



# **GUIDELINES FOR BENEFIT-COST ANALYSIS OF BICYCLE FACILITIES: REFINING METHODS FOR ESTIMATING THE EFFECT OF BICYCLE INFRASTRUCTURE ON USE AND PROPERTY VALUES**

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## Executive Summary

Following the passage of the Intermodal Surface Transportation Equity Act (ISTEA) in 1991, many communities began building and/or expanding their bicycle networks. With the increase in investment in bicycle facilities comes a need to measure the impact of the investments. This report expands on how these measurements can be done through case studies based in the Twin Cities. It is a compilation of studies related to estimating the effects of bicycle infrastructure on the community around the infrastructure and is a continuation of previous work that was included in the National Cooperative Highway Research Program (NCHRP) Report 552 *Guidelines for Analysis of Investments in Bicycle Facilities*. The work is divided into four main parts: (1) the relationship between bicycle facilities and rates of bicycling, (2) the impact of establishing bicycle facilities on residential property values, (3) the effect of building a bicycle facility on the number of bicycle crashes in the area, and (4) the impact of the Midtown Greenway on the surrounding community. In addition, the report also describes the use and refinement of an online tool for Benefit-Cost Analysis of Bicycle Facilities. . The tool was created as part of the NCHRP project, and was recently used as part of graduate planning and civil engineering course. Included in this report is the findings of the research, and feedback from the students regarding the on-line tool. The on-line tool can be found at <http://www.bicyclinginfo.org/bikecost/>.

The first section of the report examines the relationship between rates of bicycling and the presence of bicycle facilities. This is done in two ways: the first is using a longitudinal approach measuring the change in the bicycle commute mode share for Transportation Analysis Zones (TAZ) around the facility. This method demonstrated that building bicycle facilities tended to increase the rate of bicycle commuting in the areas around the facilities. The second method looked at a survey of residents of three areas (urban core, inner suburb, and outer suburb) that all have access to a bicycle facility about their use of bicycle facilities. The survey data shows that the different samples have similar shaped curves for the percent of respondents who use the facilities, based on how far the respondents live from the facility.

The report also looks at the effect of building a bicycle facility on the price of housing and the number of bicycle crashes in the area around the bicycle facility. The report concludes that there is no impact on the short term residential property values as a result of building a bicycle facility. However, the report indicates that the Midtown Greenway had a significant decrease in the number of crashes in the area, immediately adjacent to the facility. The report also contains a brief summary of the impacts of the Midtown Greenway on the area around the facility.

The final two parts of the report describe the non-research aspects of this project. Both of these aspects involve the on-line tool. The first part describes how the on-line tool was incorporated into a graduate planning and civil engineering course. The second describes the modifications that were made to the on-line tool as a result of both the research included in the report and feedback from the students who used the tool.



# 1. Introduction

The degree to which the presence of bicycle facilities affects the behaviors of the people who live near them is an important question in policy circles, for many reasons. The construction of such facilities has been booming since the passage of ISTEA in 1991; cities such as Minneapolis and Indianapolis have created extensive networks of bicycle facilities. It has been a little over a decade since some of the original facilities were constructed and as with any major investment of public resources it is important to evaluate the effect that bicycle facilities are having on the people who live near them.

The National Cooperative Highway Research Program (NCHRP) Report 552 was the first attempt to create a standard method for quantifying the impacts of investments in bicycle facilities. This work was a major step in providing necessary information to planners, engineers, policy makers, and the general public about the impacts of bicycle facilities and providing a way to compare the costs of the facility with potential benefits. However, questions remain about some of the potential impacts of investing in bicycle infrastructure. This report is an attempt to address some of those questions and seeks to further refine the methods used to determine the impacts of bicycle facilities. This report focuses on bicycle facilities' effect on human decisions, in particular their decisions regarding their use of bicycle facilities and residential locations.

In this report, residents' use of bicycle facilities is measured in two ways. The first is by examining changes in commuting habits of people who live near newly constructed bicycle facilities. The second involved surveying area residents around the bicycle facilities to determine how many of them use the bicycle facilities.

In addition to examining the bicycle facilities' effect on people's decisions to bicycle or to use the facility, the report also looked at whether or not people chose to live near bicycle facilities. People's decisions to live near bicycle facilities were measured by looking at how much people were willing to pay to live near bicycle facilities and determining if people were willing to pay a premium to live near a bicycle facility.

The Midtown Greenway, built in three phases from 2000-2006, is located in south Minneapolis. The Midtown Greenway is an off-street bicycle facility built in an old railroad right-of-way. It is designed to resemble an expressway with on/off ramps and grade separation from vehicle traffic. As a result, it provides bicyclists the ability to travel extended distances (1) without interacting with motor vehicles and (2) improving access to many destinations. It serves as a key link in a larger regional bicycle facility network. The timing of the Midtown Greenway, opening in the years prior to the beginning of this project, provided the research team with the ability to evaluate some of the immediate impacts that a bicycle facility has on the surrounding community. We used this opportunity to evaluate the impact that the Greenway is having on safety in the area around the facility.

The findings of these projects were used to refine an on-line tool that was created as part of the original NCHRP project. The on-line tool, Benefit-Cost Analysis of Bicycle Facilities, is designed to be an easy-to-use tool for planners, engineers, and policy makers

to assist in making decisions regarding building bicycle facilities. In an effort to create links between research and education at the University of Minnesota, as well as to incorporate cutting edge material into the classroom, graduate students at the Humphrey Institute of Public Affairs were asked to use the on-line tool and make recommendations regarding its usefulness for educational purposes.

## **2. Rates of Bicycling & Relationship to Facilities**

### **2.1 Longitudinal Analysis**

Planning agencies and bicycle advocacy groups have long searched for methods to quantify the impact of a bicycle facility on the community. A key component of the impact is to what extent, if any, a bicycle facility will induce more people to ride bicycles. Bicycle advocacy groups have often argued increasing the number of bicyclists in a community will provide benefits to the community as a whole because the residents will be healthier and there will be less congestion. If a bicycle facility can act as a catalyst to promote bicycling, then there is potentially a powerful argument for investment. It is important that policy makers know the effect of building a bicycle facility on the behavior of those who live near the facility.

One of the primary goals of both the NCHRP project and the current work of the research team is to determine the benefits of building bicycle facilities. The number of people who will bicycle as a result of building a bicycle facility is an important factor used in determining the other benefits of building a facility. Because of the importance of being able to predict the number of people who will use the facility in calculating the other benefits, the research team worked to refine the methods that it was using to ensure that the on-line tool was as accurate as possible. The research team studied the travel behavior of area residents around bicycle facilities in two ways. The first, which is included in this section, is a comparison of the bicycle commute mode share of census tracts near bicycle facilities before and after the construction of the facility. The second, which is the next section of the report, used a survey of people who live near a bicycle facility regarding their use of the facility.

There is a great deal of variation in bicycling rates across different metropolitan areas, and even within different parts of the same city (1). It is tempting to ascribe such differences to the presence or absence of special bicycling facilities. However, empirically measuring such a relationship has been difficult. Some studies attempt to compare bicycling rates and facilities across cities (2-4); or to explain differences within cities (5).

A substantial issue with these types of studies is the indeterminacy of causality. That is, rather than bicycle facilities inducing higher bicycling rates, it could be that existing high densities of bicyclists support a political climate and perhaps safety justification for building the facilities in the first place (2). Nonetheless, facilities tend to be used more heavily compared with ordinary streets (6), and there is evidence that commuters are willing to divert out of their way to use facilities. 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 pre-existing bicycle commuting from the effects of the facility itself would be a key advance in this regard.

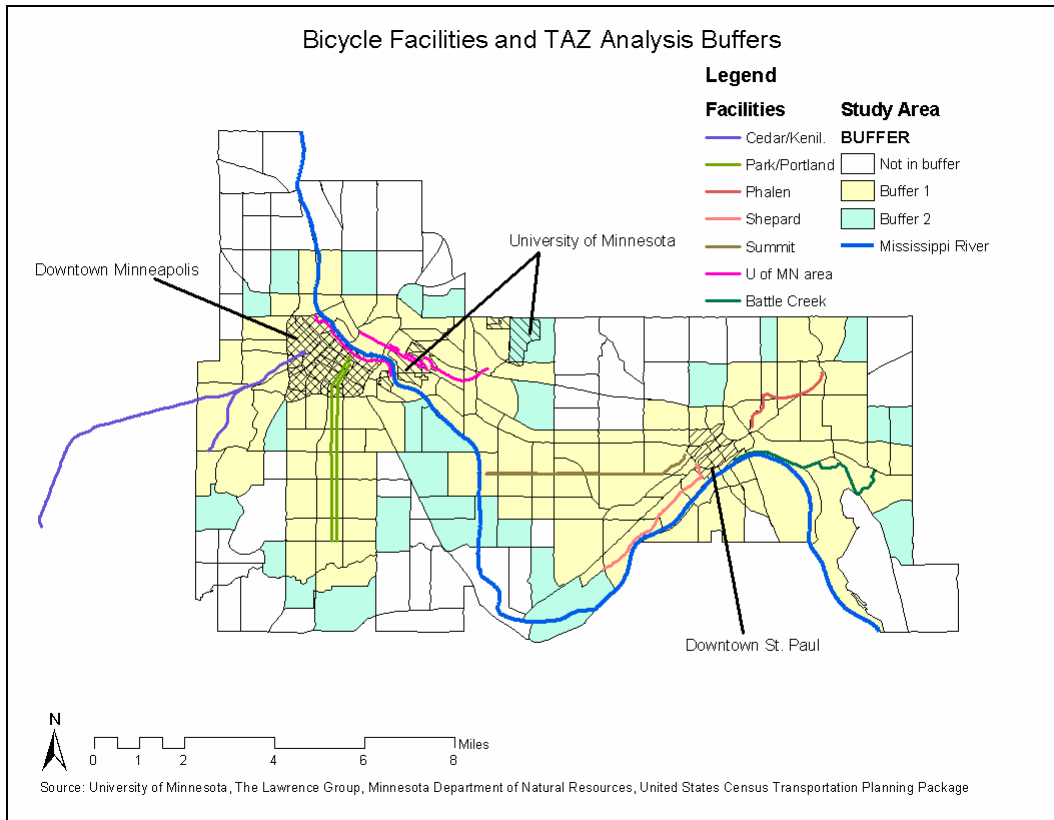
One way around this problem is to compare the same location at two different points in time. While local populations still do not remain completely constant over time, they should at least be more comparable than populations from two different cities, or even two parts of the same city. Some cities, such as Portland, have counted cyclists at certain locations over a number of years as the cycling environment was improved (7). While this study can provide detailed information on cycling in specific corridors or areas, it cannot necessarily address the larger question of how much bicycling in general has increased as a result of facility improvements, especially in the context of commuting to work.

This paper uses a longitudinal method based on the U.S. Census for determining the effect of bicycle facility construction in Minneapolis-St. Paul, Minnesota, 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 connecting existing facilities. The U.S. Census counted bicycle commuters in both 1990 and 2000, providing comparable data for the same areas at two points in time.

The relatively straightforward analysis presented below compares bicycling commute rates over a variety of areas, depending on proximity to the new facilities. The first part describes the new facilities and their primary service areas. 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 compared to different strategies for defining the area and its commuting patterns vis-à-vis the new facilities. We also comment on factors that may have influenced the results. The final section summarizes the analysis and offers suggestions for further work in this regard.

### **2.1.1 Describing New Facilities**

Our research covers the cities of Minneapolis and St. Paul, Minnesota, which border one another and are the central cities of a large metropolitan area. The central business districts are about 10 miles (16 km) apart. Both cities are endowed with on-street and off-street bicycle facilities—a combined 60 miles (96 km) of on-street bicycle lanes and 123 miles (198 km) of off-street bicycle facilities. Local residents use these trails heavily. We identified bicycle facilities created in Minneapolis and St. Paul during our study period, focusing on longer facilities likely to enhance accessibility to major employment centers (See Figure 1).



