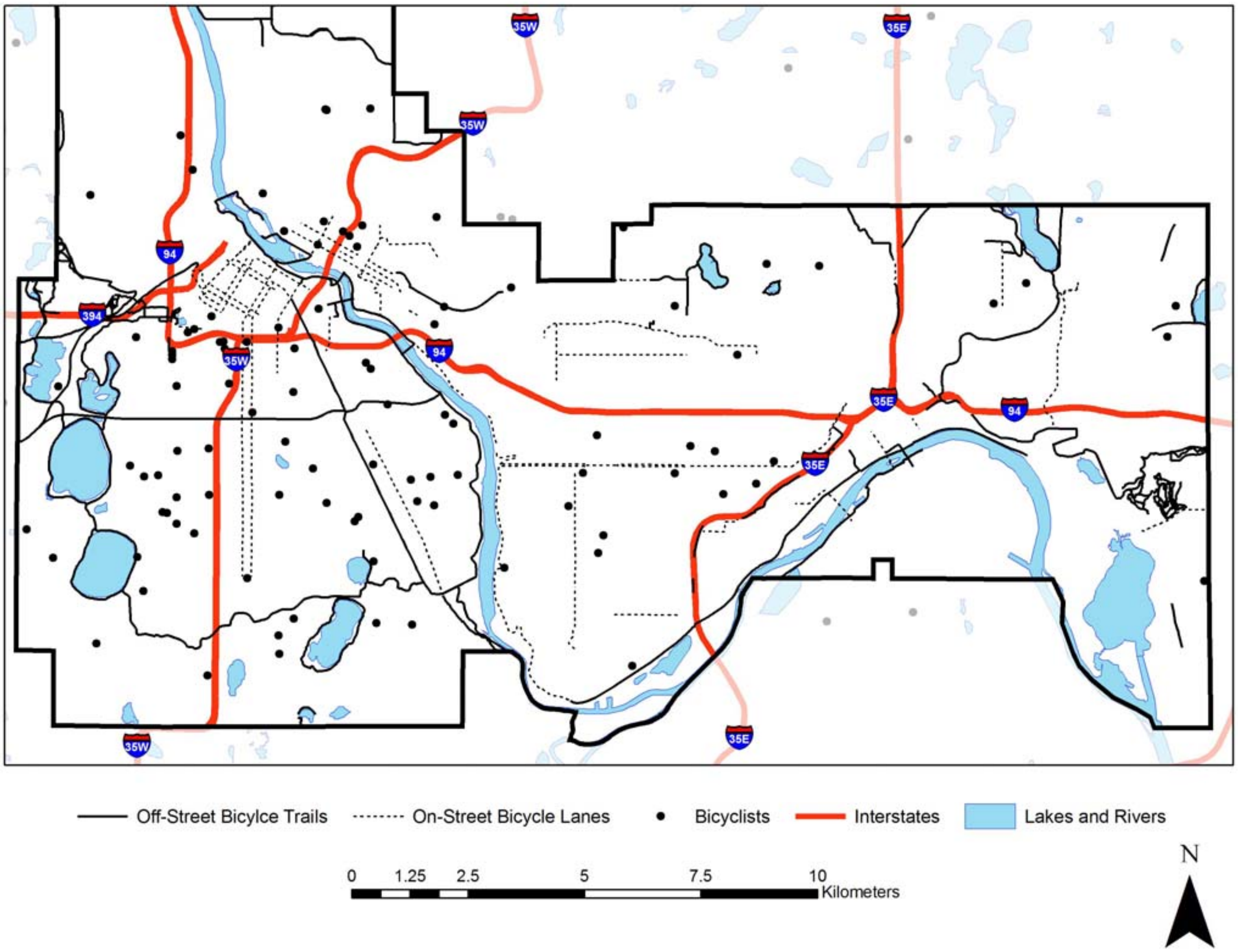

Figure 1. Map of study area showing bicycle facilities and home location of cyclists

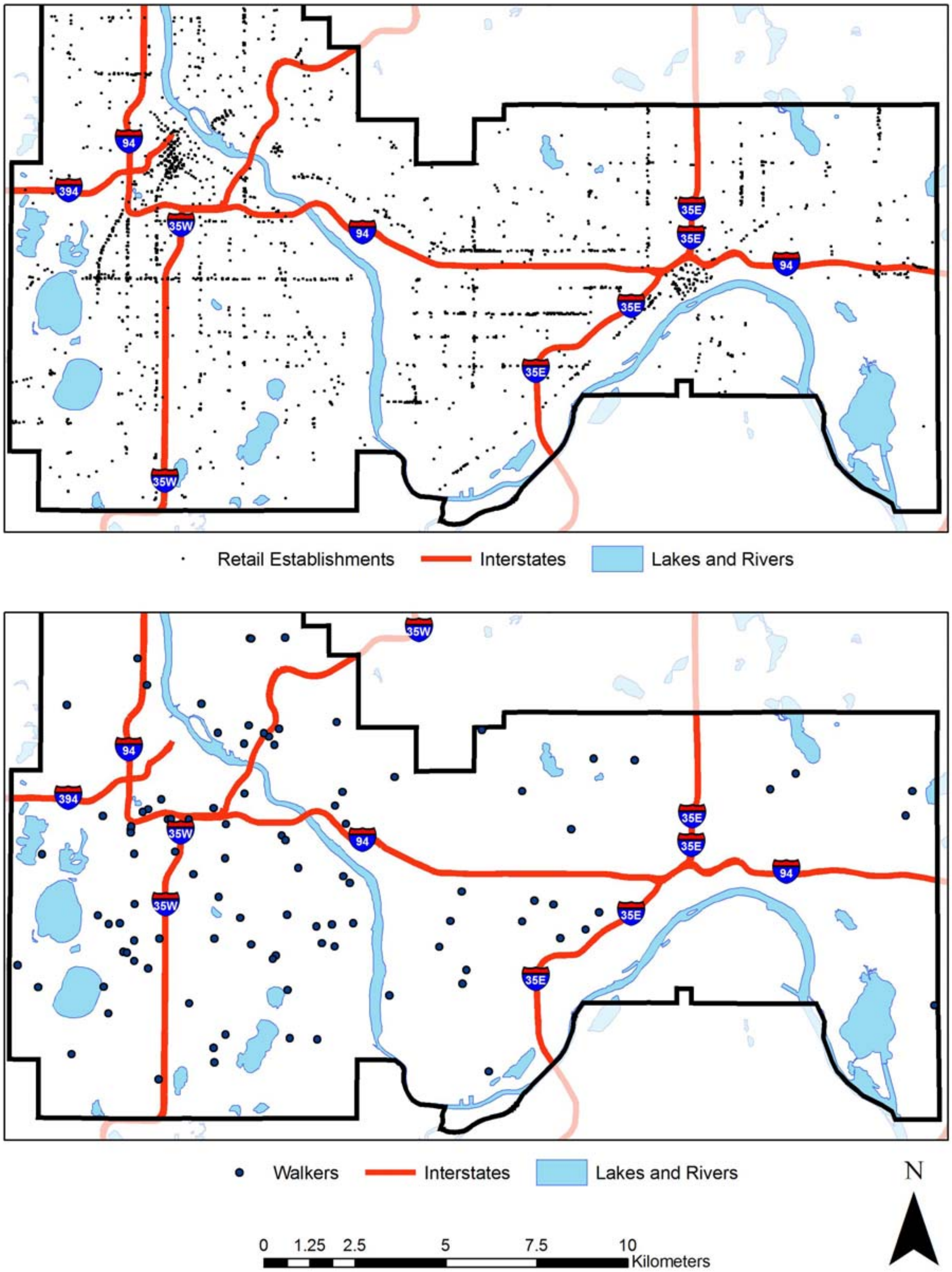

Figure 2. Maps of study area showing location of retail establishments (top) and home location of walkers (below)

Figure 3. Representative photographs of off-street trail and on-street bicycle lane (respectively)

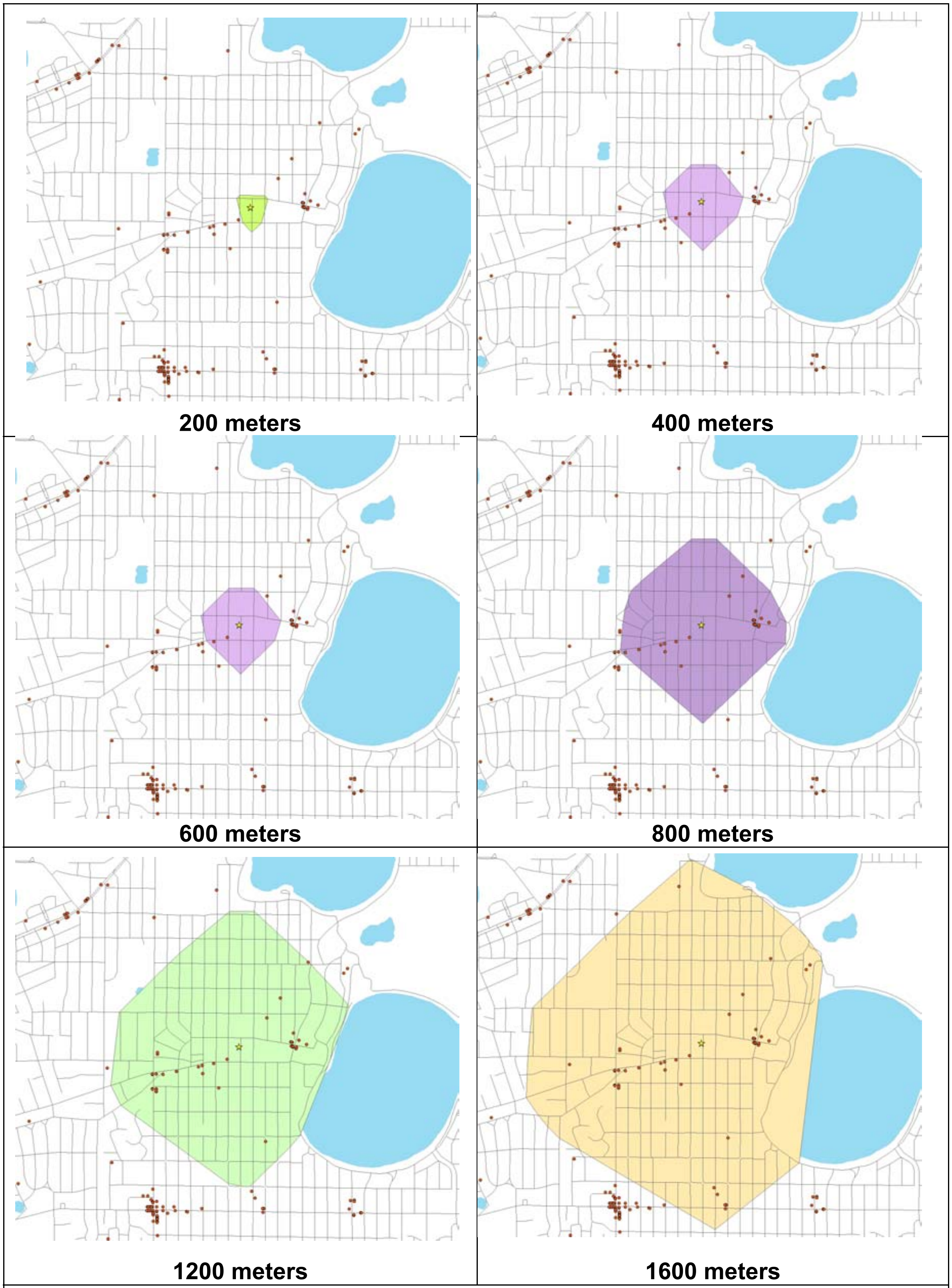

Figure 4. Retail "catchment" areas for an example home (shown in the center) and varying network walking distances. Shaded area represents catchment area.

Table 1. Models comparing the effect of distance to an on-street bicycle facility on odds of bike use (Models 1a-1c) and the effect of distance to neighborhood retail on odds of making a walk trip from home (Models 2a-2c).

	Bicycle Use				**Walk use**		
	Model 1a	Model 1b	Model1c		Model 2a	Model 2b	Model 2c
Distance to nearest on-street bicycle path				**Distance to nearest retail establishment**			
< 400 meters	2.933	3.101	2.288	< 200 meters	3.098	3.060	2.348
	(3.11)**	(3.21)**	(2.23)*		(3.41)**	(3.36)**	(2.51)*
400 – 799 m	2.108	2.012	1.511	200 – 399 m	1.653	1.616	1.316
	(2.05)*	(1.89)	(1.07)		(1.48)	(1.41)	(0.80)
800 – 1599 m	1.390	1.361	1.163	400 – 599 m	1.448	1.422	1.288
	(0.88)	(0.81)	(0.39)		(1.02)	(0.97)	(0.69)
>= 1600 m	referent	referent	referent	>= 600 m	referent	referent	referent
Individual Characteristics							
Male subject		2.015	2.160			0.760	0.787
		(2.96)**	(3.12)**			(1.80)	(1.57)
College		1.753	2.840			1.113	1.271
		(2.15)*	(3.47)**			(0.68)	(1.42)
Employed		0.783	1.187			0.771	0.901
		(0.71)	(0.43)			(1.24)	(0.49)
40-59 years		0.520	0.623			1.004	1.112
		(2.73)**	(1.83)			(0.03)	(0.64)
>=60 years		0.081	0.115			0.769	0.752
		(3.49)**	(2.98)**			(1.03)	(1.10)
Household Characteristics							
\$15,000 - \$49,000			0.402				0.874
			(2.30)*				(0.41)
\$50,000 - \$74,999			0.293				0.704
			(2.83)**				(1.00)
>= \$75,000			0.206				0.880
			(3.33)**				(0.35)
Income missing			0.172				0.886
			(3.00)**				(0.32)
Household w/ kids			0.640				0.790
			(2.21)*				(2.08)*
HH bikes per capita			2.463				0.892
			(7.85)**				(0.80)
HH vehicles per capita			0.114				0.300
			(5.29)**				(4.56)**
		Wald chi-square =	137.65			Wald chi-square =	55.61
		Log pseudolikelihood =	-262.34			Log pseudolikelihood =	-583.69
		Pseudo R-square =	0.224			Pseudo R-square =	0.058

# of observations in all models = 1653
Odds ratios, robust z statistics in parentheses.
* significant at 5 %; ** significant at 1 %

Endnotes

[i] A quick look at the data shows that 69% of our adult subjects within Minneapolis and St. Paul have a retail location within 400 meters of their home.