**Figure 1. Bicycle Facilities and TAZ Analysis Buffers**

## On-Street Bicycle Lanes

**Park/Portland Striping** Park and Portland Avenues are parallel one-way streets connecting downtown Minneapolis with residential areas to the south. The bicycle lanes are about 4 miles (6.4 km) long. Both streets experience heavy, relatively high-speed vehicle traffic. As such, bicycle lanes on these streets significantly enhance conditions for bicyclists.

**Summit Striping** Summit Avenue is a boulevard from the Mississippi River to just outside of downtown St. Paul. There are bicycle lanes in both directions along its entire length of 4.6 miles (7.4 km). The western end intersects with the East Mississippi River Parkway, which has off-street bicycling paths connecting to the University of Minnesota.

## Off-Street Bicycle Paths

**Cedar Lake/Kenilworth Trails** The Cedar Lake Trail is an off-street bicycle path that runs 7.8 miles (12.5 km) through a former rail corridor from downtown Minneapolis to the southwest. The Kenilworth Trail is a 1.8 mi (2.9 km) path connecting the Cedar Lake Trail in the north to (indirectly) a long series of very popular trails around the lakes in southwest Minneapolis. Access to these two paths is limited to occasional entry/exit points. We include only the 2.7 mi (4.4 km) portion of the Cedar Lake Trail within the city of Minneapolis in order to keep the study area consistent with the other trails.

**Shepard Road** This path runs into downtown St. Paul from the southwest, along the Mississippi River, for 2.4 mi (3.8 km). While it is an attractive recreational path, its use for commuting is limited for several reasons. Access points are limited, and for nearby residential areas there are usually more direct routes to downtown. Also, the path is lower than the surrounding land uses, so that access to both downtown and residential areas requires relatively long, steep climbs from the trail.

**Phalen Creek** This path comes from the east to downtown St. Paul. It is 2.1 mi (3.4 km) long. The area through which it runs is generally more industrial and blue-collar than most of the other facilities.

**Warner Road/Battle Creek** This path comes into downtown St. Paul along the river for about 3 miles (4.8 km) from the southeast. It has many of the same issues with regard to limited access and steep hills as does the Shepard Road path.

### **University Area Facilities**

These are three separate facilities, grouped together because of their short lengths and close proximity to each other.

**University Ave./4<sup>th</sup> St.** University Avenue and 4th Street SE are parallel one-way streets near the University of Minnesota campus in Minneapolis. The facility on University is 1.6 mi (2.5 km), while the lane on 4th Street SE is just 0.8 mi (1.4 km). Both streets experience heavy, high-speed vehicle traffic. Consequently, the bicycle lanes improve travel conditions for bicyclists.

**West River Parkway** Minneapolis and St. Paul both have nearly continuous off-street bicycle paths along the Mississippi River. A 2.5 mile (4 km) portion of the path along the downtown Minneapolis riverfront was completed during the 1990s. This provided a direct route into downtown for commuters coming from the already extant southern part of the West River Parkway, and a direct route to the University for commuters coming from the west and north.

**U of Minnesota Transitway** The University of Minnesota Transitway is a transit-only roadway between the University's Minneapolis and St. Paul campuses. During the 1990s a parallel bicycle path was established along part of the route. The facility is 1.9 mi (3.0 km) long. There are no access points in the eastern half of the facility, except at the end, and the land uses around the facility are primarily industrial in nature.

### **Other Facilities**

Other facilities were constructed in the central cities during the 1990s. However, we excluded these from the analysis for two reasons. First, we wanted to examine facilities that were long enough that they might be expected to have an impact over a fairly large area. This eliminated a number of short lane stripings. Second, our longitudinal use data is limited to commuting trips. We therefore restricted the analysis to facilities that provided access to major employment areas, either directly or by linking to existing



facilities. This eliminated a number of new or upgraded facilities in parks, around lakes, and on old rail right of way, that did not provide access to any major employment sites.

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 relatively low in the suburbs, making it very difficult to derive statistically significant conclusions, and because these facilities also tend to not serve major employment concentrations.

## **2.1.2 Research Strategy**

### **Buffering**

We determined the area for analysis specific to each facility using two different buffering techniques to define proximity. Both techniques use Traffic Analysis Zones (TAZs), which are defined by the local metropolitan planning organization for traffic forecasting purposes. In the area of our study a TAZ would typically be 1,000 to 4,000 meters across. We first selected TAZs for analysis if their geographic centroids lay within one mile (1.6 km) of a facility (referred to here as buffer 1). The second technique extended Buffer 1 by an additional 0.5 miles (0.8 km) from the endpoints of the facility (referred to here as Buffer 2). This method assumes that a facility might have more influence near its ends, as the facility can be used longer and the relative detour to use it is likely smaller. Overall, Buffer 1 contains about 170,000 commuters, Buffer 2 has 50,000, and the beyond the buffers have 100,000.

No buffering strategy is without problems and there are issues to note about these strategies. First, the size and setting of any facility likely affects its impact. For example, a facility with many access points on a direct route to important destinations will likely draw bike commuters from a larger area than facilities without these characteristics. Connections to other facilities and quality of alternative routes also play a role. Issues such as bicycle parking, the cost of car parking, and the availability of showers and other amenities add still more complexity.

For the purposes of this paper, we set the majority of these issues aside. It could very well be that some factor other than new facilities may have had an impact on the rate of bicycle commuting in some localized areas. However, by examining a relatively large overall area and by analyzing the data from multiple perspectives, we hope to separate local effects from broader trends. For example, changes in parking costs in downtown Minneapolis may affect the amount of bicycle commuting into that area, but shouldn't affect an analysis based on where people live, since both commuters who live in facility buffers and those who don't will face the same conditions at the destination.

### **Measuring bicycle commuting**

Our analysis examined changes in a variety of measures of bicycle commute shares in the two cities. We consider several perspectives representing different ways of specifying commuting patterns, in each case comparing 1990 to 2000:

- Bicycle commute shares for TAZs in facility buffers versus those that are not,
- Bicycle commute shares for the areas around individual facilities,
- Bicycle commute shares for trips crossing the Mississippi River,
- Bicycle commute shares for trips terminating in downtown Minneapolis, downtown St. Paul, and the Minneapolis campus of the University of Minnesota.

Examining river crossings was prompted by the observation that there were many bridge improvements near downtown Minneapolis and the University of Minnesota, 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 the facilities that we studied were concentrated around providing access to these three areas.

The Census Transportation Planning Package (CTPP) (8) reports mode choice at the TAZ level from three different perspectives. The Part 1 data are based on the household residence of the respondent, which can identify how facilities might impact the mode choice of nearby residents. Part 2 data are based on the workplace location; these can be used to determine the mode share coming into a particular destination, such as downtown Minneapolis. The Part 3 data are broken out by specific origin and destination TAZs. This can be used to study, for example, trips that cross the Mississippi River. However, the uses of these Part 3 data are somewhat limited because much of it is suppressed due to confidentiality issues, as point-to-point flows are often quite small.

### **Calculating Bicycle Mode Share and Statistical Significance**

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 bicycle is represented by the sample mean – the number of bicycle commuters divided by the total number of commuters. The standard deviation of this distribution is given by Equation 1.

$$\text{Standard deviation} = (N * p * (1-p))^{(1/2)} \quad (1)$$

...where N is the total sample size and p is the probability of commuting by bicycle.

As commuting data are based on a sample rather than a full count, we estimate N by multiplying the reported total and bicycle commuters by the sampling ratio for the two cities as a whole, and rounding to the nearest whole number. To illustrate the statistical 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.

## 2.1.3 Analysis and Results

### Overall Bicycle Mode Share

The Twin Cities metropolitan area overall had a relatively small increase in bicycle mode share during the 1990s. However, this increase was 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 in the central cities showed a statistically significant increase in bicycle mode share, the areas in the facility buffers showed a larger increase (See 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	1.563	1.775	2
TAZs in buffer 2	1.023	1.491	2
TAZs outside buffers	0.510	0.627	2

**Viewing St. Paul and Minneapolis separately, somewhat differing results emerge. Minneapolis has a higher bicycle mode share than St. Paul. The difference is probably due in large part to the presence of the bulk of the University of Minnesota campus in Minneapolis. Both cities showed increased bicycle mode share, with the areas in facility buffers showing generally larger increases (See Table 2. Minneapolis and St. Paul Bicycle Commute Share, 1990-2000**

2. An interesting point is that in Minneapolis, buffer 2 showed large increases and the smaller buffers did not, while in St. Paul the reverse was true. This could reflect the fact that in Minneapolis, the areas where facilities were built already had high bike commute shares, so the impact was more noticeable farther away where there was perhaps more latent demand. In St. Paul, the areas where facilities were built were no different from the rest of the city, on average, so the local impact of the facilities was more apparent.

**Table 2. Minneapolis and St. Paul Bicycle Commute Share, 1990-2000<sup>1</sup>**

	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
St. Paul	0.528	0.681	2
TAZs in buffer 1	0.559	0.797	2
TAZs in buffer 2	0.493	0.408	0
Zones outside buffers	0.476	0.566	1
Minneapolis	1.596	1.876	2
TAZs in buffer 1	2.423	2.557	1
TAZs in buffer 2	1.309	2.081	2
Zones outside buffers	0.530	0.664	1

<sup>1</sup> Table 2 shows the Central Cities portion of Table 1 broken down by Minneapolis and St. Paul, due to statistical methods used direct comparison between the two tables is difficult.

## Individual Facility Buffers

We further subdivided the area by calculating the changes in bicycle mode share in the buffers around individual facilities. Again, the measure here is of bicycle commuting by residents of these buffers. The three Minneapolis facilities share a number of TAZs in their buffers. This was problematic because the common TAZs have both a large commuting population overall and many cyclists. To clarify the results, we calculated the Cedar Lake-Kenilworth and Park-Portland buffer shares using only those TAZs that were not shared with the University of Minnesota buffer. The four St. Paul facilities similarly share TAZs around downtown; however, this area is lightly populated and was therefore not distorting the results in the same way. Thus, these buffers include common TAZs. Almost all the facilities showed statistically significant increases in bicycle mode share (See Table 3). An interesting point here is that three of the St. Paul facility areas had very low shares in 1990, and the shares in these areas basically doubled after the facilities were built. The other two Minneapolis facilities had high shares initially, and greater increases in absolute terms, but smaller percentage increases. This corresponds to a simple form of diminishing marginal returns: as bicycle mode share increases, improvements have less impact as a proportion of the starting point. This process may have reached its terminus in the University area, where the initial rate was very high, and the new facilities apparently didn't increase bike commuting among residents at all.

**Table 3. Bicycle Commute Share in Buffer Analysis Areas, 1990-2000**

Facility Buffer	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
Battle Creek	0.206	0.392	2
Cedar Lake-Kenilworth	1.497	2.138	2
Park-Portland	1.493	1.830	2
Phalen	0.181	0.403	2
Shepard	0.265	0.443	2
Summit	0.664	1.275	2
U of MN	3.515	3.280	0

## River Crossings

There are a number of Mississippi River crossings near downtown Minneapolis and the University. There is the potential for a high level of cross-river commuting, since jobs and housing are both quite dense near this area. 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. We compared the increase in bicycle mode share for trips that crossed this part of the river to that for trips that stayed within the central cities but that did not cross (See Table 4).

**Table 4. 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	3.021	4.604	2
Trips originating and terminating west of the Mississippi River	2.228	2.585	1
Trips originating and terminating east of the Mississippi River	1.982	2.775	2

The trips that crossed the river already had a relatively high bicycle mode share, but this share increased substantially during the 1990s. The increase was more than the increase for trips that remained on the same side of the river. The bridge improvements apparently considerably affected commuters' willingness to use bicycles to cross the river.