[ii] Households were recruited to participate in the TBI using a stratified sampling design. Telephone interviews were used to collect both household and individual socioeconomic and demographic data. Subsequent to the demographic interview, households were assigned a travel day on which 24-hour travel diaries were completed for all household members five years or older.

[iii] Home phone call interview information helped ensure the reliability of these self-reported measures of walking and/or cycling.

[iv] We restrict our sample to residents of Minneapolis and St. Paul primarily because theses two cities—as opposed to the suburbs—had adequate representations of walking and cycling behavior. Of the adults who completed a bicycle trip during their diary day (a total of 138 throughout the seven county area), 86 of them (62%) were from the Minneapolis or St. Paul.

We also only included the population who reported having completed any type of travel during their assigned travel diary day a procedure consistent with other transportation-related research (Zahavi, Y. and J. M. Ryan (1980). "Stability of Travel Components Over Time." Transportation Research Record **750**: 19-26). Of the original 1,801 individuals, 148 individuals (8.2%) took no trips on the travel diary day and were thus excluded. This left us with an effective sample size of 1,653 subjects (91.8% of our original sample). The 148 subjects that were excluded were not significantly different from subjects retained for analysis with respect to the likelihood of living in a household with kids or living in Minneapolis. However, compared with excluded subjects, included subjects were more likely to be employed (83% vs. 41%, $p < 0.001$); more likely to have a college education (64% vs. 20%, $p < 0.001$) and more likely to be male (48% vs. 35%, $p = 0.002$). Included subjects were also less likely to live in households with an annual income less than $50,000 (36% vs. 56%, $p < 0.001$) and less likely to be over 60 years of age (15% vs. 37%, $p < 0.001$).

[v] When measuring this dimension, it is important to measure the diversity of different types of retail establishments while controlling for the potential disproportionate drawing power of larger establishments (e.g., a large clothing store offers high employment but little diversity). We therefore set an upper limit of businesses containing more than 200 employees and tallied the number of employees for each area. The final measure is the number of employees within the "neighborhood retail" subset within 1,600 meters of each home location.

[vi] These include all businesses in the following NAICS categories:

445	Food and Beverage Stores (e.g., grocery, supermarket, convenience, meat, fish, specialty, alcohol)
446	Health and Personal Care (e.g., pharmacy, drug store)
448	Clothing and Clothing Accessory Stores (e.g., shoe, jewelry, luggage)
451	Sporting Goods, Hobby (e.g., needlepoint, musical instrument), Book, and Music Stores
452	General Merchandise Stores (e.g., includes department stores)
453	Miscellaneous Store Retailers (e.g., florists, novelty, used merchandise, pet, art, tobacco)
722	Food Services and Drinking Places (e.g., restaurants)

[vii] The principal reason from these breakpoints was to ensure adequate distribution across each category. For example, 32% of the households had a retail establishment within 200 m, 37% within 400 m, 21% within 600, and 10% for the remaining.

[viii] A continuous measure assumes that for each additional meter of distance closer/farther there is a consistent incremental increase/decrease in the odds of bike or walk use

[ix] One potential disadvantage is that by subclassifying into categories, we impose a strong homogeneity assumption. That is, we assume that the effects are the same for everyone within a given category regardless of their individual proximity to a bike trail. For example, the effect of living 400 meters from a bike trail is no different than living 799 meters from a bike trail. However, given that the increments are within roughly 400 meter, we are comfortable that there is relatively little difference, if any.

[x] Outside the downtown core of each city (for which there are very few respondents in the TBI), most of the urban housing density is the same.

[xi] These 86 cyclists completed between 1 and 10 bike trips on the assigned travel day (mean = 2.9, SD = 1.79). For 73 of these cyclists (85 percent) we also calculated the total distance traveled by bicycle, which ranged from 0.74 km to 36.71 km (mean = 8.64, SD = 7.10). As expected, the proportion of bikers varied across levels of bike facility proximity, with more bikers living closer to bike trails and fewer bikers living further from bike trails. Of interest, these distributions differed depending on which measure of bicycle facility proximity was used. In other words, the distribution of cyclists across categories of proximity to any bike facility was not statistically significant, nor was the distribution of bikers across categories of proximity to an off-street facility. However, the distribution of cyclists across categories of proximity to an on-street facility was statistically significantly different, with increasing proportions of cyclists in the hypothesized direction (chi-square = 13.42; p = 0.004).

[xii] Our definition of "walkers" did not include people who only reported a walk trip from a different location (e.g., work or other). Individuals who only reported such walk trips are not included in an effort to more cleanly identify correlations between the residential environment and walking.

[xiii] We acknowledge that some respondents may be pursuing walk trips from work or other types of locations. We only tested for walk trips from home. An additional 137 people report having a completed a walk trip, however, none of the walk trips they reported were from home.

[xiv] To be technically correct, we should have employed sampling weights. Given the secondary nature of our analysis and the fact that we used a select sub-sample, proper survey sampling weights were not available.

Appendix B

Appendix B: Valuing Bicycle Facilities with an Adaptive Stated Preference Survey

Kevin Krizek
Nebiyou Tilahun
David Levinson

Introduction

If bicycling is to be a viable mode of transportation, cyclists must have access to appropriate facilities. Evaluating what is appropriate requires an understanding of preferences for different types of cycling facilities. In this study we explore and provide a quantitative evaluation of individual preferences for different cycling facility attributes. This understanding can be incorporated into an evaluation of what facilities are warranted for given conditions.

The facilities considered here are: A) Off-road facilities, B) In-traffic facilities with bike-lane and no on-street parking, C) In-traffic facilities with a bike-lane and on-street parking, D) In-traffic facilities with no bike-lane and no on-street parking, and E) In-traffic facilities with no bike-lane but with on-street parking. The aim is to understand what feature people desire by quantifying how many additional minutes of travel they would be willing to expend if these features were to be available. This added travel time is the price that individuals are willing to pay for the perceived safety and comfort the attributes provide.

A computer-based adaptive stated preference survey was developed and administered to collect data for this study. To understand if the value that people attach to attributes of facilities is systematically related to different individual and social characteristics, the study has also collected demographic, socioeconomic, household, and current travel mode information from each participant. This information is then used to build an empirical model to evaluate relationships between these independent variables and the additional travel time that people are willing to expend for different attributes of cycling facilities. In addition to giving a measure of the appeal of the attributes under discussion, the model also highlights the social and individual factors that are important to consider in evaluating what facilities to provide.

Interest in studying bicyclists and cycling environments is growing. Recent papers by a number of authors have investigated preferences of cyclists and the bicycling environment as well as the relationship between the supply and use of facilities. Availability of cycling facilities and the type and quality of a cycling facility are important determinants of how well they are used. Studies by Dill *et. al.* (2003) and Nelson *et. al* .(1997) have shown that there is a positive correlation between the number of facilities that are provided and the percentage of people that use bicycling for commuting purposes. While both studies state that causality cannot be proved from the data, Nelson and Allen (1997) state that in addition to having bicycle facilities, facilities must connect appropriate origins and destinations to encourage cycling as an alternative commuting mode.

Bovy and Bradley (1985) used stated preference to analyze bicycle route choice in the city of Delft. Their work looked at facility type, surface quality, traffic levels and travel time in route choice. They found that travel time was the most important factor in route choice followed by surface type. Another study by Hopkinson and Wardman (1996) investigated the demand for cycling facilities using stated preference in a route choice context. They found that individuals were willing to pay a premium to use facilities that are deemed safer. The authors argue that increasing safety is likely more important than reducing travel time to encourage bicycling.

Abraham *et al.* (2004) also investigated cyclist preferences for different attributes using a stated preference survey again in the context of route choice. Respondents were given three alternate routes and their attributes and were then asked to rank the alternatives. The responses were analyzed using a logit choice model. Among other variables that were of interest to their study, the authors found that cyclists prefer off-street cycling facilities and low-traffic residential streets. But the authors also claim that this may be due to an incorrect perception of safety on the part of the respondents, and education about the safety of off-road facilities may change the stated choice.

Shafizadeh and Niemeier (1997) investigate the role that proximity to an off-road bicycle trail plays in route choice decisions. Using intercept surveys along the Burke-Gilman trail in Seattle, they find that among people who reported origins near the off-road facility, travel time gradually increases as they are further from trail to a point and then decreases, leading them to speculate that there may be a 0.5- to 0.75-mile "bike shed" 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 a more direct route seems to be preferred.

Aultmann-Hall, Hall and Beatz (1997) use GIS to investigate bicycle commuter routes in Guelph, Canada. While comparing the shortest path to the path actually taken, they found that people diverted very little from the shortest path and that most bicycle commuters use major road routes. They found little use of off-road trails. While this may be due to the location of the trails and the origin-destination pair they connect, even in five corridors where comparably parallel off-road facilities do exist to in-traffic alternatives, they found that commuters used the in-traffic facilities much more often. Only the direct highest quality off-road facility (one that is "wide with a good quality surface and extends long distance with easy access points") seemed to be used relatively more.

Stinson and Bhat (2003), using data from a web-based stated-preference survey, estimate a logit model to understand important attributes for commuter cyclist route choice. They find that respondents preferred bicycling on residential streets to non residential streets, likely because of the low traffic volumes on residential streets. While their model showed that the most important variable in route preference was travel time, the facility was also significant. It was shown that cyclists preferred in-traffic bike-lanes more than off-road facilities. Both facility types had a positive effect on utility but the former added more to utility than the latter. In addition they find that cyclists try to avoid links with on-street parking. Another study by Taylor and Mahmassani (1996) also using a SP survey to investigate bike and ride options, finds that bike-lanes provide greater incentives to inexperienced cyclists (defined as those with a "stated low to moderate comfort levels riding in light traffic") as compared with more experienced cyclists, with the latter group not showing a significant preference to bike lanes over wide curb lanes.

The results from these papers seem somewhat mixed. Though some of the research has shown a stated preference and revealed preference with some constraints for off-road facilities, others have shown that cyclists generally prefer in-traffic cycling facilities with bike-lanes. Especially in revealed preference cases, the apparent preference for in-traffic routes may be due to their ability to connect to many destinations in a more direct fashion and therefore leading to a lower travel time. In addition route choice may be restricted by facility availability, geographic features or missing information. It may also be that for people who regularly bicycle, who are most likely the subjects of the revealed preference studies, travel time and not perceived safety is likely of greater importance, as these individuals are more likely to be conditioned to the cycling environment. The actual preference therefore may not be for the in-traffic facility; however, it may be the best alternative available to the cyclists.

Commuter choices are clearly limited by facilities that are available to them. Understanding preferences and behavior is crucial to providing choices that people desire. This can be best accomplished when the value of any given improvement in facility attribute is known. Valuation of facility attributes can be done by considering what people are willing to pay for using these facilities. In this study we try to uncover this value by measuring how much additional time individuals would be willing to spend bicycling between a given origin and destination if alternate facilities with certain attributes were available to them.

In the next section we present the methodology in detail. This is followed by a description of the survey instrument and design. The analysis methodology is presented, and then the results.

Methodology

The methodology we follow to extract this valuation of attributes uses an Adaptive Stated Preference (ASP) survey. While both revealed and stated preference data can be used to analyze preferences, there are certain advantages to using the latter method in this case. In using consumer revealed preference, often, a limitation arises because only the final consumer choice is observed. This makes it difficult to ascertain how consumers came to their final decision. This complication arises because the number of choices that are available to each consumer may be very large and information on those alternatives that went into an individual's decision may not be fully known. Even in cases where all possible alternatives are known, it is difficult to assess whether the decision makers considered all available alternatives. In addition, the exact tradeoff of interest may not be readily available. Even in cases where the tradeoffs seem to be available, one cannot be certain that the consumer is acting out his preference for the attributes we are observing. The lack of appropriate data can pose a major challenge in this respect.

Stated Preference (SP) surveys overcome these complications because the experimenter controls the choices. In SP settings, the experimenter determines the choices and the respondent considers. While this may not reflect the actual market choice that individual would make because of the constraints the survey places on the choice set, it allows us to measure attribute differences between the presented alternatives. Further, by using specialized forms of SP such as

Adaptive Stated Preference (ASP) one can measure the exact value individuals attach to attributes of interest. In this type of survey each option is presented based on choices the respondent has already made. This allows for the presentation of choices that the individual can actually consider while removing alternatives that the respondent will surely not consider. This methodology has been adopted in a number of contexts, including value of time for commercial vehicle operators (Smalkoski, 2003), in mode choice experiments (Bergantino and Bolis, 2002), and in evaluating transit improvements (Falzarno *et. al,* 2000) among others.

Survey Instrument, Design and Administration

All respondents of the ASP survey were given nine presentations that compared two facilities at a time. Each presentation asks the respondent to choose between two bicycle facilities. The respondent is told that the trip is a work commute and the respective travel time they would experience for each facility is given. Each facility is presented using a ten-second video clip taken from the bicyclists' perspective. The clips loop three times and the respondent is able to replay the clip if they wish.

Each facility is compared with all other facilities that are theoretically of lesser quality. For example, an off-road facility (A) is compared with a bike-lane no on-street parking facility (B), a bike-lane with parking facility (C), a no bike-lane no parking facility (D) and a no bike-lane with parking facility (E). Similarly, the four other facilities (B, C, D and E) are each compared with those facilities that are theoretically deemed of a lesser quality. The less attractive of the two facilities is assigned a lower travel time and the alternate (higher quality) path is assigned a higher travel time. The respondent goes through four iterations per presentation with travel time for the more attractive facility being changed according to the previous choice. The first choice set within each presentation assigns the lesser quality facility a 20 minute travel time and the alternate (higher quality) path a 40 minute travel time. Travel time for the higher quality facility increases if the respondent chose that facility and it decreases if the less attractive facility was selected. A bisection algorithm works between 20 and 60 minutes either raising or lowering the travel time for the alternate path so that it becomes less attractive if it was chosen or more attractive if the shortest path was chosen. By the fourth iteration, the algorithm converges on the maximum time difference where the respondent will choose the better facility. This way the respondent's time value for a particular bicycling environment can be estimated by identifying the maximum time difference between the two route choices that they will still choose the more attractive facility. Pictures of these facilities are shown on Figure 1. Figure 2 maps the locations of the facilities where the videos were taken in St. Paul, Minnesota.

The procedure used to converge on the time trade-off for the particular facility is illustrated as follows. If the subject first chose the longer option, then the next choice set assigns a higher travel time for 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 chose the 20 minute route, the bisection algorithm will calculate a travel time that is between the now rejected option and the previously accepted option, in this case 45 minutes. By the time the respondent makes a fourth choice, the survey will have either narrowed down the respondents' preference to within two minutes or the respondent has hit the maximum travel time that can be assigned to the longer trip, which is 58.5 minutes. Table 1 shows the pairs of comparisons that were conducted and used in the analysis. Table 2 shows a sample series of travel time presentations and Figures 3(a) and 3(b) show sample screenshots of the survey instrument.