### Major Destinations

Our final analysis considers trip destinations. The facilities in this study provide improved access to the two downtowns and the University of Minnesota. In addition to these facilities, there was a major effort to demarcate on-street bicycle lanes with striping in downtown Minneapolis. We identified sets of TAZs corresponding to each of the three destinations, and used CTPP part 2 data to identify trips that ended in them (See Table 5)..

**Table 5. Minneapolis and St. Paul Major Destination Bicycle Commute Share, 1990-2000**

	1990 Bicycle Mode Share (%)	2000 Bicycle Mode Share (%)	Significance
Trips to Major Employment/ Activity Centers			
U of MN—Minneapolis Campus	2.820	3.313	2
Downtown Minneapolis	0.788	0.841	1
Downtown St. Paul	0.335	0.279	-1

There are a couple of interesting issues with regard to these results. First, there was a large increase in bicycle mode share for commuting trips to the University of Minnesota campus, which contrasts with the basically unchanged mode share for residents of this area. This indicates that the new facilities in this area may have provided more benefit to commuters coming to the area from outside rather than to local residents.

The other point is somewhat the opposite of the first. Bicycle commuting into downtown Minneapolis increased only slightly, and actually decreased into downtown St. Paul, even though these areas were the destinations of the new facilities, and even though bike commuting around the facilities increased substantially. There are a couple of possible explanations. One is that these facilities were built in a larger context of increasing commute distances, so that even if the facilities induced more bike commuting from nearby areas, this might have been offset by additional car commuting from more distant places, leading to the appearance that there was no increase in biking. In theory one could evaluate this hypothesis using census part 3 data, which specifies both origins and

destinations, but in practice so much of the information in this data set is suppressed due to confidentiality restrictions that it is hard to draw any conclusions from it.

Another possibility is that the facilities had a less direct impact on bicycle commuting. While it is nice to have a facility for commuting, an even more basic need is to have a bicycle in working order, and to be comfortable using it. To the extent that the facilities might have induced some recreational cycling, they might have put more people in a position where bicycle commuting was physically and psychologically feasible, and some of these people may have started riding their bikes to work, even if they didn't necessarily use the facilities to do it.

## Demographic and Economic Factors

It is possible that changes in the demographic and economic composition of the areas studied here might have influenced changes in bicycle commuting levels. Given the large differences in bicycle commuting across the areas in this study, two things would need to be true for these external factors to have significantly affected the outcome. One is that there would need to be large variations in bicycle commuting as a function of factors, such as age and income. Second, these variables would need to show considerable variation across areas.

Generally demographic variables are not as important to cycling rates as they are often believed to be. For age, income, and education level, the range in cycling rates is only a factor of two (9). In other words, even if people of the "right type" were extremely concentrated in one area and absent from another, the first area should have only about twice the rate of bike commuting, if these factors were the sole explanation of differences. However, our areas had differences many times this large.

A more telling point is that there are only small demographic differences across the different areas we studied. Table 6 compares different parts of the region by showing the percent of total commuters that are in the peak cycling income levels (below \$15,000 and above \$50,000) peak cycling age group (18-44), and that are in both peak groups at the same time.

**Table 6. Age and Income by Area**

	Percent with Peak Income	Percent with Peak Age	Percent with Both
All Metro	44%	64%	26%
Non-central city TAZs	45%	62%	25%
Central city TAZs	41%	71%	28%
TAZs in buffers	43%	72%	30%
TAZs outside buffers	37%	69%	24%

The suburbs have slightly fewer commuters in the peak age group, but more commuters in the peak income category than do the central cities. In the percent of commuters that are of both the "right" age and income, the suburbs are slightly lower than the buffer areas of the central cities, but are higher than the non-buffer areas. Given that the rate of bike commuting is about four times higher in the non-buffer areas than it is in the

suburbs, and eight times higher in the central cities overall, it seems hard to support a theory that demographic differences could be playing a major role in the level of bike commuting.

Given this, we conclude that while changes such as gentrification might have played a localized role in some places, they could not have played more than a very minor role overall. This does not prove that the new facilities made all the difference. But it does give us confidence that our analysis of facilities is not just detecting spurious correlation with exogenous demographic changes.

### **2.1.4 Conclusions**

The evidence here suggests that bicycle facilities significantly impacted the level of bicycle commuting. Areas near new bicycle facilities showed more of an increase in bicycle mode share than areas farther away, although all areas had increases. Trips that crossed the Mississippi River showed a larger increase than trips that did not, seemingly demonstrating the impact of several major bridge improvements.

However, the results are not free of some ambiguity. In Minneapolis, areas slightly farther away from the new facilities showed more of an increase in bicycle commuting than the closest areas, while the opposite was true in St. Paul. Another curious result was that the two downtowns showed little or no gain in bicycle share of commuting, although they were the targets of most of the new facilities, and the areas around the facilities showed substantial increases.

The results also suggest that facilities can be the effect, rather than the cause, of high bicycle use. In Minneapolis, the areas where major facilities were built already had bicycle mode shares that were considerably higher than the regional average. However, this was not the case in St. Paul, where the new facilities generally served areas with lower-than-average bike commuting. This highlights the risks inherent in trying to deduce the impact of facilities by comparing 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 using a single consistent definition. But in some cases TAZs that fell into the buffer for a facility would not necessarily be expected to use it much, because there are physical barriers to access or a more direct route to the most likely destinations. Conversely, there may be TAZs that are outside our buffer but that would probably fall within the zone of influence, because the facility lies on the route to a major destination or because it can be easily accessed using existing facilities.

It would also be helpful to better understand the differences between the central city and the suburbs. While it is tempting to explain the increase in bicycle commuting in the cities and the decrease in the suburbs to the new central city facilities, many suburbs in

fact have good bicycling conditions and sometimes even extensive systems of facilities. Differences in the distribution of commute distances may play a role here.

While there are many possible improvements to be made, the fact that this simple analysis seems to show an impact of bicycle facilities on the level of bicycle commuting is of considerable interest. Comparing bicycling levels in different places is inherently subject to the criticism that no causality is implied by any observed relationship. While not without its limitations, the approach presented above demonstrates the effect that facilities have on the level of bicycling in an area in a much less ambiguous manner.

## 2.2 Cross-sectional Analysis

There are two main questions about the impact of building a bicycle facility on rates of bicycling: (1) how many more people will bicycle and (2) how far from the facility will an increase be noticeable. In this section of the report we are focusing on the latter. In an effort to better understand how many residents of the area around the bicycle facility actually use the bicycle facility, the research team conducted a survey of residents who live near major bicycle facilities in Minneapolis and its western suburbs. The primary goal of the survey was to gather information about the relationship between residential and lifestyle preferences and the transportation decisions made by individuals. The results of the survey, along with the longitudinal study, allow for better knowledge of the impact of a bicycle facility on the travel behavior of those who live in the area around the facility.

Given the current dearth and potential value of information concerning the relationship between trail proximity and levels of use, it is surprisingly difficult to find studies that methodologically aim to understand this relationship. In this research, we apply the concept of distance decay<sup>2</sup> as a model for understanding the relationship between trail proximity and trail use. Specifically, we ask:

- Does a distance decay relationship exist between residential proximity to a bicycle/pedestrian trail and the proportion of residents using the trail?
- Does such a relationship differ at various points of the urban density spectrum?
- Does the relationship differ depending on the activity level of residents?

It is our hypothesis that the answer to all these questions is “yes.” Theory suggests that people who live closer to a trail are more likely to use it, and also that active people will tend to use such facilities more. There is no reason to predict that the functional form of the distance decay function will differ between people who are active and inactive. We also theorize that lower density areas have a weaker distance decay relationship in part

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<sup>2</sup> Distance decay describes the effect of distance on spatial interactions. In this case it describes the interaction between where people live and where the location of a bicycle facility.



because areas that are less dense tend to have a hierarchical rather than grid street pattern. Consequently, bicyclists and pedestrians are forced to use the same routes as automobiles rather than being able to use parallel, less-busy, possibly more attractive streets. This may discourage residents from using trails that are further away and necessitate traversing a busy collector street. Less-dense suburban areas are also less likely to have sidewalks, which may discourage walkers especially from using trails that are more distant.

In subsequent sections, we will outline the literature relating to trail use and distance decay functions applied in transportation settings, describe the approach used in this research, analyze the results, and make conclusions and recommendations for future research.

### **2.2.1 Literature review**

The literature relating to our research questions can be organized into three distinct, but connected, areas: research on the characteristics of trail users and trail count data, research on the factors affecting trail use, and literature relating to the distance decay concept (including its application to trail use).

Some studies that involved trail usage concentrated on the general trail usage through counting the number of users during peak and off-peak periods to determine mode split, either through manual or automated counting procedures (10-12). Such studies do not include information regarding the people who are using the trail and how far travel.

Though less comprehensive than user counts, more information can be gathered by surveying trail users. On-site surveys of trail users have been conducted on many facilities to gather demographic information, trail use frequency and purpose, residential location, and user feedback about facilities (11, 13-15). Various studies have shown that trail users in urban areas are typically wealthier, better educated, and less racially diverse than the general population (11, 13). None of these studies included a distance decay function measuring the willingness of trail users to travel to reach such facility and how active they are in terms of physical activity. A Chicago area study found that proportions of regular users varied among local, regional, and state trails. On local trails, 59% of respondents indicated they used the trail “virtually every week” or “virtually every day,” while the corresponding percentage dropped to 34% for regional trails and 25% for state trails (14). In this study, local trails were defined as those where more than 50% of the respondents came to the trail from a distance of 5 miles or less.

There have been many efforts to measure factors affecting why people do or do not choose to bicycle. These studies take a variety of approaches, yet a common factor between them is the use of highly aggregated data. This is in contrast to the present study, where the individual is used as the unit of analysis. Using the latter method, relationships between variables within specific individuals can be analyzed in greater detail.

A Federal Highway Administration meta-analysis of bicycle/pedestrian data (16) concluded that cities with high levels of “utilitarian cycling” have the following: more people commuting short distances, a high proportion of bikeways and bike lanes, a mild

climate, and a large proportion of students in the population. A more recent study also used bicycle mode share as a dependent variable; in this instance an analysis was performed on data from 35 cities (17). Variables included miles of bicycle facilities, the existence of a bike coordinator staff position, and other land use and demographic variables. The strongest correlation with bicycle commute mode share was found with the number of type 2 bike lanes, on-street bicycle facility, per square mile. Pucher, et al., (4) examined factors affecting levels of cycling using seven case studies of North American cities. That study concluded that cycling infrastructure is one of eight factors affecting cycling levels; others include public attitude and image, city size and density cost of car use and public transport, income, climate, danger (18).

All the above studies suggest that the presence of bicycle facilities is a strong incentive for people to bicycle. The question remains, how close must these facilities be in order to be attractive to potential users? The concept of distance decay may be applicable in answering this question.

The distance decay principle has been used by geographers for decades to describe the “flows of phenomena over the landscape.” (19, p. 1) Kim (20) reports that U.S. highways in Missouri have distance decay effects on surrounding employment. A recent Dutch study addressed the topic of multi-modal trips by dividing each trip into three parts: access, riding time, and egress. For users who use walk as their access mode, 98 percent do so over distances of less than 2.5 km, while 86 percent of those who cycle as their access mode do so for distances of less than 5 km (21). These studies suggest that increasing access distances will negatively influence walking and bicycling mode share.