The survey was administered in two waves, once during winter and once during summer. The winter and summer respondents were shown video clips that reflected the season at the time of the survey taken at approximately the same location. Our sample for both waves was compromised of employees from the University of Minnesota, excluding students and faculty. Invitations were sent out to 2500 employees, randomly selected from an employee database, indicating that we would like them to participate in a computer-based survey about their commute to work and offering $15 for participation. Participants were asked to come to a central testing station, where the survey was being administered. A total of 90 people participated in the winter survey and another 91 people participated in the summer survey, making a total of 181 people. Among these 13 people had to be removed due to incomplete information leaving 168 people. Of these 168, 68 people indicated that they have bicycled to work at least once in the past year. Thirty eight of these sixty eight identified themselves as regular bicycle commuters at least during the summer. Also, 127 of the 168 people said they have bicycled to somewhere including work in the past year. Further demographic information on the respondents is given in Tables 3.

Model Specification and Results

Switching Point Analysis

The adaptive nature of the survey allows us to extract the actual additional minutes each individual is willing to travel on an alternate facility. In the context of the survey, this is the maximum travel time beyond which the respondent would switch to use the base facility. For each pair of facilities that are compared during the summer and the winter, the averages of this switching point are computed and plotted in Figure 4. On average, individuals are willing to travel more on an alternate facility when the base facility is E (undesignated with on-strret parking), followed by D (no bike-lane without parking) and C (bike-lane with parking). For example individuals are willing to travel further on facility B when the base facility is E, as opposed to D or C.

Figure 4 shows the hierarchy among facilities clearly – each of the lines plotted connects the average additional travel time that individuals are willing to bicycle over the 20 minutes that they would have bicycled if they had chosen the base facility. For example, looking at the winter data, the top solid line connects the average additional time individuals say they would travel on an alternate facility when the base facility is E (in-traffic with parking at 20 minutes). The alternate facilities are as shown on the horizontal axis. For example, on average respondents are willing to travel about 22 additional minutes if an off-road bike-lane were available and if the alternative were to bike in traffic. We can further describe the data by employing techniques such as the non-parametric bootstrap. The bootstrap approximates the sampling distribution of the mean by repeatedly sampling with replacement from the original data. We employ the non-parametric bootstrap where no prior assumptions are made on the distribution of the statistic. The bootstrap approach was first developed by Efron in 1979 (Efron and Tibshirani, 1993).

Consider the histogram shown in Figure 5(a). It reflects the additional travel times individuals in the sample said they would travel between facilities A (off-road) and C (in traffic with parking). It is difficult to make any distributional assumptions based on the observed sample. Employing the nonparametric bootstrap on this data with 5,000 resamples (Figure 5(b)), we can see that the bootstrap distribution of the mean is very close to normal, and hence a normal interval can be built around it. The bootstrap distributions of all nine pairs of comparisons lead to very symmetric distributions that show no evidence of non-normality. The percentile confidence interval based on the actual 2.5% and 97.5% values of the bootstrapped mean are also computed.

The bootstrap also allows us to estimate the bias of the sample mean. The sample mean, the estimate of the bias and the confidence interval (CI) using the normal distribution and the percentile of the bootstrap are reported in Table 4 for each pair of comparisons both for the combined and season-specific data.

Model

We start with the economic paradigm of a utility maximizing individual, where given a bundle of goods, the individual chooses that bundle which results in the highest possible utility from the choice set. In the current context then, given two alternatives, the chosen alternative is the one that the respondent derives a higher utility from. We can then break down each bundled alternative to its components to understand what amount each contributes to utility. This will enable us to extract the contribution of each feature of the facility in the choice consideration of the individual. Mathematically, we would state this as alternative A is selected if U_A is greater than U_B, where A and B are the alternatives and U is the utility function.

We hypothesize that the utility a user derives from using a bicycle facility depends on the features of the facility and the expected travel time on the facility. Choices are also affected by individual characteristics that we may not directly observe, but can try to estimate using individual specific variables such as income, sex, age etc. As discussed earlier, each individual records a response over various alternatives and therefore the data reflects the repeated choices over the same respondent. This implies that the errors are no longer independently distributed. To overcome this problem one can use a generalized linear mixed model which would estimate 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 zero mean and separate variances. The error term of the utility's linear component is assumed to have a Gumbel distribution. The model's linear utility component is specified as follows:

$$U = f\text{ (Facility, Travel Time, Season, Individual Variables)}$$

The utility of a particular alternative can be written as

$$U_{iA} = V_{iA} + \varepsilon_{iA}$$

$$V_{iA} = \beta_0 + \beta_1 W_{iA} + \beta_2 O_{iA} + \beta_3 B_{iA} + \beta_4 P_{iA} + \beta_5 T_{iA} + \beta_6 S_{iA} + \beta_7 A_{iA} + \beta_8 I_{iA} + \beta_9 H_{iA} + \beta_{10} C_{iA}$$

Where:

W = Weather (winter =1, summer=0)

O = dummy indicating whether the facility is off-road (1=Yes, 0= No)

B = dummy indicating whether the facility has a bike-lane (1=Yes, 0= No)

P = dummy indicating whether on-street parking is absent or present (1= absent, 0= present)

T = Expected travel time on the facility being considered

S = Sex (Male =1, Female =0)

A = Age

I = Household Income (Inc/1000)

H = Household Size (>2 = 1, Otherwise=0)

C = Cyclist at least during summer (Yes =1, No=0)

$\varepsilon \sim$ Gumbel $(0, \lambda)$

To interpret the model appropriately it is important to note how the dummy variables are coded (Table 5). Variable B represents whether a facility has a designated bike-lane, O represents whether the facility is off-road, and P represents whether a facility has no parking adjacent to it. This would allow separately valuating bike lanes as well as being off-road. It should be observed that O is not equivalent to an off-road trail. B and O together constitute an off-road trail.

The parameter estimates of binomial logit model are given in Table 6. The model is estimated such that the results indicate the odds of choosing the theoretically better facility. Choices depend on the attributes of the facilities, the travel time the user experiences on the facilities, and individual characteristics. The signs of the estimated parameters are as expected. The travel time is negative showing an aversion to longer trips. The improvements (off-road, bike-lane and no parking) all have a positive and significant influence on choice of different magnitudes. Of these three, a bike-lane improvement increases the odds much more than a parking elimination or that of an off-road improvement alone.

The season variable is negative and significant, indicating that people have lower odds of choosing the higher travel time facility during winter than during summer. Looking at the individual covariates that are used, income and sex are not significant at the 0.10 level, however the signs seem to indicate that women have a higher tendency to choose the facilities that are perceived safer (better quality) than men (p-value=0.11); and higher incomes seem to be associated with a tendency to choose the better quality facility (p-value=0.11). The cyclist variable, which indicates whether the respondent uses bicycling as the main mode at least during summer, is highly insignificant; indicating that preferences are not dictated by experience at least in this SP context. The model also tells us that older individuals have higher odds of choosing the better quality facility. Also individuals whose household size is greater than two have lower odds of choosing the better quality, longer travel time facility. This may be because these individuals have higher constraints on their time than individuals who live in single or two person households.

The estimates of a linear utility model can be used to determine the value of an off-road facility, a bike-lane facility and a facility with no parking in terms of the time cost of travel. These are derived using the marginal rate of substitution between each of the facility features and travel time. These values are derived based on SP questions that have a 20 minute base travel time, and should be interpreted as such. Accordingly, a bike-lane improvement is valued at 16.3 minutes, a no parking improvement is valued at 8.9 minutes and an off-road improvement is valued at 5.2 minutes. This is to say, keeping utility at the same level, one can exchange the off-road improvement for 5.2 minutes of travel time, a bike-lane for 16.3 minutes of travel time and a no parking improvement for 8.9 minutes of travel time. This says that the most value is attached to having a designated bike lane. While having an off-road facility would certainly increase the utility of the individual, most of the gains of an off-road facility seem to be derived from the fact that such facilities provide a designated bike lane. The absence of parking is also valued more than taking the facility off-road.

An alternate specification of the model looks at time as a dependent variable, and features of the facility as independent variables along with demographic covariates. This specification also employs a mixed models approach to account for the repeated measurements taken over the same subject. The dependent variable is the switching point travel time minus the base facility travel time. This approach yields similar patterns in the order of valuation of the different attributes of the facilities and the expected directions of the parameter estimates. A side by side comparison of the two model coefficients is not possible; however, we can compare the values derived for different facility pairs based on our logit model and the linear model. This is given in Table 9 and Figure 6. As can be seen, most comparisons are very close to one another in magnitude. As Figure 6 shows, the results derived from the logit model more closely replicate what is observed in the raw data even though that is not always the case across the nine comparisons.

The overall assessment of the models suggests that designated bike lanes seem to be what cyclists value the most. It is also important to consider that both the linear and logit models found no evidence against the possibility that preferences between cyclists and non-cyclists are the same. This is encouraging in many respects, because it avoids the dilemma of which interest to serve. The policy implication is that by addressing this common preference, we can ensure cyclists receive the facilities they prefer and non-cyclists get the facilities that they could at least consider as a viable alternative.

Conclusion

This paper analyzes preferences for different cycling facilities using a computer-based adaptive stated-preference survey with first-person videos. Using the survey on 168 randomly recruited individuals, we derive the values that users attach to different cycling facility features and expose which are most important. The choice data was collected based on individual preferences between different facilities having different travel times, but the same origin and destination. From the raw data we have demonstrated that a hierarchy exists between the facilities considered and we have extracted a measure of how many additional minutes an individual is willing to expend on an alternate facility if it were available and provided certain features that were not available on the base facility. The data was then used to fit a random parameter logit model using a utility maximizing framework. A linear model was also estimated and compared to the results from the mixed logit model. The results show that users are willing to pay the highest price for designated bike-lanes, followed by the absence of parking on the street and by taking a bike-lane facility off-road. In addition, we are able to extract certain individual characteristics that are indicative of preferences such as age, household structure and loose connections with sex and household income. Such an understanding can be incorporated into the planning process to help planners make appropriate recommendations and investment decisions in developing bicycle facilities that are more appealing to the public.

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Tables and Figures

(A) Off-road bicycle facility

(B) Bike-lane, no parking

(C) Bike-lane, on-street parking

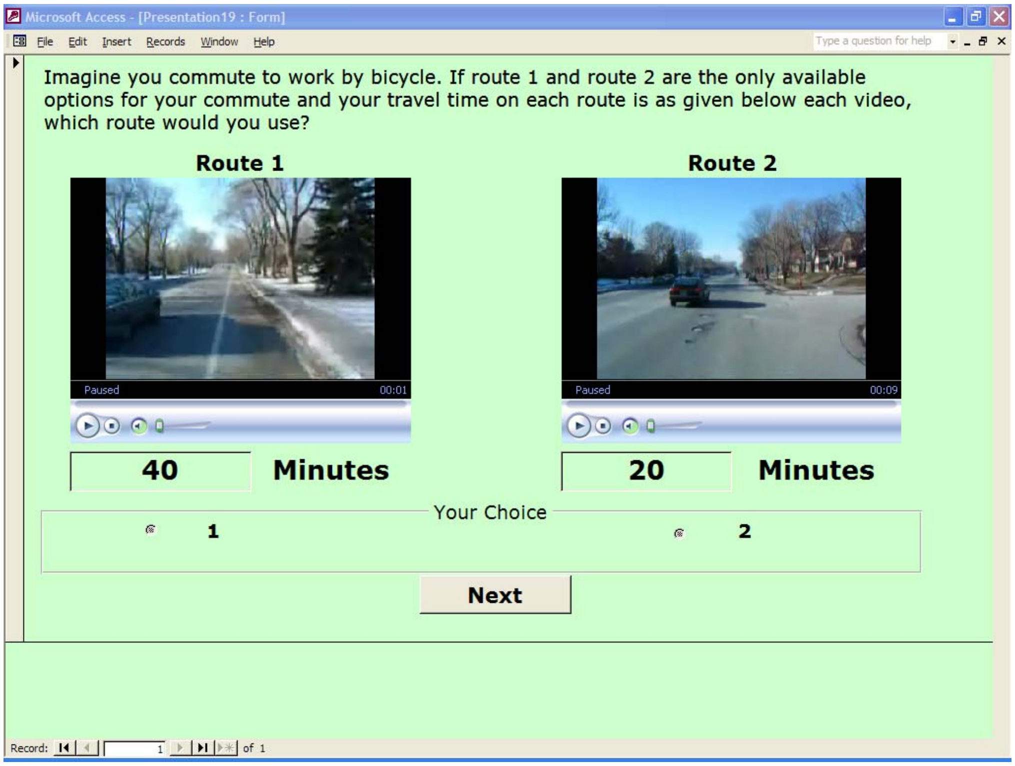
(D) Bike-lane, no parking

(E) No bike-lane, on-street parking

Figure 1. Cycling facilities used in the study

Figure 2. Location of Facilities used in the Adaptive Stated Preference Survey

Note: (A) off-road facility
(B) bike-lane, no parking facility
(C) a bike-lane, on-street parking facility
(D) a no bike-lane, no parking facility
(E) a no bike-lane, on-street parking facility.



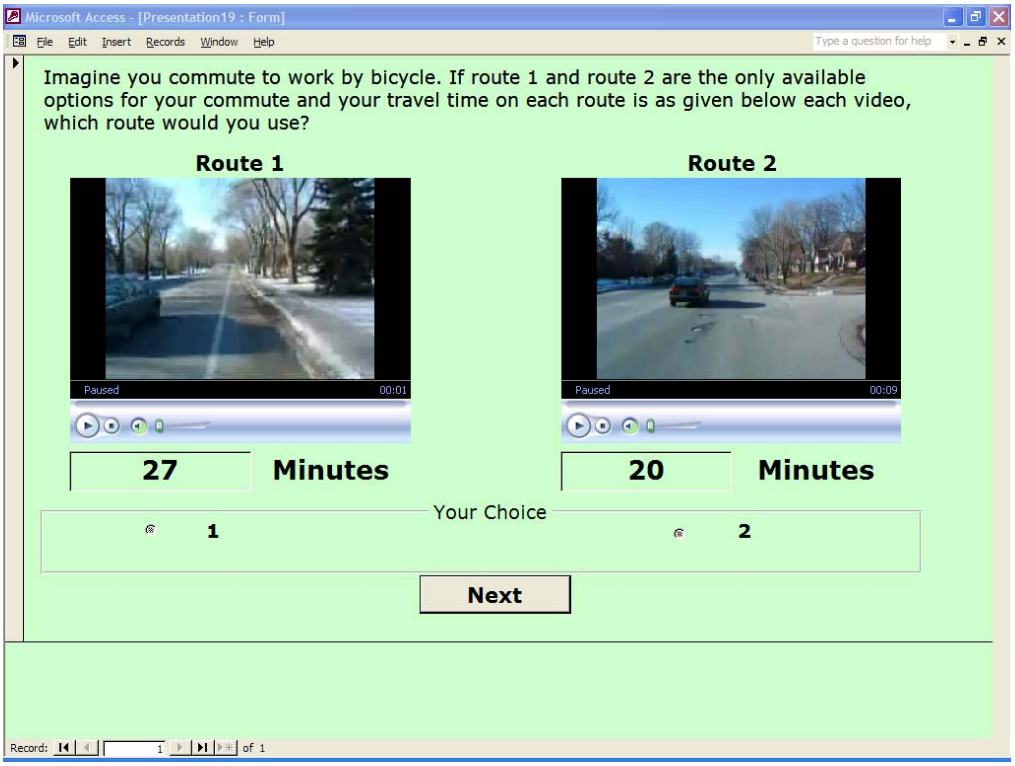
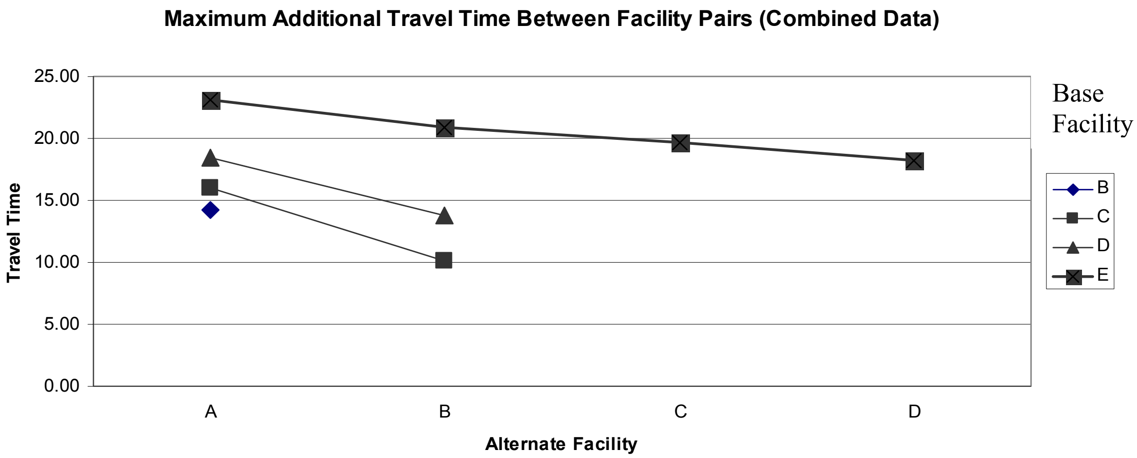
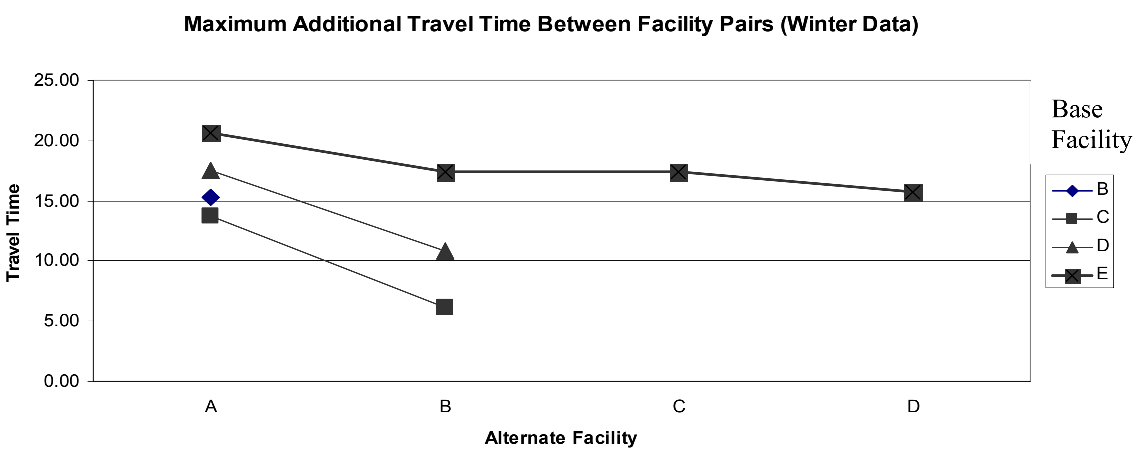


Figure 3a. (top) Comparing designated bicycle lanes with no parking with in-traffic bicycling with no parking

Figure 3b. (bottom) Same presentation three iterations later





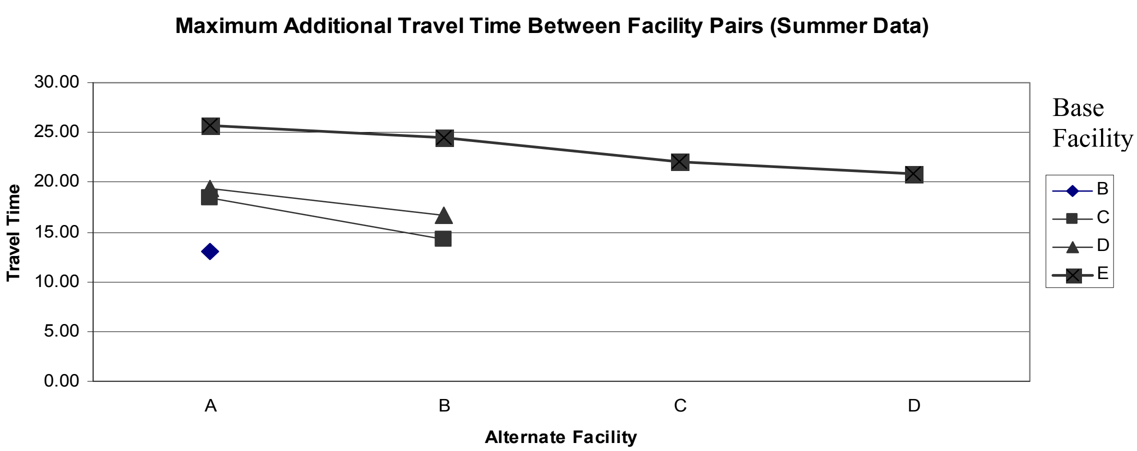


Figure 4. Hierarchy of Facilities
Note: (A) off-road facility; (B) bike-lane, no parking facility; (C) a bike-lane, on-street parking facility; (D) a no bike-lane, no parking facility;(E) a no bike-lane, on-street parking facility.

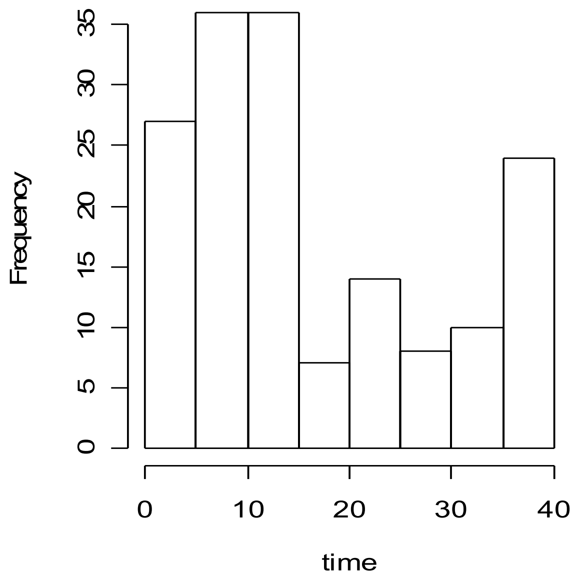


Figure 5(a) Distribution of the additional travel time for facility C over facility A.

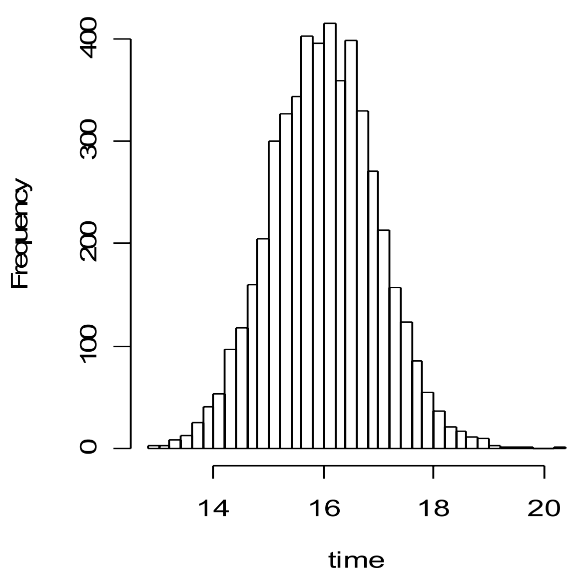


Figure 5(b). The bootstrapped mean for the additional travel time between facilities A and C (based on 5000 resamples).

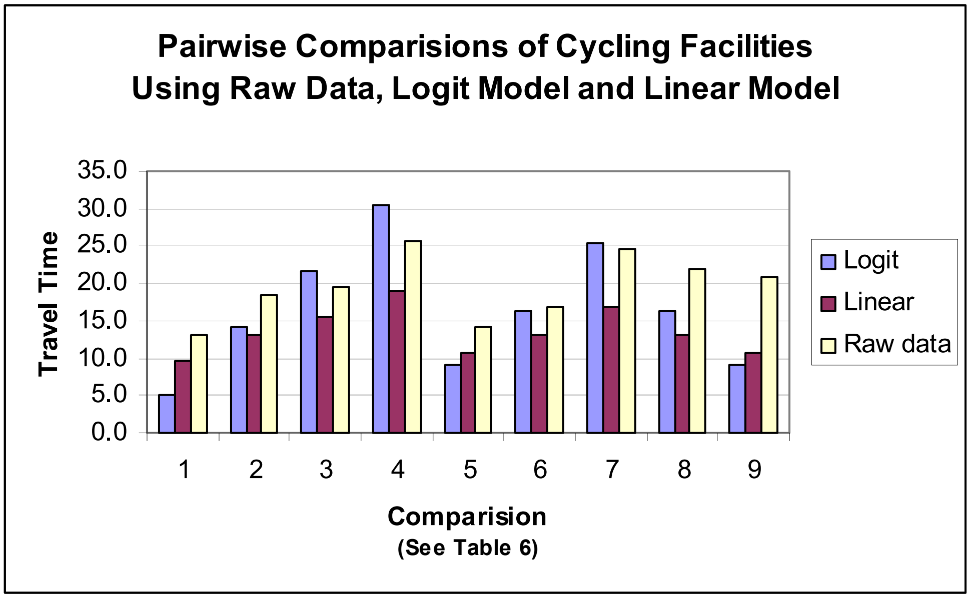


Figure 6. Comparison of the estimates of the additional time willing to travel between facility pairs based on logit model, linear model and the raw data.

Table 1. Facility pairs compared in the ASP survey.

		Base Route			
		B Bike-lane, no parking	C Bike-lane with on-street parking	D No bike-lane, no parking	E No bike-lane with on-street parking
Alternate routes	A off-road	**T_1**	**T_2**	**T_3**	**T_4**
	B Bike-lane, no parking	N/A	**T_5**	**T_6**	**T_7**
	C Bike-lane with on-street parking	N/A	N/A	N/A	**T_8**
	D No bike-lane, no parking	N/A	N/A	N/A	**T_9**

T_i represents the average additional travel time user are willing to travel.

Table 2. Choice order for a sample presentation.

Presentation	Facility Travel Time		Choice
	Route 1	**Route 2**	
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
$\mathbf{T_i}$	36 min		

Table 3. Demographic distribution of respondents

Number of subjects		168
Sex		
	% Male	34.5%
	% Female	65.5%
Age	Mean (Std. deviation)	44.19 (10.99)
Usual mode (Year round)		
	%Car	69.7%
	%Bus	18.5%
	%Bike	9.2%
	%Walk	2.6%
Bike commuter		
	All season	9.2%
	Summer	22.6%
HH 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%
HH Size		
	1	25.0%
	2	32.7%
	3	16.7%
	4	20.8%
	> 4	4.8%

Table 4. Mean additional travel time between facility pairs and confidence interval of the bootstrapped distribution of the mean.