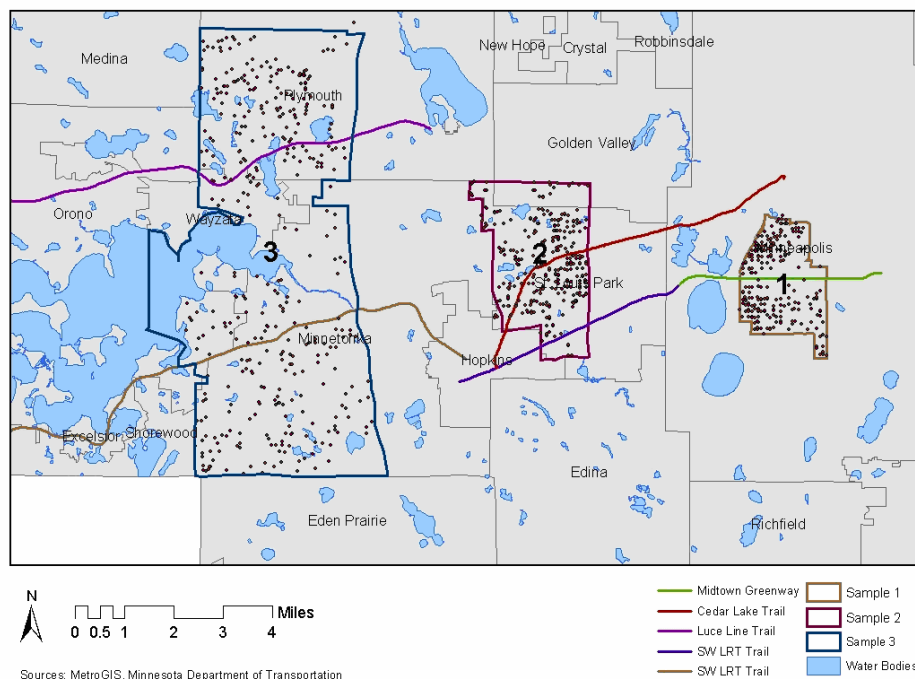
Some studies examining characteristics of trail users have addressed the issue of distances traveled to access trails. Furuseth and Altman (13) found that, of users of the Capital Area Greenway System in Raleigh, NC, over half lived within a 5 mile radius of the trail, and 90% live less than 10 miles from the facility. A survey of trail users in the Indianapolis area found that most users travel less than 5 miles to reach trails (22). These studies suggest that most users of urban trail systems live near the trails, but do not investigate variation in levels of use at smaller distance intervals.

Relatively little research to date has explicitly applied the distance decay concept to bicycle/pedestrian trails. In one such application, users of 13 Chicago-area trails were surveyed on various topics including trail use and residential location (14). Researchers plotted the reverse cumulative frequency distributions for respondents who had traveled a given distance to reach each of three trail types (local, regional, and state). The curve for local trails drops off very steeply, with over 50% of users traveling less than 5 miles to reach them. The curve for regional trails is less steep, and the curve for state trails is least steep of all, suggesting that users are willing to travel longer distances to use regional or state trails. One explanation offered for this phenomenon is that population densities are higher around local trails than the other two types, meaning that this type of trail has a larger population of potential users living within a short distance of the trail.

### 2.2.2 Approach

The data set used in this analysis was from a survey conducted in summer of 2005 in the Twin Cities metropolitan area. Three study areas were selected that surround off-road bicycle/pedestrian paths<sup>3</sup> in urban, inner suburban, and outer suburban contexts (See Figure 2). 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, with a focus on questions pertaining 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 and were followed with three reminder mailings. Excluding surveys 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. The data was then subjected to a cleaning process to remove people who moved from the trail area and others who did not answer the questions of interest reaching a sample size of 1,024.



**Figure 2. Study areas and respondent home locations**

<sup>3</sup> These paths are not necessarily the only bicycle/pedestrian paths in each study area. The trails discussed here as “trails of interest” are, in the authors’ estimation, by far the highest quality and most attractive bicycle facilities in each study area.

The characteristics of the three study areas and the trails of interest corresponding to each warrant some description. The first study area, from which Sample 1 was selected, lies within the central part of the City of Minneapolis. The mean age of the study area is 31.8 years, 46.8 percent are non-white and 28.6 percent of households make less than \$20,000 a year.<sup>4</sup> The population density of census tracts in the study area ranges from 7,670 to 25,688 persons per square mile (2,961 to 9,918 persons/sq km). The trail of interest in the sample is the Midtown Greenway (See Figure 3). The Greenway runs through a trench formerly used for rail; the trail connects the scenic Chain of Lakes area of the city on the west to the Hiawatha light rail and state highway corridor in the east; plans are in place to extend the trail east to the Mississippi River. Because the Greenway is below grade, access is limited to 15 access points along its four-mile length, including eastern and western termini. The trail is completely paved and for much of its length has separated pedestrian and bicycle lanes.



**Figure 3. Midtown Greenway**

The second study area is contained within the first-ring suburb of St. Louis Park, to the west of Minneapolis. The mean age here is 38.6; 14.9 percent of the population is non-white and 15.1 percent of households make less than \$20,000 per year<sup>5</sup>. The population

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<sup>4</sup> The corresponding statistics for the sample (N = 269) are 43.2 years, 15.2 percent non-white, and 14.5 percent making less than \$20,000/year.

<sup>5</sup> The corresponding statistics for the sample (N = 348) are 52.4 years, 5.2 percent non-white, and 5.7 percent making less than \$20,000/year.

density in the study area is 3,839 persons per square mile (1482 persons/sq km). Two trails of interest pass through the study, the Southwest LRT trail and the Cedar Lake Trail. The Southwest LRT trail follows an old railroad line from the terminus of the Midtown Greenway through St. Louis Park to Hopkins, where it splits into two branches continuing westward. The trail is largely separated from traffic, but users must navigate several busy road crossings. The portion of the trail in St. Louis Park is paved. The Cedar Lake Trail/Hutchinson Spur Trail runs through a former rail corridor from downtown Minneapolis through St. Louis Park to Hopkins, for a total length of about 7.6 miles (12.5 km) (See Figure 4). The surroundings include industrial and residential areas as well as parkland. The entire trail length is paved, and part of the trail has separate paths for pedestrians and cyclists.

The third study area includes parts of several outer-ring suburbs, including Minnetonka, Wayzata, and Plymouth. The mean age in this study area is 37; non-whites comprise 6.4 percent of the population and only 6.6 percent of households make less than \$20,000 per



**Figure 4. Cedar Lake Trail**

year.<sup>6</sup> The zip codes comprising this study area have population densities ranging from 901 to 2,541 persons per square mile (348 to 981 persons/sq km). The two trails of interest in this study area are the Luce Line Trail and the Southwest LRT Trail (northern branch) (See Figure 5). This portion of the Southwest LRT trail, between Hopkins and Victoria, MN, has a crushed limestone surface and few road crossings; the landscape is largely exurban residential in nature. The Luce Line Trail is a state trail extending 63 miles west of Plymouth, MN, through a former railroad bed. The trail is surfaced with crushed limestone and the surrounding landscape ranges from exurban to rural. As with the Southwest LRT trail, there are several at-grade road crossings.

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<sup>6</sup> The corresponding statistics for the sample (N = 407) are 54.7 years, 3.9 percent non-white, and 2.9 percent making less than \$20,000/year.





**Figure 5. Luce Line Trail**

In summary, the three study areas embody the metropolitan density gradient, ranging from extremely dense inner-city districts to sparsely populated exurban areas. The corresponding trails of interest have in common a limited number of access points and largely grade-separated road crossings, but differ in their surfaces and surrounding landscape.

For purposes of analysis, it was necessary to define respondents as either trail users or non-trail users, and as active or inactive. One survey item asked respondents to indicate if, in the past 12 months, they had used the trail(s) of interest in any of the following ways: walking, roller skating, running, bicycling, or other. If respondents circled at least one of these responses, they were classified as a trail user.

Admittedly, 12 months is a large window; under this classification scheme, the designation “trail user” encompasses everyone from the individual taking a single yearly walk on the trail to the daily runner. Some survey items did address trail use in a more constrained time frame (7 and 30 days), but these questions apply to cycling only and therefore do not encompass all the ways a nearby resident might use the trail. 535 of the 1024 respondents (52 percent) of the respondents were classified as trail users.

Another survey item asks each respondent if s/he has done any of the following in the past seven days:

- Ride a bicycle with your home as the starting point?
- Walk from home to work (or school)?
- Walk from home for recreation, fitness, or exercise?
- Walk from home to do errands such as going to the corner store, the library, or a coffee shop?
- Ride public transit (bus, light rail)?

Respondents were classified as active if they answered “yes” to any of the first four behaviors. This resulted in 67.9 percent of the 1,024 respondents being classified as

active (or 695). Though this way of measuring activity excludes those who do other forms of exercise, we theorize that respondents who are active in other ways are quite likely to report the above active travel behaviors. In 2001, 48.5 percent of Minnesotans engaged in moderate or vigorous activity three or more days per week<sup>7</sup> (23). This supports our measure indicating that 67.9 percent of respondents engaged in activity at least one day a week.

When undertaking distance decay analysis, the way in which distance is measured becomes a pertinent issue. The two major types of distance are Euclidian and network; the former measure the simple “as the crow-flies” distance between two points and the latter is a measurement of the distance one must travel on a network (typically road) to travel between two points. Newell found that a consistent relationship exists between these two measurements. An added complication in the current research is that the trails of interest are limited access facilities; that is, because the trails are largely grade separated, it is not possible to enter a trail at every point where it intersects with a street (24). Current research (25) examines which of these measurement conventions most closely aligns with respondents’ perceptions of distance, and concludes that different conventions may be selected for use depending on the nature of the investigation and other variables. In the analysis at hand, network distance between respondents’ homes and trail access points was used, as it best represents the physical barriers faced by residents when traveling to nearby facilities.

### **2.2.3 Analysis**

Overall, 52 percent of respondents reported having used the trail in the past year. This figure was consistent across the three geographic samples. Different urban densities in the aggregate do not seem to affect the proportion of residents using a facility. It was necessary to analyze the data in a more rigorous way in order to fully address our research questions.

Because trail use is a yes-no variable, it was not possible to graph individual data points and see a distance decay effect; some form of data grouping was necessary. Consequently, respondents were sorted into intervals based on the network distance from their residence to the nearest trail access point. These intervals are 400 m (roughly a quarter of a mile) in size. Four hundred meters was chosen as a convenient interval; this distance resulted in interval groups containing enough respondents that outlier data was not magnified by a small N. Thus, all respondents living between 0 and 400 meters from a trail access point were placed in the first interval, those living 401 to 800 meters from an access point in the next interval, and so on. Interval sizes range from 26 to 193 observations.

For each interval, the number of respondents indicating they had used a trail of interest in the past year was divided by the total number of respondents in the interval. The resulting

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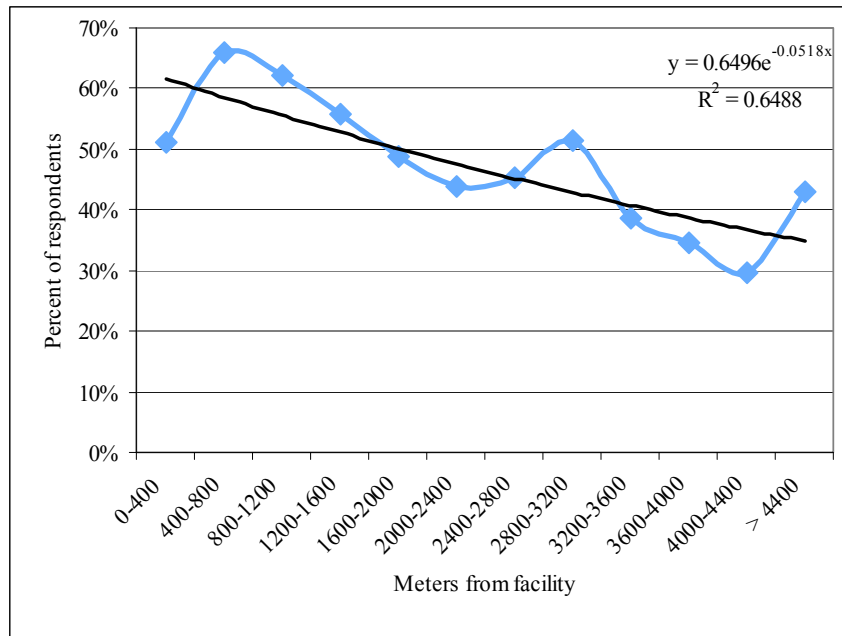
<sup>7</sup> CDC guidelines are 30 minutes or more of moderate activity 5 or more days per week, or 20 minutes or more of vigorous activity 3 or more days per week.

percentages were graphed, showing the proportion of respondents in each interval that had used a trail of interest in the past year (See Figure 6).