Fac1	Fac2	Original Mean	Bias	Standard Error	Normal 95% CI	Percentile 95% CI
Combined Data						
A	B	14.21	0.0223	0.962	(12.30, 16.08)	(12.41, 16.17)
A	C	16.00	0.0136	0.964	(14.10, 17.88)	(14.16, 17.92)
A	D	18.46	-0.0160	0.984	(16.55, 20.41)	(16.58, 20.40)
A	E	23.14	-0.0051	0.939	(21.30, 24.98)	(21.26, 24.94)
B	C	10.13	0.0092	0.973	(8.21, 12.03)	(8.25, 12.06)
B	D	13.73	-0.0008	0.957	(11.85, 15.61)	(11.90, 15.62)
B	E	20.87	0.0245	0.956	(18.97, 22.72)	(19.09, 22.84)
C	E	19.65	-0.0033	0.950	(17.79, 21.51)	(17.79, 21.49)
D	E	18.25	0.0211	1.002	(16.27, 20.20)	(16.35, 20.22)
Winter Data						
Fac1	Fac2	Original Mean	Bias	Standard Error	Normal 95% CI	Percentile 95% CI
A	B	15.33	0.0208	1.335	(12.69, 17.92)	(12.78, 18.00)
A	C	13.69	0.0339	1.327	(11.06, 16.26)	(11.21, 16.40)
A	D	17.57	-0.0252	1.344	(14.96, 20.23)	(14.99, 20.19)
A	E	20.66	-0.0025	1.319	(18.08, 23.25)	(18.16, 23.28)
B	C	6.17	-0.0064	1.197	(3.83, 8.52)	(3.97, 8.57)
B	D	10.86	-0.0244	1.180	(8.57, 13.19)	(8.58, 13.25)
B	E	17.45	-0.0101	1.248	(15.02, 19.91)	(15.02, 19.91)
C	E	17.39	-0.0097	1.264	(14.92, 19.87)	(14.98, 19.92)
D	E	15.72	0.0074	1.270	(13.22, 18.20)	(13.22, 18.22)
Summer Data						
Fac1	Fac2	Original Mean	Bias	Standard Error	Normal 95% CI	Percentile 95% CI
A	B	13.04	-0.0051	1.338	(10.43, 15.67)	(10.49, 15.74)
A	C	18.43	0.0146	1.353	(15.76, 21.07)	(15.84, 21.16)
A	D	19.40	0.0079	1.434	(16.58, 22.20)	(16.58, 22.25)
A	E	25.73	-0.0071	1.292	(23.21, 28.27)	(23.18, 28.27)
B	C	14.28	0.0154	1.397	(11.53, 17.01)	(11.63, 17.10)
B	D	16.75	-0.0128	1.481	(13.86, 19.66)	(13.89, 19.68)
B	E	24.46	-0.0072	1.332	(21.85, 27.07)	(21.78, 27.06)
C	E	22.03	0.0013	1.403	(19.27, 24.77)	(19.30, 24.82)
D	E	20.92	-0.0055	1.485	(18.01, 23.83)	(17.96, 23.82)

Table 5. Coding for facility features

Facility	O	B	P
A (Off-road)	1	1	1
B (Bike-lane, No parking)	0	1	1
C (Bike-lane, on-street parking)	0	1	0
D (In traffic, No parking)	0	0	1
E (In traffic, on-street parking)	0	0	0

Table 6. Logit Model

Random effects:

Group	Variance	Std.Dev.
subject	1.550	1.245

Fixed effects:

Variable	Description	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)		-0.620	0.472	-1.315	0.1885	
W	Season (1= winter, 0=summer)	-0.627	0.207	-3.028	0.0025	**
T	Travel time	-0.051	0.004	-12.685	0.0000	***
O	Offroad Improvement?	0.264	0.060	4.386	0.0000	***
P	Parking improvement?	0.456	0.065	7.067	0.0000	***
B	Bikelane improvement?	0.831	0.067	12.475	0.0000	***
A	Age	0.021	0.010	2.126	0.0335	*
S	Sex (1=M, 0=F)	-0.350	0.223	-1.567	0.1171	
I	Income	0.005	0.003	1.584	0.1132	
H	HHsize (1 if >2, 0 otherwise)	-0.594	0.229	-2.589	0.0096	**
C	Cyclist (1=atleast summer,0=No)	-0.133	0.253	-0.524	0.6003	

Table 7. Time Values of Facility Attributes

Attribute	Marginal Rate of Substitution (minutes)
O – Off street improvement	5.20
P – Parking improvement	8.98
B – Bikelane improvement	16.36

Table 8. Linear Model

Random effects

	(Intercept)	Residual
StdDev:	8.98	8.01

Fixed effects:

	Description		Value	Std.Error	t-stat	p-value	
(Intercept)			7.24	3.377	2.143	0.032	*
W	Seaon Winter?	Yes =1 No = 0	-4.13	1.485	-2.782	0.006	***
O	Offroad improvement?	Yes =1 No = 0	2.38	0.429	5.540	0.000	***
P	Parking Improvement?	Yes =1 No = 0	3.50	0.456	7.673	0.000	***
B	Bikelane Improvement?	Yes =1 No = 0	5.98	0.456	13.127	0.000	**
A	Age	Yes =1 No = 0	0.15	0.071	2.092	0.038	*
S	Sex	Male =1 Female=0	-3.36	1.604	-2.093	0.038	*
I	Inc/1000		0.03	0.021	1.475	0.142	
H	Household Size	>2 = 1 ≤2 = 0	-3.75	1.645	-2.278	0.024	*
C	Summer Cyclist?	Yes =1 No = 0	-2.22	1.818	-1.221	0.224	

Significance ***0.001 **0.01 *0.05 +0.1

Table 9. Comparison of travel time values between facilities using the linear model and the logit model

Comparision	Facility 1	Facility 2	Logit	Linear	Mean (raw data)
1	A	B	5.2	9.6	13.0
2	A	C	14.2	13.1	18.4
3	A	D	21.6	15.6	19.4
4	A	E	30.5	19.1	25.7
5	B	C	9.0	10.7	14.3
6	B	D	16.4	13.2	16.7
7	B	E	25.3	16.7	24.5
8	C	E	16.4	13.2	22.0
9	D	E	9.0	10.7	20.9

Appendix C

Appendix C: Longitudinal Approaches To Examining The Effects Of Bicycle Facilities On Mode Share

Gary Barnes
Kristin Thompson
Kevin Krizek

Introduction

Planning agencies and bicycle advocacy groups have long searched for ways to quantify the effects of building new bicycle facilities. Before funding bicycle facility projects, funding agencies often want to know, "if we build it, will they come?" This question is difficult to answer. Many factors affect how many people bicycle, for what purpose, and how often.

There is a great deal of variation in bicycling rates across different areas, and often even within different parts of the same city (*1*). It is tempting to ascribe these differences to variations in the bicycling environment in general, and specifically to the presence or absence of special bicycling facilities. Some studies have attempted to compare bicycling rates and facilities across cities (*2, 3,4*), and at least one has tried to explain intra-city differences this way (*5*). These studies have had limited success, in part because of the difficulty of acquiring comparable bicycling data from different cities, and of developing consistent definitions of facilities.

Perhaps a bigger issue with this type of study, though, is the indeterminacy of the causality. That is, rather than bicycle facilities inducing higher bicycling rates, it could be that existing high densities of bicyclists created the political climate and perhaps safety justification for building the facilities in the first place (*2*). Nonetheless, facilities are very heavily used compared with ordinary streets (*6*), and there is evidence that commuters are willing to divert out of their way to use facilities (*7, 8*). From these indications of the value that bicyclists place on facilities, it seems logical to deduce that their presence will induce at least some people to commute by bicycle who wouldn't have otherwise. Separating the effects of preexisting bicycle commuting from the effects of the facility itself would be a key advance in this regard.

Seemingly the only way around this problem would be to compare the same location at two different points in time. While local populations still do not remain completely constant over time, they should at least be more comparable than populations from two different cities, or even two parts of the same city.

This paper uses such a longitudinal method for determining the effect of bicycle facility construction in Minneapolis-St. Paul, MN, on journey-to-work bicycle mode share. During the 1990s a number of new facilities were created in the two central cities; many of them focused on the bicycle commuting hotspots of the University of Minnesota and nearby downtown Minneapolis, and on connection to existing facilities. The U.S. census in both 1990 and 2000 counted bicycle commuters; we believe that this is the first time that such comparable data from two different surveys has been available in this country. The analysis is fairly simple, comparing bicycling commute rates over various parts of the city, and between specific origins and destinations, depending on proximity to the new facilities.

The first part of the paper describes the facilities and the areas they serve, and offers a few intuitive hypotheses regarding how they might be expected to be used. This section also describes two buffering methods that we used to characterize the area of influence of the facilities. The next section describes the rate of bicycle commuting over a variety of different ways of defining the area and its commuting patterns vis-à-vis the new facilities, and discusses some implications of these findings. The final section concludes and offers some suggestions for further research.

The Facilities

Seven new bicycle facilities in the cities of Minneapolis and St. Paul were selected for the buffer analysis method. Three are on-street bicycle lanes, and the remaining four are off-street bicycle trails. They do not necessarily represent a comprehensive list of all new facilities created during the 1990s, but they are of particular interest for this study because they all are located in areas where they could reasonably be expected to impact the rate of bicycle commuting through providing improved access to the major employment centers of downtown Minneapolis and the University of Minnesota, which are about one mile apart.

There were also a number of major bridge improvements during the 1990s. Both downtowns and the University are located on the Mississippi River. Two new bicycle bridges were constructed near the University, and wide bicycle lanes were added as part of the general rebuilding of several other road bridges in the area. Thus it could be expected that there would be more cross-river commuting by bicycle in 2000 than in 1990. We examine this possibility as part of our analysis, but without trying to define spheres of influence for specific bridges, as we do for linear facilities.

On-Street Bicycle Lanes

Park/Portland Striping Park and Portland Avenues are parallel one-way thoroughfares running into and out of downtown Minneapolis, respectively. The bicycle lane on Portland Avenue is 4.22 miles (6.79 km) long, while the lane on Park Avenue is 4 miles (6.44 km) long. South of downtown, the lanes pass through the residential heart of Minneapolis. Both lanes terminate at 46th St., half a mile north of the Minnehaha Creek bicycle path, a popular recreational route. Both Park and Portland Avenues see heavy vehicle traffic traveling at relatively high speeds. As such, the existence of bicycle lanes on these streets significantly improves conditions for bicyclists.

Summit Striping Summit Avenue is a boulevard traversing central west St. Paul from the Mississippi River to just outside of downtown St. Paul. Bi-directional bicycle lanes traverse 4.58 miles (7.37 km) of its length. The western end of the boulevard intersects with the East Mississippi River Parkway, which has recreational walking and off-street bicycling paths. The character of the surrounding neighborhoods is primarily residential. Because Summit Avenue is wide and relatively lightly traveled, it is unlikely that the addition of bicycle lanes in the 1990s greatly improved conditions for bicyclists.

University/4th Striping University Avenue and 4th Street SE are parallel one-way thoroughfares near the University of Minnesota Twin Cities Campus in Minneapolis. The southeast-bound facility on University is 1.56 mi (2.51 km), while the northwest bound lane on 4th St SE is just .84 mi (1.36 km) split into two segments. The two segments are interrupted by a

0.16 mi (0.26 km) stretch with no lane striping. As with Park and Portland Avenues, University Avenue and 4th Street SE experience heavy, high speed vehicle traffic. Consequently, the bicycle lanes improve travel conditions for bicyclists.

Off-Street Bicycle Paths

Cedar Lake Trail The Cedar Lake Trail is an off-street bicycle path that runs 7.79 miles (12.54 km) through a former rail corridor from the northwest side of downtown Minneapolis to the southwest Minneapolis suburb of Hopkins. Access to the path is limited to occasional entry/exit points, much like a limited-access highway. As such, it is possible to live in close proximity to the trail without having similarly proximate trail access. In this analysis, only the 2.73 mi (4.40 km) portion of the trail within the city of Minneapolis is included.

Kenilworth Trail The Kenilworth Trail is a 1.78 mi (2.87 km) path connecting the Cedar Lake Trail in the north and to the Midtown Greenway, an off-street bicycle path completed in 2000, in the south. The trail runs through a small Minneapolis neighborhood nestled between Lake of the Isles and Cedar Lake. As with the Cedar Lake Trail, access to the path is limited to a few entry/exit points.

West River Parkway Minneapolis and St. Paul both have nearly continuous off-street bicycle paths along the Mississippi River. Portions of the path along the downtown Minneapolis riverfront were completed during the 1990s, from Plymouth Avenue in the north to the Washington Avenue bridge (on the University of Minnesota campus) in the south. This portion of the path is 7.96 mi long (12.81 km). The completion of this portion provided a direct route into downtown for commuters coming from the already extant southern part of the West River Parkway.

U of MN Transitway The University of Minnesota Transitway is a transit-only connection between the University's Minneapolis and St. Paul campus. During the 1990s a parallel bicycle path was established along part of the route, from the Minneapolis campus east to Energy Park Drive. The facility is 1.86 mi (3.00 km) long. There are multiple access points on the western end of the facility, but in the eastern half it is not possible to enter or exit the path except from its termination point at Energy Park Drive. The land uses surrounding the facility are primarily industrial in nature. A consequence of these two characteristics is that the facility is likely used for trips whose routes include its entire length.

We believe that this is a comprehensive list of major facilities that were created in the central cities during the 1990s that are viable for commuting. One other major new central city facility, the Gateway Trail, originates in St. Paul and goes out into the countryside to the northeast. We omitted it from this analysis because, while it is very heavily used as a recreational trail, it does not seem suitable for commuting, as it does not pass near or even aim toward any major employment centers. Our own analysis confirmed that there are virtually no bicycle commuters in this corridor.

There were also facilities, both on- and off-street, created in the suburban Twin Cities during the 1990s. Again, however, we omitted these for purposes of this study, both because bicycle commuting rates are very low in the suburbs, and because the facilities tend to not serve major employment concentrations.

Two different buffering techniques were employed for trails and lanes. In the first technique, Traffic Analysis Zones (TAZs) were selected if their centroids lay within one mile (1.61 km) of the facility (referred to as buffer 1). This method assumes that the importance of a residential or employment location's proximity to the facility remains constant for the entire length of the facility. In the second technique, the endpoints of the facility were buffered to a distance of 1.5 miles (2.43 km), and if these two buffers did not intersect, the remainder of the facility was buffered to a distance of one mile (referred to as buffer 2). This method allows for the possibility that the ends of the facility attract riders from a greater distance. Again, TAZs were selected if their centroids lay within the buffer.

In the case of paired bicycle lanes, the most extreme endpoints of each set of lanes were used for this analysis. For example, the Portland Avenue bicycle lane is a few hundred meters longer than the Park Avenue bicycle lane, so the endpoints of the former were buffered. In the case of the Cedar Lake Trail, which extends beyond the Minneapolis city limits, only the endpoint located within the central city was buffered to 1.5 miles. The reasoning for this is that while the other endpoint of the trail for purposes of this analysis is at the city limits, this is not the true endpoint for the facility and therefore should not be analyzed as such. Overall, the buffers covered a majority of the city of Minneapolis, but much less of St. Paul (Figure 1).