This same process was repeated with two variations. In the first, the respondents were split into the three geographic samples, resulting in three sets of intervals<sup>8</sup>. The sample sizes for these smaller intervals are somewhat smaller, ranging from 5 to 82. The percentage of respondents using a trail of interest was recalculated for these smaller intervals. The resulting three sets of data points were graphed together. The purpose of this variation was to compare the shapes of the data points in the three study areas. Differences encountered may be related to variation in the urban form of the three areas (See Figure 7).

In the second variation, the original set of intervals was split into two groups, active and inactive, based on the activity variable described above. Here, Ns for individual intervals ranged from 27 to 135. As with the first variation, the percentage of respondents using a trail of interest was recalculated for the smaller intervals and the resulting two sets of data points were graphed together. This variation explores differences in the shape and accuracy of distance decay with active and inactive respondents.

A negative exponential trend line was fitted to each set of points on each of the graphs. This type of trend line was reasonably similar to the shape of the data, and has been used in previous distance decay applications. Zhao, et al., (26) used a similar technique to model transit walk accessibility.



**Figure 6. Percent of residents who use the facilities by how far they live from the facility**

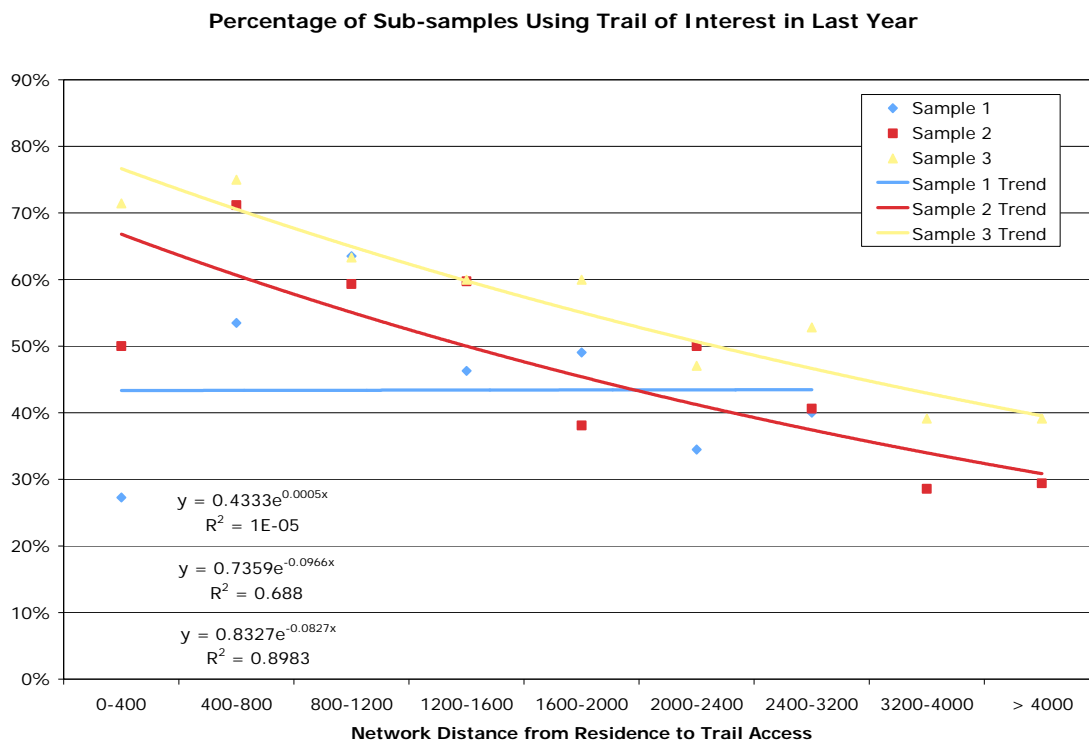
<sup>8</sup> Sample 1, the most dense and urban of the three, has no respondents living more than 2800 m from a trail access point. Consequently, this sample has no data points for the two outermost intervals.



Using the full sample of respondents, a distance decay trend is clearly exhibited. More than half of respondents (66 percent) living 400 to 800 meters from a trail of interest reported having used the trail in the past year, versus 37% of those living greater than 4000 meters from a trail. The proportion of respondents using the trail drops below the average (52 percent) beyond 1600 meters. It is clear from the figure that trail usage tends to decline as distance from trail access points increases.

The fitted exponential curve has an  $R^2$  of 0.6488, and a functional form  $\exp(-0.0518x)$ , where  $x$  is the network distance from residential address to the nearest trail access point. The decay function shows the rate at which trail use (defined as at least one annual use session) will decrease as network access increases. Though a decay trend is evident, trail use for respondents living greater than 4000 meters is still nearly 40 percent, about half the rate of trail use in the 400-800 meter interval.

Notably, respondents in the 0-400 meter interval use the trail at the same rate as those in the 1600-2000 meter interval. This phenomenon will be discussed further in the conclusions section.



**Figure 7. Percent of sub-samples using trail of interest in the past year, at various distances from the trail**

When the three geographic sub-samples are graphed, differences emerge. As with the full sample, levels of trail usage drop below average (52 percent) for sample two at 1600 meters. For sample three, this threshold is not crossed until 2000 meters; for sample one

it is crossed at 1200 meters. These differences suggest that catchment areas vary in radius across the spectrum of metropolitan densities.

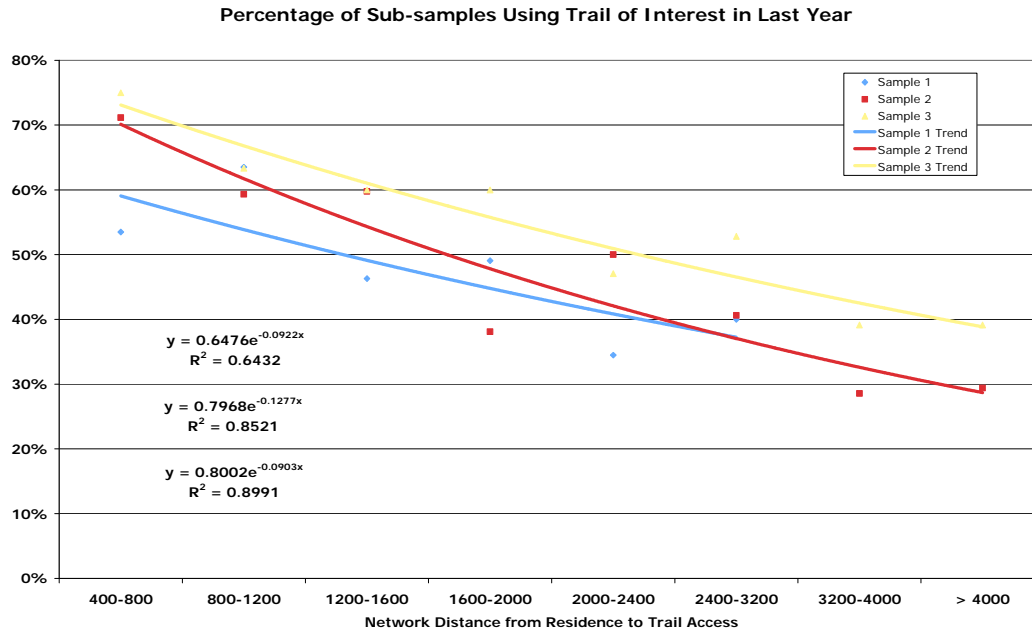
Samples two and three have similar slopes, but sample three shows higher levels of trail use at every distance. Thanks to the small percentage of respondents in the 0-400 meter interval who report having used the trail, the trend line for sample one is virtually flat, with the functional form  $\exp(0.0005x)$ , and has an  $R^2$  value close to zero. The trend line for sample two has an  $R^2$  of 0.688 and the functional form  $\exp(-0.0966x)$ . For sample three, the  $R^2$  is 0.8983 and the functional form  $\exp(-0.0827x)$ .

**Table 7. Exponential Function Coefficients**

Study Area	Functional Form	R-squared
Sample One	$0.0005x$	1.00E-05
Sample Two	$-0.0966x$	0.688
Sample Three	$-0.0827x$	0.8983
Combined Sample	$-0.0622x$	0.7144

An unexpected trend that emerged from the results is that respondents in the 0-400 meter interval did not use the trails of interest at the same rate as those in the next most proximate interval. This phenomenon is visible in the full sample graph (See Figure 6), and appears to be quite strong in study areas one and two (See Figure 7). It was expected that respondents living adjacent to the trails of interest would report very high levels of use.

A possible explanation for low levels of trail use among residents in the 0-400 meter interval is that residents in this interval live in apartments at about twice the rate of those in the 400-800 meter interval, 37 percent and 17 percent, respectively. Apartment dwellers may have little storage space for bicycles and in-line skates, which may constrain their trail use. This explanation is supported by the fact that residents in study area three live in apartments at a lower rate (14.2 percent) than respondents in study area one (65.3 percent) or two (20.5 percent).

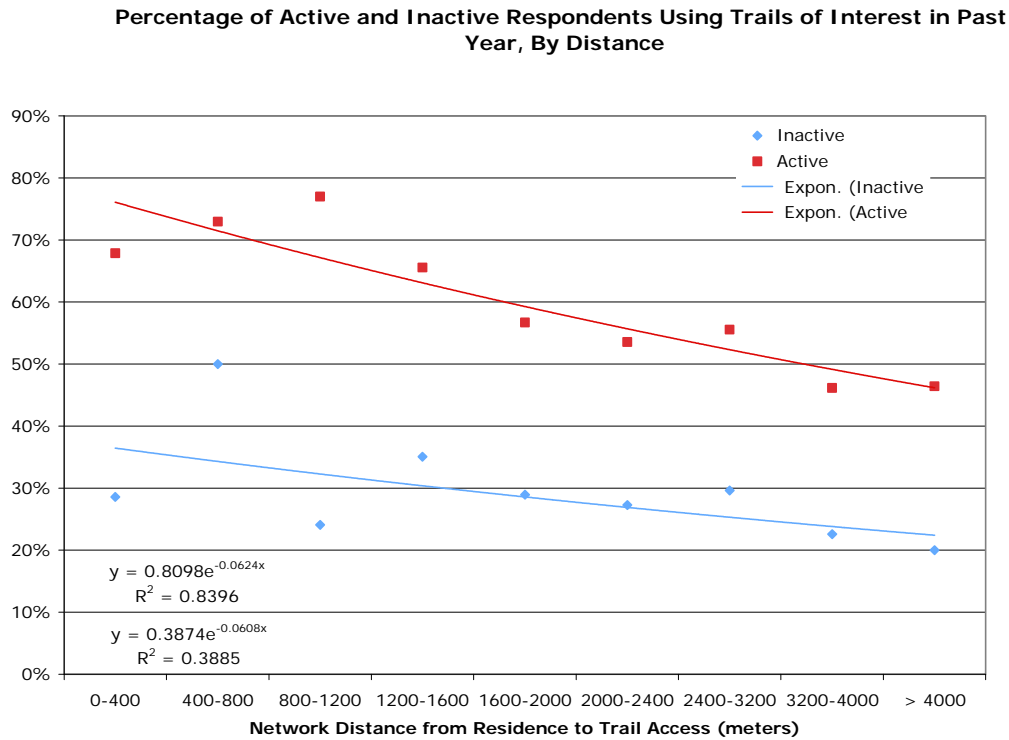


**Figure 8. Geographic Sub-samples, 0-400 Meter Interval Removed**

Removing the 0-400 meter interval from the graph results in more consistent functional forms across the three study areas (See Figure 8; Table 8. In this variation, the slopes for samples one and three are virtually identical, while the curve for sample two drops off more steeply.