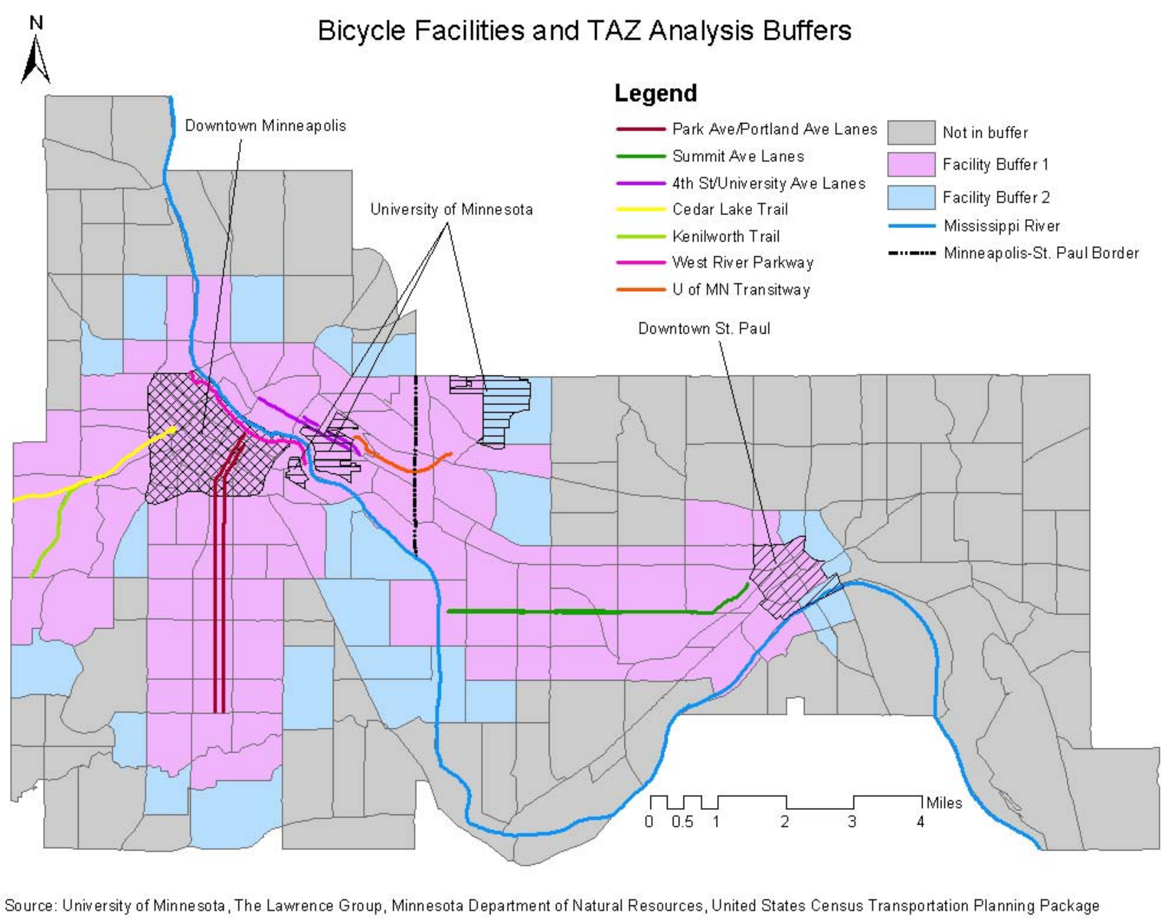


FIGURE 1 Bicycle Facilities and TAZ Analysis Buffers

Analysis

Our analysis examined various measures of bicycle commute shares in the central cities of Minneapolis and St. Paul. We focus on residential measures, that is, the bicycle commute rate for people who live in a given area. We looked also at the mode share for people who work in a given area, but the results were generally so similar to the residential measures that it seemed redundant to include both, with one exception noted in the bullets below. We consider a sequence of measures that represent different ways of specifying commuting patterns, in each case comparing 1990 to 2000:

- Overall mode shares for different parts of the metro region
- Shares for TAZs in facility buffers versus those that are not
- Point-to-point shares for trips that are within facility buffers
- Shares for the areas around individual facilities
- Share for trips that cross the Mississippi River
- Shares for trips terminating in downtown Minneapolis, downtown St. Paul, and the Minneapolis campus of the University of Minnesota.

The examination of river crossings was prompted by the observation, noted earlier, that there were many bridge improvements including the addition of bicycle lanes to existing road bridges. We look at point to point data to determine if trips crossing the river gained a significant number of bicycle commuters as a result. The study of the three trip destinations derived from the fact that many of the major improvements were concentrated around providing access to the University of Minnesota and downtown Minneapolis, and in particular the connection between them, while there were few or no improvements of similar magnitude around downtown St. Paul.

Overall Bicycle Mode Share

Calculating the percentage of all commute trips that were done by bicycle is straightforward enough. There is a small complication that arises because the numbers that are reported in the Census Transportation Planning Package (CTPP) are scaled up based on the results of a smaller sample. Furthermore, the scaled-up counts by mode are rounded off to multiples of five; this could introduce bias since there are often very few bicyclists in a given TAZ. However, in calculating the mode share based on the reported (scaled-up) totals, and an estimate of the actual samples, there was virtually no difference in the bicycle mode share. We concluded from this that using the scaled-up numbers will not introduce any major errors.

A related issue is calculating the statistical significance of increases in bicycle mode share. A person is either a bicycle commuter or not; the characteristics of a sample of commuters can thus be represented as a binomial distribution. The probability that a person commutes by bike is represented by the sample mean: the number of bicyclists divided by the total number of commuters. The standard deviation of this distribution is given by Equation 1.

Standard deviation = $(N*p*(1/p))^{(1/2)}$ (1)

Where N is the total sample size,

p is the probability of the outcome of interest.

In determining the significance of changes in bicycle commute share, we calculate the number of standard deviations by which the observed number of bicycle commuters in 2000 exceeds the number that would be expected based on the sample mean in 1990. We represent this in the tables in this paper in its own column; a “2” means that the observed number exceeds the 1990 rate by at least two standard deviations; “1” exceeds by at least one standard deviation, and “0” is less than one standard deviation. It should be noted that the sample size in this calculation is based on the actual long form sample size, not the total number of commuters as scaled up by the census bureau.

The Twin Cities metropolitan area overall had a very small increase in bicycle mode share during the 1990s. However, this increase was all concentrated in the two central cities; the suburbs actually showed a slight decline from an already low level. The increases in the central cities were relatively concentrated in the areas around facilities; while all areas showed a statistically significant increase in bicycle mode share, the areas in the facility buffers showed a larger increase (Table 1).

TABLE 1 Twin Cities Metro Area Bicycle Commute Share, 1990-2000

	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
All Metro	0.442	0.462	1
Non-central city TAZs	0.187	0.164	-2
Central city TAZs	1.153	1.386	2
TAZs in buffer 1	1.859	2.051	2
TAZs in buffer 2	1.701	2.000	2
TAZs outside buffers	0.428	0.535	2

Viewing the two cities separately, similar results emerge. Minneapolis has a much higher bicycle mode share than St. Paul does, probably due to a large extent to the large University of Minnesota campus located there. All parts of both cities showed increased bicycle mode share, with the areas in facility buffers showing generally larger increases (Table 2). An interesting point is that in Minneapolis, the larger buffers showed increases where the smaller buffers did not, indicating that all the increase in the larger buffers was in the outermost TAZs that were not included in the smaller buffers. This is somewhat puzzling, especially in light of the fact that the zones that were outside the buffers entirely did not show such large increases. It does hint at the possibility that one effect of facilities is to make longer commutes more viable, while the impact may be less significant on shorter commutes.

TABLE 2 Minneapolis and St. Paul Bicycle Commute Share, 1990-2000

	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
St. Paul	0.528	0.681	2
TAZs in buffer 1	0.855	1.125	2
TAZs in buffer 2	0.828	1.090	2
Zones outside buffers	0.332	0.415	1
Minneapolis	1.596	1.876	2
TAZs in buffer 1	2.423	2.557	1
TAZs in buffer 2	2.127	2.439	2
Zones outside buffers	0.530	0.664	1

Trips in Facility Buffers

One concern with this analysis is that it may be capturing trips that originate near a facility, but go in some other direction entirely. To control for this, we further confined the mode-share calculations to trips that both began and ended within facility buffers, using the census part 3 data to consider both origins and destinations. To simplify the analysis we considered just the larger buffers. We also eliminated all trips that were less than one mile long; since our buffers extended a mile or more away from the facilities, this reduced the possibility of counting trips that could begin and end in the buffer but never get to the facility. For comparison, we considered other trips that began and ended in the central cities, but where at least one end was not in a buffer (and which were at least one mile long).

These results again show that trips within the facility buffers show a larger increase in bicycle mode share than do trips that leave the buffers; however, all trips in the central city show an increase (Table 3).

TABLE 3. Minneapolis and St. Paul Bicycle Commute Share For Commutes Longer than One Mile, 1990-2000

	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
St. Paul	0.696	1.068	2
TAZs in buffers 1 & 2	1.202	1.649	1
TAZs outside buffers	0.453	0.678	1
Minneapolis	2.337	3.267	2
TAZs in buffers 1 & 2	3.157	4.283	2
TAZs outside buffers	0.942	1.173	1

An interesting side note on this table is that in our early calculations we restricted the trips to those less than five miles long, on the theory that this would focus the analysis more directly on bicycle-length trips. We arrived at the puzzling result that the facility-based trips in St. Paul showed no increase in bicycle mode share, although Table 2 had shown that the full set of trips originating near these facilities showed a significant increase. In attempting to solve this riddle, we found that a substantial fraction of the trips originating near St. Paul facilities were in fact more than five miles in length, and that these long trips were in fact responsible for almost all the increase in total bicycle commuting around these facilities. This may be due to increased commuting to the University of Minnesota campus, to which these facilities provide key links; this again indicates that a major effect of facilities may be to make long-distance commuting more viable.

Finally, we calculated the changes in bicycle mode share in the buffers around individual facilities. Here we counted trips that began in the buffer of a given facility but that ended in the buffer of any facility; this seemed appropriate since one of the important features of the facilities is their degree of interconnection. Again, almost all the facilities showed statistically significant increases in bicycle mode share; even in the three cases where small buffers showed no increase, the corresponding large buffer did (Table 4).

TABLE 4. Bicycle Commute Share in Buffer Analysis Areas, 1990-2000

Facility Buffer	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
University/4th buffer 1	7.030	9.320	2
University/4th buffer 2	6.100	7.822	2
Cedar Lake Trail buffer 1	1.698	1.270	0
Cedar Lake Trail buffer 2	2.502	3.551	2
Kenilworth Trail buffer 1	1.423	1.427	0
Kenilworth Trail buffer 2	1.727	3.039	2
Park/Portland buffer 1	3.237	4.636	2
Park/Portland buffer 2	3.494	4.540	2
Summit Avenue buffer 1	0.833	1.926	2
Summit Avenue Buffer 2	1.005	2.362	2
U of MN Transitway buffer 1	6.991	7.481	0
U of MN Transitway buffer 2	6.367	7.829	2
West River Parkway buffer 1	5.462	7.946	2
West River Parkway buffer 1	5.480	7.175	2

River Crossings and Major Destinations

The Mississippi River flows more or less south through a part of Minneapolis, skirts the downtown and the University of Minnesota, and then divides Minneapolis and St. Paul. Later it turns east and divides St. Paul from its southern suburbs and from a small portion of St. Paul that lies on the south side of the river. On the east-flowing portion there were no bicycle-accessible crossings between the river bend and near downtown St. Paul, the one bridge in this stretch being an interstate highway; there were two crossings in downtown and one just outside. (A bicycle lane has since been added to the interstate bridge as part of a larger reconstruction.) On the south-flowing part of the river there are a number of crossings; more closely spaced near downtown and the university, and much farther apart away from this area. There is the potential for a good deal of cross-river commuting, especially since jobs and housing are both quite dense near the downtown.

During the 1990s two new bicycle bridges were built near the university, and bicycle lanes were added to two other road bridges in this area as part of their reconstruction. As a result the ease and safety of crossing the river by bicycle was greatly enhanced; the number of bridges with dedicated bicycle facilities went from two to six. This might be expected to impact the bicycle mode share for cross-river commutes. We again used CTPP part 3 data to identify the side of the river that central city commute trips began and ended. We compared the increase in bicycle mode share for trips that crossed the river to that for trips that stayed within the central cities but that did not cross (Table 5).

TABLE 5. Minneapolis and St. Paul River Crossing Bicycle Commute Share, 1990-2000

	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
Trips crossing south-flowing portion of Mississippi River	3.340	4.543	2
Trips originating and terminating west of the Mississippi River	2.264	2.607	1
Trips originating and terminating east of the Mississippi River	1.768	2.629	2

The trips that crossed the river already had a very high bicycle mode share, but this share increased substantially during the 1990s; much more than the increase for trips that remained on the same side of the river. The bridge improvements did seem to have a considerable effect on commuters' willingness to use bicycles to cross the river.

Our final analysis considers trip destinations. As noted earlier, most of the facilities provide improved access to the University of Minnesota and downtown Minneapolis. In addition to the facilities we analyze, there was a major program of striping bicycle lanes on streets in downtown Minneapolis. By contrast, there were few if any such improvements in and around downtown St. Paul. We hypothesized that as a result of this discrepancy in facility construction there should be a bigger increase in bicycle mode share for trips going to the Minneapolis destinations.

We identified sets of TAZs corresponding to each of the three destinations. Once again, we used CTPP part 3 data to identify trips that began in the central cities and that ended in one of the three destination areas (Table 6). We excluded trips that began outside the central cities because they rarely use bicycles, and since they are becoming more prevalent over time, they tend to keep the overall bicycle mode share low, obscuring any changes that might be happening among shorter trips.

TABLE 6. Minneapolis and St. Paul Major Destination Bicycle Commute Share, 1990-2000

Trips to Major Employment/ Activity Centers	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
U of MN—Minneapolis Campus	6.604	8.528	2
Downtown Minneapolis	2.266	2.583	1
Downtown St. Paul	0.643	0.591	0

Our hypothesis was supported by this analysis. There was a very large increase in bicycle mode share to the University of Minnesota campus, and a smaller but still sizable increase to downtown Minneapolis. Downtown St. Paul, by contrast, showed a very slight decrease. This is especially surprising in light of the fact that bicycle commuting by residents of St. Paul went up substantially; apparently none of this increase was aimed at downtown. This indicates that the density of facilities in Minneapolis did likely substantially impact the use of bicycles for commuting in this area.

Conclusions

While the results are not entirely unambiguous, the preponderance of evidence seems to support the hypothesis that the major bicycle facilities constructed in the Twin Cities during the 1990s did in fact significantly impact the level of bicycle commuting. The suburban parts of the region showed a decline in bicycle commuting, contrasted with a sharp increase in both central cities. Within the central cities, areas near bicycle facilities tended to show more of an increase in bicycle mode share than areas farther away, although this trend is less sharply defined. Trips that crossed the Mississippi River showed a much larger increase than trips that did not, seemingly demonstrating the impact of several major bridge improvements. Finally, trips into downtown Minneapolis and the University of Minnesota, where improvements were concentrated, showed substantial increases, while trips into downtown St. Paul, where few improvements were made, showed a slight decline.

The results also provide considerable support for the alternative hypothesis that facilities are the effect, rather than the cause, of high bicycle use. In the Twin Cities, the areas where major facilities were built already had bicycle mode shares that ranged from twice the regional average up to nearly 15 times the regional average. While the facilities did increase the bicycle mode share in their buffers by about 17.5% overall (from 1.7% to 2.0%), this is far from the factor of ten difference that is observed between the facility and non-facility areas when considering the year 2000 in isolation (2.0% compared to 0.2%). This highlights the risks inherent in trying to deduce the impact of facilities by trying to compare two different places.

There are a number of further lines of work that could add more insight to this analysis. One would be experimenting with different buffering methods. We defined our buffers somewhat arbitrarily in order to simplify the analysis. But in some cases TAZs that fall into the buffer for a facility would not necessarily be expected to use it much, because there are physical barriers to access or because there is a more direct route to the most likely destinations. We believe that this may be what is happening with some of the buffers that showed no increase in bicycle mode share. Conversely, there may be TAZs that are outside our buffer but that fall within the zone of influence, because the facility falls on the route to a major destination or because it can be easily accessed using existing facilities. For example, both the West River Parkway in downtown Minneapolis and the Kenilworth Trail seem likely to derive much of their value by providing needed links or extensions to already existing facilities.

Another improvement would be a more careful reckoning of new facilities in the area. Our accounting of new facilities in Minneapolis was perhaps more thorough than those in St. Paul due to the sources we were able to access. The large increase in bicycle mode share outside of the facility buffers in St. Paul leads us to wonder if there are important facilities that we failed to include in our analysis. A related improvement would be to extend the analysis some distance into the suburbs, again being careful to identify major possible bicycle commuting facilities. There was one of our facilities that extended into the suburbs, and understanding the impact on bicycle commuting in this area compared with similar inner suburban areas without facilities would be interesting.

In this paper we did not try to control for demographic variables. The areas that we are studying seemed sufficiently large that major demographic shifts would be unlikely in such a short time, although they certainly could have had an impact on specific locations. Generally variables such as age and income are not as important as they are often believed to be (*9*); the differences across ages and incomes are only a small fraction as large as the differences across geographic locations. However, there would be value in confirming this point within the specific context of this analysis.

While there are many possible improvements to be made, the fact that this simple analysis seems to show a clear impact of bicycle facilities on the level of bicycle commuting is of considerable interest. Reliance on comparison of bicycling levels in different places is inherently subject to the criticism that no causality is implied by any observed relationship; facilities might have been built because many people already rode bikes, rather than the facilities causing the high levels of riding. This approach provides a method for demonstrating the effect that facilities have on the level of bicycling in an area in a much less ambiguous way.

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Appendix D

Appendix D: A Survey of Residents Near Three Minneapolis-Area Bike Trails

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Introduction

This report describes the results of a survey that was sent to residents of three off-road bicycle trails in and west of Minneapolis. The survey was aimed at a number of complementary objectives centered on better understanding the relationships between various lifestyle preferences and behaviors, and access to recreational facilities and how they are used. This report focuses on the characteristics of those who reported riding bicycles versus those that did not. Because the survey explored a wide range of issues beyond the ordinary demographic descriptors, this adds a great deal to our understanding of the factors that are related to bicycling behaviors.

The trails were the Midtown Greenway, the Cedar Lake Trail, and the Luce Line Trail. These were selected to represent urban, inner suburban, and outer suburban contexts. Study areas were selected that surrounded these trails. The Greenway study area was in Minneapolis, the Cedar Lake area was in St. Louis Park, and the Luce Line area included parts of Plymouth, Orono, Wayzata, Minnetonka, and small parts of several other towns. For the outer two trails, the study area borders coincided with zip code borders. For the Greenway, due to higher residential densities, using zip codes did not sufficiently constrain the study area. Thus here Census 2000 block-group boundaries were substituted.

One thousand surveys were sent to randomly selected households in each of the three study areas. In total, 3000 surveys were sent. The sample groups were obtained from databases of all addresses in the study areas; all non-institutional household types were included in the sample. The eight-page survey encompassed a wide variety of questions: the majority of questions pertained to trail access and use and residential attributes. Questions about household automobiles, consumer preferences and basic demographics were also included.

Surveys were mailed in mid-July, followed a week later with a postcard reminder. A second reminder letter, including another copy of the survey, was sent in early August. A final postcard reminder was mailed in late August. Excluding surveys that were returned as undeliverable, the response rate was roughly 50%. The two suburban study areas had similar response rates, while the response rate for the urban study area was somewhat lower. The latter study area also had a higher percentage of surveys returned as undeliverable, reflecting the higher rental rates and concomitant residential turnover in that study area. A few people returned the survey but indicated that they no longer lived in the study area. Excluding these, there were a total of 1075 completed surveys.

Many surveys have established some general facts with regard to the level of bicycling as well as some demographic patterns. This survey sought to further support this existing knowledge, as well as adding local (Twin Cities) specificity. There were also two other, more original objectives. One was to gather information, typically ignored in other surveys, regarding lifestyle and political (broadly defined) choices and preferences. We and others have hypothesized that pro-bicycling attitudes may typically be part of a package of attitudes and preferences that does not necessarily closely relate to standard demographic categories, but that may be more predictable by other information, such as political preferences or priorities in home location choice.

The other major objective was to better understand the role of bicycle-specific facilities in bicycling choices. Specifically, we wanted to know more about the extent to which the presence of high-quality off-road facilities would be associated with higher levels of bicycling, how the facilities were used, and again, the demographic and lifestyle factors associated with facility use in the different areas. This can ultimately help in better understanding the likely impacts of new facilities on cycling behavior in different types of residential environments.

The survey questions can be roughly divided into four categories:

- Bicycling, trail use, and other transportation information
- Home location and preferences
- Lifestyle and politics
- Demographic

The main body of this report is divided into parts corresponding to these four categories. The first part of the analysis establishes information about the most recent bicycle ride for each respondent. We take this as a proxy of the frequency with which respondents ride (although this is not strictly speaking what was asked). These bicycling frequency levels then become a basis for comparing and analyzing the answers to all the subsequent questions.

Bicycling, trail use, and transportation information

Information about the most recent bicycle ride, which we take as a proxy for cycling frequency, can be described in four levels: the past seven days, the past 30 days, the past year and no riding in the last year (Table 1). This is derived from two different questions; the first established the latter three categories and the second asked about activities in the last seven days. A large number of people did not answer the question of whether they had ridden in the past seven days; for these we took the answer to be “no” (most of these had said that they had not ridden in the past year). Both questions asked specifically about cycling with home as the starting point; the intent being to exclude atypical vacation rental cycling and such.

TABLE 1 Cycling Frequencies by Location

	Greenway	Cedar Lake	Luce Line
Past 7 days	25%	23%	23%
Past 30 days	13%	8%	11%
Past year	13%	12%	14%
No biking	50%	56%	51%
(Each column above adds to 100%)			
Ave. # of rides in past 7 days	3.57	2.28	2.28
% with more than 2 rides in past 7 days	61%	34%	29%

The fraction who did not bike, at about 50%, is consistent with earlier studies. However, of those that did bike, the percentage who reported biking in the last week was far higher than past studies, which would have indicated more like 10-15%, rather than the 25% observed here. There are a couple of plausible explanations. First, this survey was done during prime bicycling season. Some people who only ride once a year may just have done it that week, so taking the most recent ride as an indicator of frequency may be inappropriate here. Another issue is that people could choose when to fill out the survey. Some people may have looked at the survey, seen that most of the early questions related to trail use and physical activity in general, and decided to wait to finish the survey until they had gone for a bike ride, so that they could answer those questions. These hypotheses are supported by the last line, which indicates that 65-70% of the riders in the outer areas rode two times or less. While this may inflate the apparent frequency of cycling, it does not seem that it should bias the answers to other questions, since these are presumably mostly people who do ride bikes anyway; the bias is just in the timing of the ride.

Another surprising result here was that there was no basic difference in riding frequency between the Greenway and the other trails. Evidence from other local surveys led us to expect that the rate should be much higher in the Greenway area. However, closer examination, shown in the last two lines of the table, shows that "past 7 days" riders in the Greenway area had 50% more rides on average, and about twice as many of them had more than two rides, as compared with the outer two trails. So there is a somewhat higher frequency of riding in the Greenway area, although the difference is still not as great as has been indicated by other sources.

For those that reported that they did not ride a bike at all in the past year, a follow-on question probed for the reasons (Table 2).

TABLE 2 Reasons for not Cycling

	Greenway	Cedar Lake	Luce Line
Don't like to ride	16%	18%	14%
No bike	61%	62%	48%
Traffic	23%	8%	10%
Bad trail access	4%	1%	1%
No time	16%	20%	18%
Bike inoperable	19%	11%	11%
Don't know trails	5%	5%	1%
Out of shape	13%	22%	17%
(Multiple responses allowed)			

Combining questions about the number of bikes owned by the household, and the number of people in the household, gives the number of bikes per person (Table 3).

Table 3 Bikes per Person, by Location and Biking Frequency

	Greenway	Cedar Lake	Luce Line
Past 7 days	1.2	1.2	1.2
Past 30 days	0.9	1.0	1.0
Past year	0.9	0.9	1.0
No biking	0.3	0.3	0.4

Respondents were asked about the purpose of their most recent bicycle trip. This (and many subsequent tables) is shown in two ways, first based on the location of the respondent, and second based on when the last bike trip was made (Tables 4a and 4b).

TABLE 4a Purpose of Most Recent Bicycle Trip (by Location)

	Work/school	Exercise/rec.	Errand	Other
Greenway	15%	64%	16%	4%
Cedar Lake	7%	82%	7%	5%
Luce Line	0%	90%	3%	7%
(Each row adds to 100%)				

TABLE 4b Purpose of Most Recent Bicycle Trip (by Biking Frequency)

	Work/school	Exercise/rec.	Errand	Other
Past 7 days	10%	79%	6%	5%
Past 30 days	5%	79%	8%	8%
Past year	1%	84%	11%	4%
(Each row adds to 100%)				

Respondents were asked about the primary setting of their most recent bicycle trip. There were three major choices: the local trail (Greenway, etc.), which was named based on the survey area (surveys were customized by area in this way), a different off-road trail, or the street or sidewalk (Tables 5a and 5b).

TABLE 5a Setting of Most Recent Bicycle Trip(by Location)

	Local trail	Other trail	Street/sidewalk
Greenway	30%	28%	42%
Cedar Lake	60%	9%	31%
Luce Line	40%	19%	42%

(Each row adds to 100%)

TABLE 5b Setting of Most Recent Bicycle Trip(by Biking Frequency)

	Local trail	Other trail	Street/sidewalk
Past 7 days	49%	15%	35%
Past 30 days	43%	21%	37%
Past year	31%	22%	46%

(Each row adds to 100%)

Those who did not use their local named trail for their most recent bike trip were asked why (Table 6).

TABLE 6 Reasons for not Using Trail

	Greenway	Cedar Lake	Luce Line
Ride on streets	15%	21%	28%
Prefer different path	16%	5%	3%
Access too hard	2%	9%	6%
Not on route	65%	48%	50%
Don't like path	6%	2%	4%
Other	11%	19%	18%

(Multiple responses allowed)

Respondents were asked about the different activities for which they had used their local named trail in the past 12 months (Tables 7a and 7b).

TABLE 7a Uses of Trail (by Location)

	Greenway	Cedar Lake	Luce Line
Walk	22%	35%	36%
Skate	7%	7%	3%
Run	9%	11%	11%
Bike	38%	35%	32%
Other	1%	1%	2%
No use	48%	44%	45%

(Multiple responses allowed)

TABLE 7b Uses of Trail (by Biking Frequency)

	Past 7 days	Past 30 days	Past year	No biking
Walk	38%	37%	35%	27%
Skate	8%	10%	4%	4%
Run	17%	23%	10%	5%
Bike	81%	72%	46%	1%
Other	2%	2%	1%	2%
No use	13%	18%	38%	69%

(Multiple responses allowed)

Greenway respondents were much less likely to use the trail for walking than people in the other trail areas. Another interesting point here is that people who have not biked in the past year were also much less likely to have used their local trail for any other physical activity.

A question asked about use of walking and transit in the past seven days. (Tables 8a and 8b).

TABLE 8a Walking and Transit Use (by Location)

	Greenway	Cedar Lake	Luce Line
Walk to work	14%	5%	2%
Walk for rec./ex.	65%	55%	60%
Walk for errand	70%	23%	16%
Transit	34%	13%	7%

(Multiple responses allowed)

TABLE 8b Walking and Transit Use (by Biking Frequency)

	Past 7 days	Past 30 days	Past year	No biking
Walk to work	6%	4%	8%	7%
Walk for rec./ex.	71%	59%	63%	54%
Walk for errand	43%	28%	32%	32%
Transit	20%	14%	14%	17%

(Multiple responses allowed)

Greenway residents were much more likely to have walked for transportation reasons and to have used transit, but all areas were about the same in walking for exercise or recreation. People who had biked more recently were somewhat more likely to have walked or used transit, but the differences were much less large in this way of dividing the data.

A series of questions asked about various aspects of respondents' auto ownership and driving behaviors (Tables 9a to 9d).

TABLE 9a Cars per Adult, by Location and Biking Frequency

	Greenway	Cedar Lake	Luce Line
Past 7 days	0.8	1.1	1.1
Past 30 days	0.9	0.9	1.1
Past year	0.9	1.0	1.1
No biking	0.8	0.9	1.0

TABLE 9b Percent with Driver's License, by Location and Biking Frequency

	Greenway	Cedar Lake	Luce Line
Past 7 days	92%	98%	99%
Past 30 days	97%	100%	100%
Past year	92%	98%	98%
No biking	86%	94%	98%

TABLE 9c Average Auto Trips per Day, by Location and Biking Frequency

	Greenway	Cedar Lake	Luce Line
Past 7 days	3.3	4.4	4.4
Past 30 days	3.9	4.1	5.8
Past year	3.6	4.0	4.3
No biking	3.5	3.5	3.6

TABLE 9d Average Driving Miles per Week, by Location and Biking Frequency

	Greenway	Cedar Lake	Luce Line
Past 7 days	106	142	182
Past 30 days	119	162	192
Past year	112	166	203
No biking	101	131	164

Greenway residents, as might be expected, are slightly to significantly lower in all of the auto use categories. It is interesting, however, that the frequency of cycling does not seem to be related to the amount of auto use in any location. The one apparently surprising exception is that people who have not biked at all also make fewer car trips and drive fewer miles, as compared with those that have biked at all. While Table 7b had shown that non-cyclists were less likely to participate in other physical activities, here it appears that they do not leave home as much in general. However, this result occurs because many non-cyclists are over 65 years old. When the sample is restricted to those younger than this, the differences disappear; however, non-cyclists still do not drive more than cyclists (Table 9e).

TABLE 9e Average Driving Miles per Week, Respondent Age Under 65

	Greenway	Cedar Lake	Luce Line
Past 7 days	104	137	186
Past 30 days	119	159	191
Past year	115	142	212
No biking	101	155	192

Finally, an important question asked about the distance to the respondent's local named trail. The values reported here are the respondents' reported distances, not actual measured distances (Table 10a).