**Table 8. Exponential Function Coefficients, 0-400 Meter Interval Removed**

Study Area	Functional Form	R-squared
Sample One	-0.0922x	0.6432
Sample Two	-0.1277x	0.8521
Sample Three	-0.0903x	0.8991
Combined Sample	-0.0847x	0.9325



**Figure 9. Active and Inactive Samples**

Figure 9 compares the trail usage of active and inactive respondents; respondents were characterized as “active” if they reported having ridden a bicycle or walked to a destination or for exercise at least once in the past week. Trail use is clearly higher for active respondents, ranging from 46 to 77 percent, than for inactive respondents, ranging from 20 to 50 percent.

The trend lines for active and inactive respondents are similar in shape, with functional forms of  $\exp(-0.0624x)$  and  $\exp(-0.0608x)$ , respectively. However, the trend line for active respondents fits the data better than does the trend line for inactive respondents: The active trend line has an  $R^2$  of 0.8396, versus 0.3885 for the inactive trend line. The 0-400 meter interval effect discussed above is much more evident for inactive than active respondents. This suggests that active respondents living close to the trails are more determined to use the trail in spite of any barriers such as lack of storage space.

Of the 695 respondents classified as active, 259 (37 percent) had not used a trail of interest in the past year. One might ask why, if the trails are considered to be so attractive, this might be the case. There are a few possible explanations. One might be that those who are active but are not using the trails of interest live farther away from the studied trails. This proves to be the case. Respondents who are both active and report using a trail live on average 1,663.5 meters from a trail access point, while respondents who are active but do not report using a trail live, on average, 2,115.4 meters from the nearest trail access point.

Other possible explanations can be found in another survey item. If respondents had not used a trail of interest on their most recent bicycle outing, the survey asked them to indicate one or more reasons why. Though this item referred specifically to cycling rather than all trail use, responses may speak to the latter as well as the former. The two most popular responses were “the path was not on your intended route” and “you mostly rode on city streets.” These responses, particularly the former, would more likely apply to respondents who live further from a trail<sup>9</sup>; as such this item supports the above theory that distance from trails is the primary barrier to their use by active respondents.

## **2.2.4 Conclusions**

The biggest conclusion to be drawn from the preceding analysis is that, based on this survey data, a cogent distance decay pattern exists between network distance to a trail access point and rate of trail use. Aside from the anomaly of the 0-400 meter interval, respondents who live closer to a trail use it at higher rates than do respondents living further away.

However, there are differences in the shape of the curves across the three geographic sub-samples; samples two and three are relatively similar in slope, while the curve for sample one is flat. We speculate that this variation is due to a higher concentration of apartment dwellers in the 0-400 meter interval, particularly in sample one. Further research is needed to verify and explain the relationship between apartment living and levels of trail use.

In the data from the full sample, the proportion of respondents reporting having used a trail drops below average (52 percent) after 1600 m (about a mile). This distance varies from 1200 m in study area one to 2000 m in study area three. This variation suggests that residents in denser areas are willing to travel shorter distances to trail access points than are residents in more sparsely populated areas. There are a few possible explanations for this. First, residents in denser areas may use trails for transportation while residents of less-dense areas use them for recreation; consequently, residents in denser areas are more likely to be deterred from using a trail if it does not go to or near their destination. Second, in denser areas, there are more facilities competing for use by residents, such as bicycle lanes and ubiquitous sidewalks, so residents do not need to travel as far to get to a facility they find attractive and useful. In suburban areas, there are fewer alternatives, and so residents may be willing to travel farther to reach trails.

Even among respondents identified as active, the distance decay concept applies, debunking the idea that active people will travel any distance to use an attractive trail. Of active respondents, those who report having used a trail of interest live on average 500 m closer to a trail access point than those who did not. However, it seems that inactive respondents are more affected by the 0-400 meter interval anomaly than are active respondents.

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<sup>9</sup> Theory suggests that respondents who live relatively close to the trail might be willing to go slightly out of their way to use a superior facility, and that as the distance to such a facility increases, the relative attractiveness of it decreases.

It is difficult to compare the present research with Gobster's (14) distance decay application, largely because the scale of the effects measured is so different. In the 1995 research, miles from home to trail ranged as high as 50, while in this analysis, distances ranged from 0 to 3 miles. All three curves resulting from Gobster's data are far steeper than those shown above, suggesting a comparatively forceful distance decay effect. Had the survey analyzed here been distributed in larger study areas such that distances to trail access points were greater, it is likely that the resulting fitted trend lines would have been steeper.

Compared to distance decay research based on transit walk accessibility (26), the results of the present analysis show that walking transit access drops off much more quickly than does trail access when distances from home to access point (or transit stop) are increased. In Zhao, et al (26), the fitted curve had a functional form of  $\exp(-0.0013x)$ , versus  $\exp(-0.0622x)$  for the full sample in this analysis. Trail users more often access the trail by bicycle than on foot, which means they are less sensitive to increased distances than are people walking to transit stops.

### **Limits to methodology**

There are some obvious drawbacks to the methodology described above. Of primary importance is that survey data is self-reported—participants may report having used a trail when they did not actually do so, and vice versa. Because exercise and active behaviors are considered socially desirable, it is likely that respondents would over-rather than under-report trail use and active travel. Another reason for cautious interpretation of results is the possibility of sampling bias. Though the individuals who received surveys were randomly selected, those who choose to fill it out and send it in are self-selected. Survey recipients who are interested in bicycling and trails may have been more likely to return the survey; these same individuals are more likely to use the trails and be active. There is no reason to believe that the size of either of these types of error would change with distance from the trail, so the shape of the distance decay curve is probably unaffected.

The definitions of “trail use” and “active” respondents could also stand improvement. A better trail use measure might have asked whether the respondent used the trail in the past month, or even how frequently they used the trail (never, a few times a year, monthly, weekly, or daily). Having the option to include frequency of use in the analysis would have added a layer of richness to the results. Similarly, the definition of “active” might have included more activities (i.e. participation at a gym), or been given more meaning through the addition of a dimension of frequency.

Lastly, the distance convention chosen may have affected outcomes. We hypothesized that the different street patterns evident in urban and suburban areas might have an effect on trail use. In suburban areas, the hierarchical street patterns and cul-de-sacs often result in greater network distances between two points than would be found with a grid pattern. That is, respondents who live the same Euclidian distance from a trail access point may have been sorted into different intervals by virtue of the street pattern, and differences in trail use between them would therefore be attributed to distance from the trail. By using

the network distance measurement in the present analysis, the effect of street pattern on trail use is likely muted.

### **Application**

The exponential coefficients calculated here, or those created using a fine-tuned version of this methodology, can be used by planners in the selection of sites for trail facilities. Planners can apply the distance decay function to various potential trail alignments to determine which will generate the greatest number of users. As opposed to the usual approach of buffering the alignment at some distance and designating a certain percentage of the residents within the buffer as likely trail users, using this method may generate a more fine-grained, accurate snapshot of potential trail user.





### 3. Effect of Bicycle Facilities on Housing Prices

In many communities there are ongoing efforts—public discussion, community initiatives, and land use-transportation policies—intended to increase the livability of the community. A component that is often included in the livability is the ability of residents to freely move about. A key component of this is pedestrian and bicycle travel. Communities with sidewalks and bicycle facilities are often thought of as being more livable than those without. Advocates often use this as an argument for the construction of bicycle facilities.

If livability is an element that people look for in a community and are willing to pay extra to have, and bicycle facilities are a factor in the livability of a community, then the value gained by living near the facility should factor into the price they are willing to pay to be part of the community, the price of their home. Documenting people's willingness to pay for a bicycle facility is important because it provides for a better informed and thorough public debate. Determining people's willingness to pay can be difficult for non-market goods such as bicycle facilities because those receiving the benefit of the facility are not paying for the benefit.

Determining the value of non-market goods can be accomplished in one of two ways: stated preference and revealed preference. Stated preference involves asking those who benefit from the good how much they would be willing to pay for the benefit they receive. This can be problematic for a few reasons; because they have never had to pay for the good, it can be difficult to quantify. They may also have an incentive to lie, because some may use the results as an argument for more or less of the good to be made available. Revealed preference measures their actual behavior. In this case, how much is someone willing to pay to live in proximity to a bicycle facility?

This study is a second attempt to try and quantify the impacts of bicycle facilities on property values. The first attempt by Krizek, et al., used a hedonic model. This study revealed that off-street facilities that are alongside busy streets are negatively associated with home sale prices in both the city and suburbs. However, off-street facilities away from busy streets had a positive relationship with home sale prices in the city and a negative relationship in the suburbs. On-street facilities had no discernable effect on property values in the city but had a negative relationship with property values in the suburbs (27). This seemed to indicate that both the type of facility and the location seemed to affect the impact that a bicycle facility would have on home sale prices. However, concerns remain about whether or not these factors were possibly due to additional factors that are tied to the location of the individual facilities.

In an effort to try and replicate the results of the hedonic model, the research team used a matched-pairs longitudinal approach to look at the change in the property values in the same neighborhoods overtime. The longitudinal approach allows us to control for the factors that are unique to the individual geographic areas that the bicycle facilities are located in, by comparing the same area to itself overtime with a control area that has similar traits. The previous study indicated that only high quality off-street bicycle facilities appeared to positively affect property values. As a result, this study included

only those bicycle facilities that were considered to be high quality bicycle facilities, off-street paved facilities of significant length or shorter segments that provided critical links in larger networks of bicycle facilities. The study also included facilities in central cities, as well as inner and outer ring suburbs.

### 3.1 Methodology

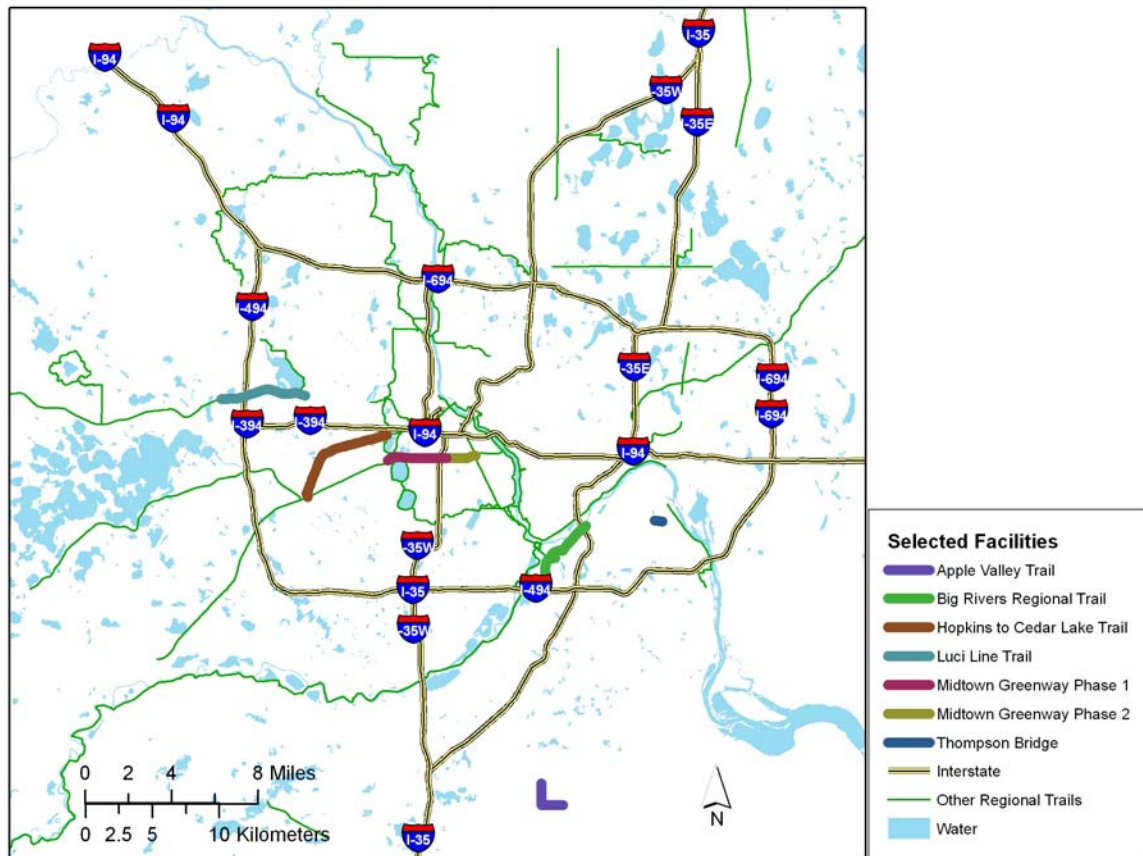
For the purpose of this study, the research team selected seven high quality bicycle facilities constructed from 2000-2004. The study uses census tracts that have their geographic center within three (3) kilometers of the bicycle facility. Each census tract in the study area was matched with a control census tract. The percent change in the average sale values of owner occupied homes in each tract was compared.

#### Selected facilities

Seven high quality bicycle facilities were selected for the study (See Figure 10). The facilities were constructed between 2000 and 2004. The facilities are:

- **Apple Valley Trail**—Located in the southern suburb of Apple Valley, it runs alongside two roads.
- **Big Rivers Regional Trail**—Runs along the south bank of Minnesota and Mississippi Rivers. Although the majority of this facility existed prior to 2000, it was not connected to the neighborhoods on the south end of the selected segment and it did not cross the Mississippi River. Prior to these connections, the bicycle trail was rather difficult to access for most cyclists without using a motor vehicle.
- **Hopkins to Cedar Lake Trail**—Runs in a railroad right-of-way connecting downtown Hopkins and the Cedar Lake trail (which continues into downtown Minneapolis). This facility provides access to downtown Minneapolis by off-street bicycle facility from the western suburbs of Hennepin County.
- **Luce Line Trail**—Although the Luce Line Trail existed prior to 2000, the selected portion was paved for the first time in 2001. It is part of a larger trail system by the same name; the rest of which is maintained by the Minnesota Department of Natural Resources. It connects second and third ring suburbs with exurban communities to the west of the Twin Cities.
- **Midtown Greenway Phase 1**—Located in south Minneapolis where 29<sup>th</sup> St. S would exist between the Chain of Lakes and 5<sup>th</sup> Ave. E. The Midtown Greenway is probably the most publicized and promoted bicycle facility in the Twin Cities area. It is designed to be a key element of neighborhood revitalizations. It was built in three phases. Together the Midtown Greenway connects the western suburbs to the Chain of Lakes, the Uptown neighborhood, the improving Midtown neighborhood, the Hiawatha LRT/Trail and the Mississippi River. As an east-west bicycle facility, it connects four major north-south bicycle facilities in south Minneapolis (Chain of Lakes Trails, Park and Portland Bicycle Lanes, Hiawatha LRT Trail, and West River Trail).
- **Midtown Greenway Phase 2**—An extension of the Midtown Greenway; Phase 2 stretches from 5<sup>th</sup> Ave E to Hiawatha Ave.
- **Thompson Bridge**—A bridge over U.S. Highway 52 connecting West St. Paul with South St. Paul. The bridge connects two larger bicycle networks providing

access from several neighborhoods to shopping/employment and the Mississippi River.



**Figure 10. Map of selected bicycle facilities**

### **Selection of treatment areas**

Following the selection of the bicycle facilities, the research team then determined the treatment areas for each of the bicycle facilities. Census tracts were selected as the unit of analysis. To select the tracts that would be included in the study area, a three-kilometer buffer was drawn around each of the facilities. The census tracts whose center was within the three-kilometer buffer were then selected as the study area for the bicycle facility.

There were two exceptions to this method for selecting study areas. The first exception was in selecting the Thompson Bridge test area; two-census tracts had their center within three-kilometers of the bicycle bridge. However, these census tracts were located on the other side of the Mississippi River and there are no bridges over this portion of the river. The other case is when a census tract was within three-kilometers of more than one bicycle facility. These tracts were assigned to the bicycle facility to which it was closest. This resulted in 120 test census tracts.

### **Selection of control areas**

As part of the analysis, the research team selected a control census tract for each of the 120 treatment census tracts. The following criteria were used to select the census tracts.

In selecting the control tracts the research team aimed to select tracts that were similar to the study tract. The research team controlled for three factors:

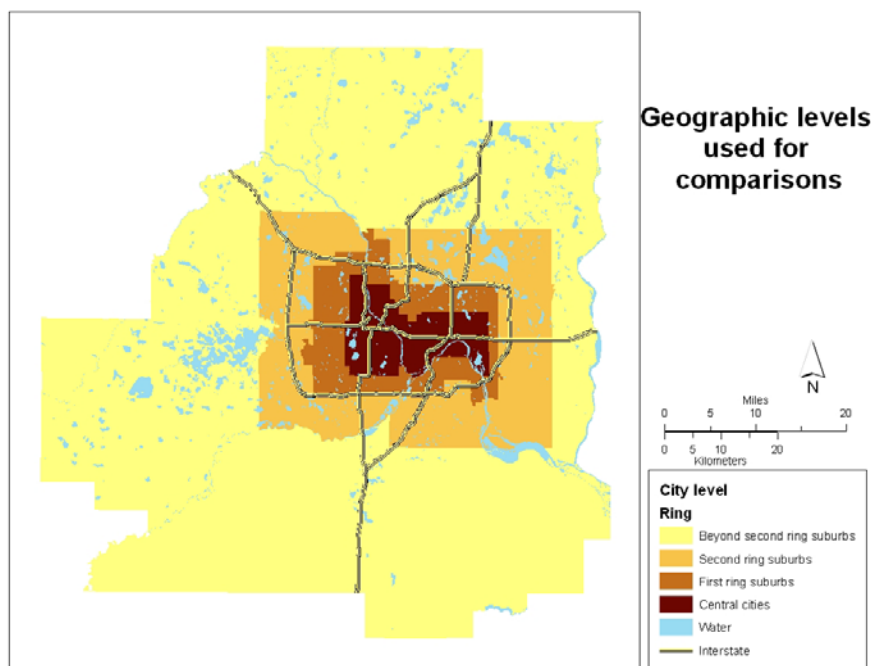
1. Geographic location,
2. Median household income, and
3. Population density.

**Geographic location** acted a proxy for many neighborhood attributes including proximity to downtown, age of housing stock, and development patterns. For this variable, the metropolitan area was divided into four sections (core cities, first ring suburbs, second ring suburbs, and third ring suburbs). A criterion in selecting control tracts was that they had to be in the geographic section of the track to which they are being compared.

**Median household income** allows for comparisons between economic conditions of various neighborhoods.

**Population density** is used as a proxy for the type of developments that are common in the area. Drawing distinctions between large lot single family and apartment/condominium house differentiates different types of residents.

Both the median household income and population density provide insights about the type of amenities that are typically found in the neighborhoods. For this reason, the two variables were combined into a single formula to select the control tracts for each study tract (formula shown below). Median household income was weighted as more important than population density in this equation because the research determined that income was a better indicator of the type of neighborhood than density.



**Figure 11. Map of the geographic levels used in matching the study tracts with control tracts**

The first three steps were conditions that had to apply to all control tracts. The fourth step is how the best matches were determined from among the various tracts that met the first three requirements.

1. A control tract cannot be a study tract.
2. A control tract cannot be paired with more than one study tract.
3. A control tract must be in the same “urban ring” as the study tract it is paired with (see Figure 11).
  - a. Core city (Minneapolis or St. Paul)
  - b. First ring suburb
  - c. Second ring suburb
  - d. Beyond second ring suburb
4. In order to select the best 120 matched pairs of study tracts and control tracts the following logic test was applied.

For each matched pair the following formula was used:

Study tract	= T
Control tract	= C
Median household income test tract	= H <sub>T</sub>
Median household income control tract	= H <sub>C</sub>
Population per sq. kilometer test tract	= P <sub>T</sub>
Population per sq. kilometer control tract	= P <sub>C</sub>
Similarity of matched pairs	= S <sub>TC</sub>

$$S_{TC} = \frac{(H_T - H_C)}{H_T} + \frac{(P_T - P_C)}{P_T} * .75$$

$$\text{Minimize } \sum_{1-120} S_{tc}$$

## Parcel data

We began with the point parcel data from October 2006. This data was downloaded from MetroGIS which collects the data from each of the seven county assessors in the Twin Cities Metropolitan region. Each of the agencies is responsible for the quality of the data they provide<sup>10</sup>.

For this project, the seven counties’ point parcel data was combined into a single file, which contained the records for all land parcels (or properties) in the Twin Cities. This was then filtered down to the records that were most applicable to our study.

The first step in this process was to select properties that are owner-occupied; this was done by selecting properties in which the owner has applied for the homestead tax credit. The reason for this is that there are additional factors that go into the sale price of commercial, industrial, and investment real-estate. Any evaluations should look at each type of real-estate separately.

<sup>10</sup> The Metadata for each of the counties and the data can be found on MetroGIS.

An effort was made to eliminate properties or transactions that occurred under unique or unusual circumstances. These included transactions that involved things in addition to the home transaction, the transaction was between family members, or when there appears to be an error in the sale records. The sale values that were used were truncated at \$50,000 and \$10,000,000, due to the small number of homes in region priced below \$50,000 or above \$10,000,000. The final criteria is that the most recent sale took place in the period of time two years prior and two years following the construction period for the study, 1998-1999 and 2004-2005.

### Linking property data to the tracts

Spatial joins were done between study tracts and the before and after property data with a count feature. Those tracts that did not have at least 30 properties sold in the before or after time period were eliminated from the study because they could easily be skewed by a particular property. There were 33 tracts that had less than 30 sales of owner-occupied housing in either the before or after period. As a result these tracts were removed from the study. Figure 12 shows the location of tracts included in the analysis.

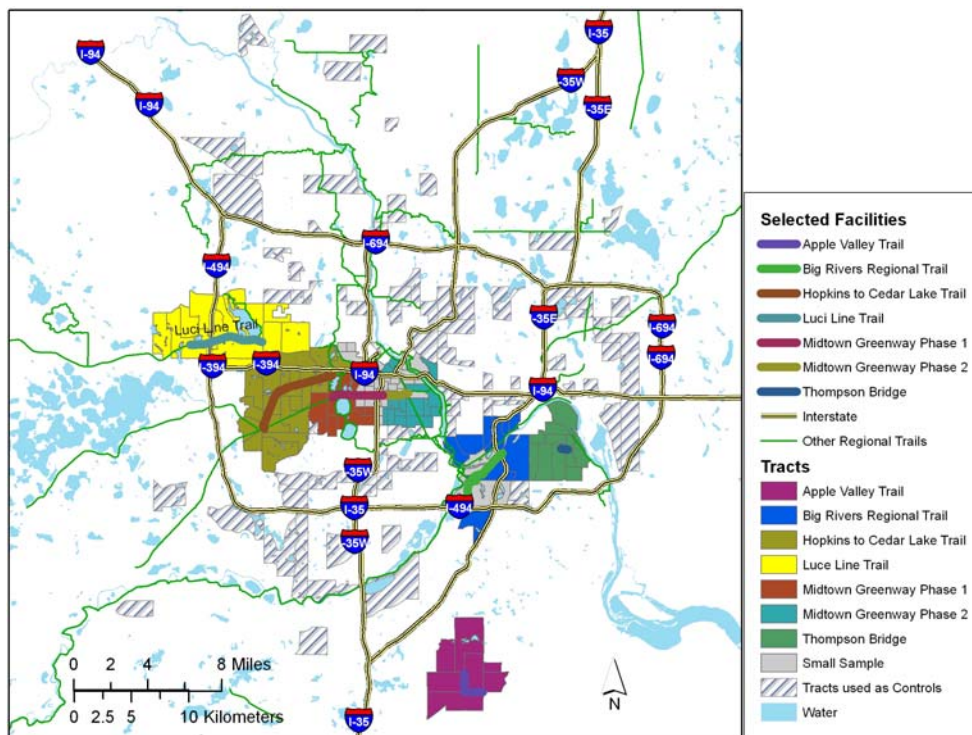


Figure 12. Location of treatment and control tracts used in the study

## 3.2 Results

Using matched pair analysis comparing the census tracts near the bicycle facilities to previously identified control census tracts, the research team was able to determine that constructing high quality bicycle facilities does not have a significant effect on the sale price of owner-occupied homes. This conclusion is based on a t-test to comparison of the percent change in median housing price between the tracts around each facility to control

tracts. This analysis demonstrates no significant difference in the change of home sale price between the areas near a newly constructed bicycle facility and the control tracts (See Table 9).