TABLE 10a Distance to Trail (by Location)

	Greenway	Cedar Lake	Luce Line
<1/4 mile	25%	25%	22%
1/4 to 1/2 mile	18%	18%	19%
1/2 to 3/4 mile	15%	15%	11%
3/4 to 1 mile	11%	13%	15%
>1 mile	8%	15%	23%
Don't know distance	5%	6%	3%
Don't know trail	17%	9%	8%
(Each column adds to 100%)			

Another way to consider these data is to look at biking frequency for people living at various distances from the trail (Table 10b).

TABLE 10b Distance to Trail (by Biking Frequency)

	Past 7 days	Past 30 days	Past year	No biking
<1/4 mile	31%	14%	16%	39%
1/4 to 1/2 mile	30%	11%	13%	46%
1/2 to 3/4 mile	28%	11%	9%	52%
3/4 to 1 mile	26%	15%	11%	48%
>1 mile	22%	11%	17%	51%
Don't know distance	4%	6%	17%	73%
Don't know trail	4%	1%	9%	87%
(Each row adds to 100%)				

There does appear from this table to be a gradual degradation in biking frequency as the distance to the trail becomes longer. The percentage who have biked in the last seven days is higher for those living within a quarter mile of the trail, while the percentage who have not biked at all is higher at the longer distances.

This can also be characterized as the percent in each area who have biked at least once in the past year (Table 10c). This combines and condenses the information from Tables 10a and 10b.

TABLE 10c Percent Biking in Past Year (by Location)

	Greenway	Cedar Lake	Luce Line
<1/4 mile	59%	60%	63%
1/4 to 1/2 mile	65%	48%	52%
1/2 to 3/4 mile	63%	40%	42%
3/4 to 1 mile	56%	57%	46%
>1 mile	52%	48%	49%
Don't know distance	33%	14%	42%
Don't know trail	13%	0%	26%
(Entries are percent who have biked at least once in the past year)			

Again, there is a slight trend toward declining probabilities of biking as the distance to the trail gets longer, but the trend is not very consistent. The probabilities appear to decline more slowly in the Greenway than in the other areas.

Finally, it is interesting to look at the probabilities by distance for different activities (Table 10d).

TABLE 10d Distance to Trail (by Uses of Trail)

Q1	Walk	Skate	Run	Bike	No use	Overall
<1/4 mile	38%	32%	33%	33%	17%	27%
1/4 to 1/2 mile	21%	21%	21%	22%	21%	21%
1/2 to 3/4 mile	18%	21%	20%	16%	12%	15%
3/4 to 1 mile	11%	9%	9%	15%	15%	14%
>1 mile	10%	14%	15%	13%	27%	18%
Don't know distance	2%	2%	2%	2%	9%	5%
(Each column adds to 100%)						
Total count	323	56	107	350	356	906

For all the activities, the percentage of participants who live within a quarter mile is higher than for the sample as a whole. Those who didn't use the trails at all are much more likely to report living more than a mile away. It is interesting that the rate of decay does not seem to vary much by activity; one might expect that living more than a mile away would be a barrier to walking but not to biking, for example. But that does not appear to be the case here, or perhaps only slightly.

Home Location and Preferences

The survey included a long table in which respondents were asked to rate the importance of various factors to their home location decision. There were some significant differences across locations, for example schools much more important for residents around the Luce Line, while having shops within walking distance was more important for Greenway residents. But in terms of comparing cyclists to non-cyclists, only two factors showed a sizeable difference: closeness to walk/bike paths, and having recreation/parks within walking distance. For frequent cyclists the average rating of these was 3.3, for non-cyclists 2.6. No other factor had a difference as much as half this big.

A follow-on question asked which of the 18 home location characteristics were most and second most important to the respondent. There were no interesting patterns in the answers to this, from a bicycling standpoint. A few fairly standard factors dominated (e.g., schools, neighborhood appeal), and the degree of domination did not vary systematically by cycling frequency. The two factors that rated higher for cyclists on average did not differ much in this measure because very few people rated them as first or second most important.

Lifestyle and Politics

For these questions we report the results broken down only by the last reported bicycling trip. We reported results by location earlier, in the context of bicycling and other travel behaviors, but are not interested in location for these lifestyle questions. Since bicycling behavior does not vary a great deal across locations, this should not lead to much that is misleading about the results.

The survey asked about the type of grocery store that respondents used most often (Table 11). Those who shop mostly at natural food stores or co-ops were three times as likely to have biked in the past seven days as to not have biked at all. Those who shop at high-end chains were slightly more likely, while those using the other types were more likely to have not biked at all.

TABLE 11 Grocery Shopping Preferences

	Past 7 days	Past 30 days	Past year	No biking
High-end	26%	22%	23%	21%
Discount	57%	69%	66%	69%
Food club	3%	3%	5%	4%
Natural/co-op	12%	8%	4%	4%
Local	5%	1%	7%	7%

(Each column adds to 100%)

Another question asked about the primary source of news (Table 12). Those who use the internet were more likely to bike more frequently, relative to those who mostly read papers and especially compared to those that mostly watch TV news. This may to some extent reflect the relative ages of the audiences.

TABLE 12 Primary News Sources

	Past 7 days	Past 30 days	Past year	No biking
Network TV	30%	37%	35%	42%
Cable TV	9%	3%	18%	16%
Internet	22%	21%	16%	13%
Paper	31%	27%	27%	31%

(Each column adds to 100%)

Another question asked about political affiliation (Table 13). The results here were somewhat unexpected in that patterns of biking versus not biking were not different between those who identified themselves as democrats and republicans.

TABLE 13 Political Affiliation

	Past 7 days	Past 30 days	Past year	No biking
Democrat	43%	39%	51%	47%
Green	7%	7%	3%	2%
Independence	5%	9%	3%	4%
Republican	28%	28%	24%	29%
Other/NA	17%	16%	18%	18%

(Each column adds to 100%)

Finally, there were a number of other miscellaneous lifestyle questions (Table 14).

TABLE 14 Miscellaneous Lifestyle

	Past 7 days	Past 30 days	Past year	No biking
Eat take-out*	1.70	1.63	1.57	1.38
Listen to NPR	74%	69%	67%	58%
Donate to environmental cause	53%	55%	45%	34%
High speed internet	60%	55%	58%	41%

* average times per week, all other lines are percent who report activity

A curious result here is that people who identify themselves as republican are less likely to donate to environmental organizations (25% to 50% for democrats) and listen less frequently to NPR (average of 5 times per week compared to 14) but are not less likely to ride bikes. In looking more closely at the first of these, about 55% of people of both parties who donated to environmental organizations also rode bikes. But of those that didn't donate, 43% of republicans rode, compared to 38% of democrats. This indicates that political affiliation in itself may not be a good predictor of cycling behavior, even within a given area. People identify with political parties over a range of issues, only some of which are correlated with bicycling.

Demographic Factors

In these tables we include the count of the number of individuals in each category, to give a sense of the overall distribution of the sample. In each case, the percentages add to 100% when summed across the four levels of biking frequency (Tables 15-23).

TABLE 15 Cycling Frequency by Gender

	Male	Female
Past 7 days	30%	17%
Past 30 days	11%	11%
Past year	12%	14%
No biking	47%	58%
Count	578	488

This table shows the expected result that men are more likely to ride than are women. It also shows the unexpected result that the survey respondents were more likely to be men. This may have had some influence on our high observed biking frequencies.

TABLE 16 Cycling Frequency by Age

	18-30	30-45	45-65	65+
Past 7 days	22%	28%	27%	13%
Past 30 days	13%	18%	10%	3%
Past year	16%	19%	13%	7%
No biking	49%	35%	50%	77%
Count	110	296	407	224

The breakdown by age is somewhat surprising in that other studies have indicated that cycling rates decline steadily with age, with an especially large dropoff after age 45. Here the rate actually seems to increase slightly with age, and holds fairly steady all the way to age 65, when it drops substantially. This may reflect the relatively high income and education levels of the older participants in our survey.

TABLE 17 Cycling Frequency by Marital Status

	Past 7 days	Past 30 days	Past year	No biking	Count
Married	28%	14%	14%	44%	609
Widowed	5%	1%	1%	93%	83
Div./Sep.	21%	7%	18%	54%	145
Never Married	21%	8%	13%	58%	224

Married people are somewhat more likely to ride; this may reflect rides with children.

TABLE 18 Cycling Frequency by Education

	Past 7 days	Past 30 days	Past year	No biking	Count
< High school	13%	0%	13%	73%	16
HS graduate	14%	7%	6%	73%	88
Some coll/tech	21%	5%	10%	63%	213
Assoc. deg.	22%	10%	10%	58%	104
Bach. Deg.	26%	14%	15%	45%	428
Grad/prof deg.	28%	12%	16%	44%	238

As had been found in other studies, biking rates increase with education.

TABLE 19 Cycling Frequency by Employment Status

	Past 7 days	Past 30 days	Past year	No biking	Count
Full time	27%	13%	15%	45%	655
Part time	24%	10%	17%	48%	116
Not working	23%	12%	12%	53%	66
Retired	12%	4%	7%	77%	222

Among people who are still in the workforce, there is an insignificant difference between those who are currently employed and those who are not.

TABLE 20 Cycling Frequency by Race

	Past 7 days	Past 30 days	Past year	No biking	Count
White	24%	11%	13%	52%	999
Black	9%	9%	5%	77%	22
Hisp./Asian/Other	22%	17%	22%	39%	36

Although there appears to be large racial differences in biking rates, the sample of non-whites in this survey is too small to draw any conclusions. Given the large non-white population in the Greenway area, this may indicate a degree of bias in the survey respondents.

TABLE 21 Cycling Frequency by Occupation

	Past 7 days	Past 30 days	Past year	No biking	Count
Professional	28%	13%	14%	45%	548
Technical	20%	11%	18%	51%	131
Clerical/Sales	23%	7%	11%	58%	124
Manual	26%	7%	13%	54%	84
Service	13%	13%	11%	63%	70

More than half of the respondents to this question classified themselves as "professionals." They had slightly higher cycling rates than the other job categories, but the difference was not large.

TABLE 22a Cycling Frequency by Income (all respondents)

	Past 7 days	Past 30 days	Past year	No biking	Count
<$20K	15%	1%	7%	76%	71
20-40	15%	6%	13%	66%	171
40-60	21%	11%	11%	58%	200
60-80	23%	11%	13%	53%	150
80-100	28%	19%	12%	40%	137
100-120	34%	14%	18%	34%	79
>$120K	30%	14%	19%	37%	192

There is a major difference across income levels in cycling rates; the higher incomes are far more likely to have ridden recently. However, some of this is because retirees tend to fall into the lower income categories.

TABLE 22b Cycling Frequency by Income (age less than 65)

	Past 7 days	Past 30 days	Past year	No biking	Count
<$20K	26%	3%	10%	62%	39
20-40	20%	8%	18%	54%	105
40-60	22%	14%	12%	52%	147
60-80	25%	12%	13%	50%	119
80-100	28%	21%	14%	37%	123
100-120	34%	15%	19%	32%	74
120+	30%	14%	20%	36%	176

When retirees are excluded, the difference is reduced somewhat, but is still fairly large.

TABLE 23 Cycling Frequency by Presence of Children in Household

	No children	Children
Past 7 days	23%	32%
Past 30 days	10%	21%
Past year	15%	17%
No biking	52%	31%
Count	507	275

Finally, the presence of children in the household increases the frequency of cycling. This table already excludes retiree households.

Conclusions

The results of this survey generally support the findings of other surveys. Various demographic factors are associated with a higher likelihood of bicycling. This survey added to the existing stock of knowledge by exploring the relationship between cycling and various other lifestyle preferences and behaviors, and by studying the influence of facility access in more depth.

One concern with this survey is that there appears to be some bias in the characteristics of the respondents. Generally the people who filled out this somewhat long mail-in survey were older, better educated, and higher income than the general population in the areas where the survey was done (Tables 24 a through 24c).

TABLE 24a Survey Sample Age and Race

	Greenway		Cedar Lake		Luce Line	
	Population	Sample	Population	Sample	Population	Sample
Total N	58003	304	25,458	443	61,797	355
Mean age	31.8	42.6	38.6	54.8	37	52.4
Race:						
White	53.2%	86.7%	85.1%	97.7%	93.6%	96.5%
Hispanic	15.7%	2.3%	3.9%	0.5%	1.3%	0.6%
Black	20.3%	6.0%	5.1%	0.7%	1.7%	0.9%
Asian	4.8%	2.0%	3.5%	0.7%	2.2%	1.2%
Other	6.1%	3.0%	2.4%	0.5%	1.2%	0.9%

TABLE 24b Survey Sample Education

	Greenway		Cedar Lake		Luce Line	
	Population	Sample	Population	Sample	Population	Sample
Education (of those older than 25):						
N (over age 25)	37,549	281	18,366	423	41,891	341
< High school	17.3%	1.8%	8.7%	0.5%	3.5%	2.3%
High school/GED	18.4%	8.2%	21.9%	6.6%	14.8%	9.7%
Some college	23.1%	17.4%	25.3%	20.8%	21.9%	18.5%
Associate's degree	5.4%	7.8%	7.0%	8.0%	6.9%	10.9%
Bachelor's degree	25.6%	38.8%	28.2%	41.1%	36.4%	40.2%
Graduate/prof degree	10.1%	26%	8.9%	22.9%	16.5%	18.5%

TABLE 24c Survey Sample Income

	Greenway		Cedar Lake		Luce Line	
	Population	Sample	Population	Sample	Population	Sample
Household income:						
N (households)	27,797	n/a	11,454	n/a	23,196	n/a
< $20,000	28.6%	13.6%	15.1%	3.3%	6.6%	6.3%
$20,000-$39,999	35.6%	29.6%	24.9%	11%	13.9%	13.6%
$40,000-$59,999	17.9%	22.8%	23.5%	13%	15.5%	25.6%
$60,000-$99,999	13.2%	23.2%	25.1%	28.3%	27.4%	33.5%
$100,000 or more	4.7%	10.9%	11.4%	39.9%	36.7%	21.1%

The differences between the survey sample and the general population of the areas from which they were drawn are especially large in the Greenway area. In certain important ways, for example, race and education, the survey respondents in the Greenway were more similar to the survey respondents from the other areas than they were to the general population of the Greenway area. The very high rate of people who classified their occupation as “professional” also points to the conclusion that a certain type of person was more likely to fill out this survey. This need not render the results invalid, but some care must be taken to consider whether the nature of the sample might bias the results of particular findings. One key example is the frequency with which people ride bikes; this sample was strongly weighted toward the type of person that is more likely to ride. Thus the results here should not be taken as indicative of riding frequencies among the general public.