The research team then tried to determine if a new bicycle facility had a different impact on different income neighborhoods. Since many of the facility include a variety of neighborhoods an increase in low income neighborhoods may be hidden by an decrease in higher income neighborhoods, or the opposite, resulting in no significant impact. An example, Phase 1 of the Midtown Greenway runs through both the wealthy neighborhoods around Lake of the Isles and the low income neighborhoods around Lake and 35W.

**Table 9. Percent change in sale price for owner occupied housing near new bicycle facilities compared with their control tracts**

Facility	% Change in Study tracts	% Change in Control tracts	T-Value	Sig. 05	N
Apple Valley	76.26%	69.22%	0.17	Not Sig.	7
Thompson Bridge	45.87%	79.25%	-0.81	Not Sig.	5
Big River Regional Trail	81.25%	82.40%	-0.04	Not Sig.	9
Luce Line	70.10%	60.05%	0.33	Not Sig.	12
Hutchinson Spur	53.16%	63.60%	-0.56	Not Sig.	22
Midtown Greenway	74.22%	84.18%	-0.43	Not Sig.	27
Midtown Greenway Phase 1	61.57%	83.55%	-0.68	Not Sig.	12
Midtown Greenway Phase 2	84.34%	84.68%	-0.01	Not Sig.	15
All	67.18%	73.35%	-0.12	Not Sig.	82

In an effort to measure the role of income, tracts were divided based on whether their median household income for the tract is above or below the median household income for the Twin Cities Metropolitan Area,(\$54,304) (28). Once again it appears as though building a bicycle facility has no significant effect on the property value of owner occupied housing prices (see Table 10).

**Table 10. Percent change in sale price for owner occupied housing by census tract comparing low income and higher in census tracts.**

	% Change in Study tracts	% Change in Control tracts	T-Value	Sig. 05	N
Tracts with Median Household income below Twin Cities Median Household income	70.59%	78.97%	-0.51	Not Sig.	46
Tracts with Median Household income above Twin Cities Median Household income	62.83%	66.18%	-0.21	Not Sig.	36

### 3.3 Conclusions

The above findings indicate that building bicycle facilities does not have an impact on the sale price of owner occupied housing in the area immediately adjacent to the facility. It is likely that although some residents of the area around the facilities look at the facility as a

detriment to their property values, an equal portion of the community look at bicycle facilities as an asset. Although this study indicates that in the short run there is little or no effect on owner occupied property values, the long term effect of building the bicycle facilities is something that should be examined further over time.



## 4. Safety & Relationship to Facilities

Across the United States there are efforts to increase the levels of bicycling. An important element of efforts to increase bicycling is to ensure that there is a safe environment for bicyclists. Discussions regarding the best methods to ensure safety for bicyclists have lead to a debate regarding the safety of off-street bicycle facilities. This debate started because the overwhelming majority of bicycle accidents resulting in fatalities are caused by collisions with motor vehicles (29, 30). As a result, many bicycle safety enthusiasts to promote off-street bicycle facilities as a way to provide bicyclists with the ability to bicycle without sharing the roadway with motor vehicles (31). However, opponents of off-street bicycle facilities argue that off-street bicycle facilities will not have an effect on safety or will make bicycling less safe because only a minority of bicycle crashes with motor vehicles were not caused by cars passing bicycles, the only interaction that many off-street facilities would reduce (29, 32, 33). Proponents of bicycle networks argue that bicycle facilities are safer and more attractive for less experienced bicyclists (31, 34). Most proponents of bicycle facilities are not advocating for laws requiring bicyclists to use the facilities over streets when available, but instead argue that the option to use facilities should be available. Opponents claim that properly trained bicyclists can travel safer and faster by operating as a vehicle on the roadway (33). Both sides of the argument agree that there is a need to increase knowledge of laws regarding bicycling among both drivers and bicyclists (31, 33, 34).

Although there has been extensive research into the relationship between the urban environment and bicycle crashes (29, 35, 36), existing research does not address questions regarding the effect of modifying the urban environment on the safety of bicycle travel. This paper examines the effect of the adding an off-street bicycle facility on bicycle safety in the area around the facility.

### 4.1 Description of the Midtown Greenway

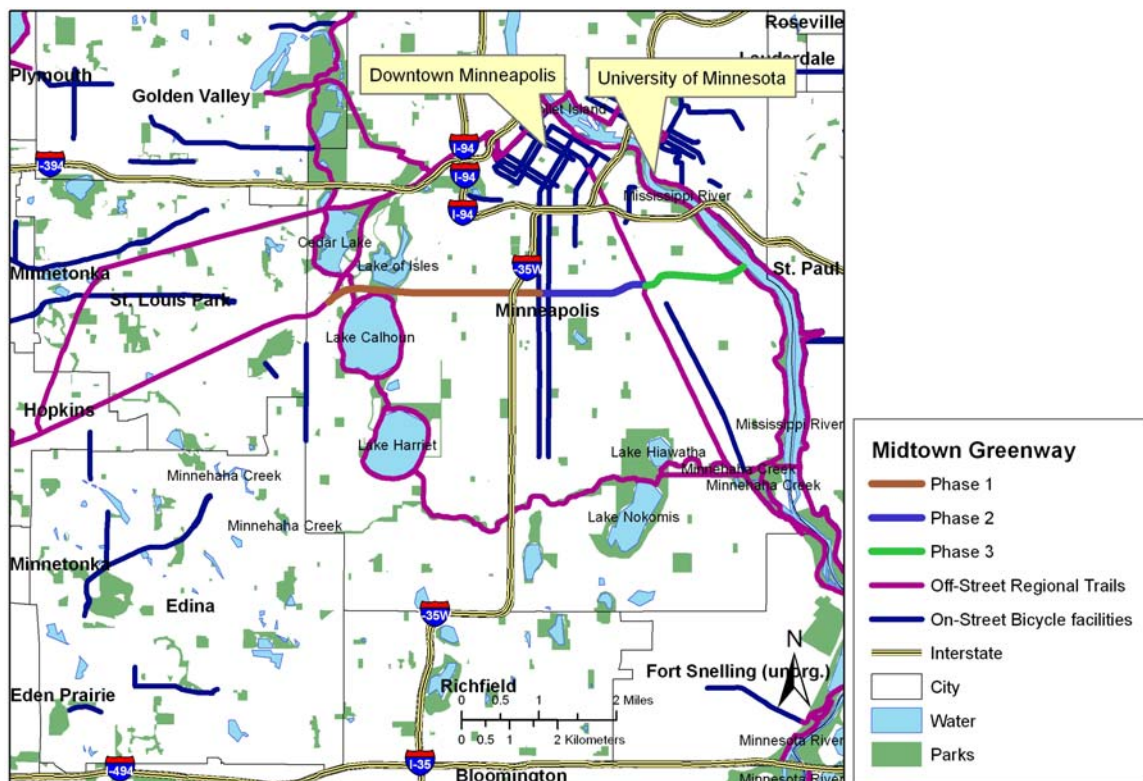
This study examines the effects of building an off-street bicycle facility, Phase-1 of the Midtown Greenway<sup>11</sup>, on the safety of bicycling in the area. It serves as a potential model of how such studies can be designed. However, the uniqueness of the Midtown Greenway raise questions about how transferable the results are to other off-street bicycle facilities. The Midtown Greenway is an off-street bicycle facility built in an old railroad right-of-way. The Greenway construction was spread over three phases. Phase-1, which opened in 2000, extends from the western edge of Minneapolis, between Lake Calhoun and Lake of the Isles, to Fifth Avenue E. Phase-2, which opened in 2004, extends from Fifth Avenue to Hiawatha Avenue. Phase-3, the most recent phase which opened in the fall of 2006, extends from Hiawatha Avenue to the Mississippi River (See Figure 13).

The Greenway not only connects city parks and trail systems from the Chain of Lakes to the Mississippi River, but it is also an integral part of a larger system of regional bike facilities that stretches from Carver County to the Mississippi River, and that includes over 73 miles of continuous off-street facilities. Regional plans include expanding the

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<sup>11</sup> The study focuses only on Phase 1 of the Midtown Greenway because of the ability of crash data. Data for crashes after the opening Phases 2 and 3 were not yet available when the project began.

network over the Mississippi River into St. Paul and east to the St. Croix River, the Minnesota-Wisconsin border. The Greenway is directly connected to the 17-mile network of on-street facilities located in Downtown and South Minneapolis.



**Figure 13. Map of bicycle facilities in South Minneapolis and Southwest Suburbs**

Phase-1 of the Midtown Greenway, unlike most off-street bicycle facilities, is designed more like an expressway with access through on-off ramps (See Figure 14). Phase-1 of the Greenway is 2.8 miles (4.5 kilometers) long, and over this stretch there are three at-grade crossings, while there are 20 underpasses and two overpasses. The three at-grade crossings are residential streets, with low traffic volumes, concentrated over an 1/8 mile (200 meters) stretch. This enables bicyclists to travel at higher speeds before and after the crossings.



**Figure 14. The Midtown Greenway is primarily a grade-separated bicycle facility with on-off ramps for access**

## 4.2 Methodology & Analysis

Forester, in his empirical test, compared a single roadway to a bicycle facility (33). Research suggests that a bicycle facility will draw bicyclists from distances further than a single block (37). For this reason, this study took a corridor approach to determine if there had been an effect on the number of reported bicycle crashes<sup>12</sup>. A corridor approach includes not only the crashes that were occurring on parallel streets to the Midtown Greenway, but perpendicular streets that could be used to access the Midtown Greenway. This prevents a change in the location of crashes from appearing as a change in the number of crashes.

Krizek, et al., work on how far bicyclists are willing to travel to use a bicycle facility concluded “...more than half of the users cycled less than 2,500 meters to reach the trail and there was a sharp decline thereafter (37)<sup>13</sup>.” The research team hypothesized, based on the work of Krizek, et al. that if there is an effect on safety that it will occur within 2.5 kilometers of the Greenway. For this reason, the study focused on a 2.5 kilometer buffer parallel<sup>14</sup> to the Phase-1 of the Midtown Greenway.

It is difficult to determine the impact on bicycle safety of a new bicycle facility because of the lack of information related to the number of bicyclists in the area. In an attempt to reduce the impact of the number of bicyclists and how often they ride in the area, this study compares the same geographic area over time. Because the study is comparing a geographic area to itself on annual basis over five years, the research team is assuming that there were not significant changes in the number of bicyclists. In addition it is assumed that the number of bicyclists did not decrease over time with the addition of the bicycle facility. The final assumption is based on previous research (1, 38).

<sup>12</sup> Although, reported crashes do not necessarily involve a motor vehicle, most crashes that are reported involve a motor vehicle. In order for the crash to be reported in Minnesota, it must result in either bodily injury or \$1,000 in property damage these are more likely to occur if motor vehicle is involved.

<sup>13</sup> The Midtown Greenway was one of the bicycle facilities used in Krizek et. al.’s study (3).

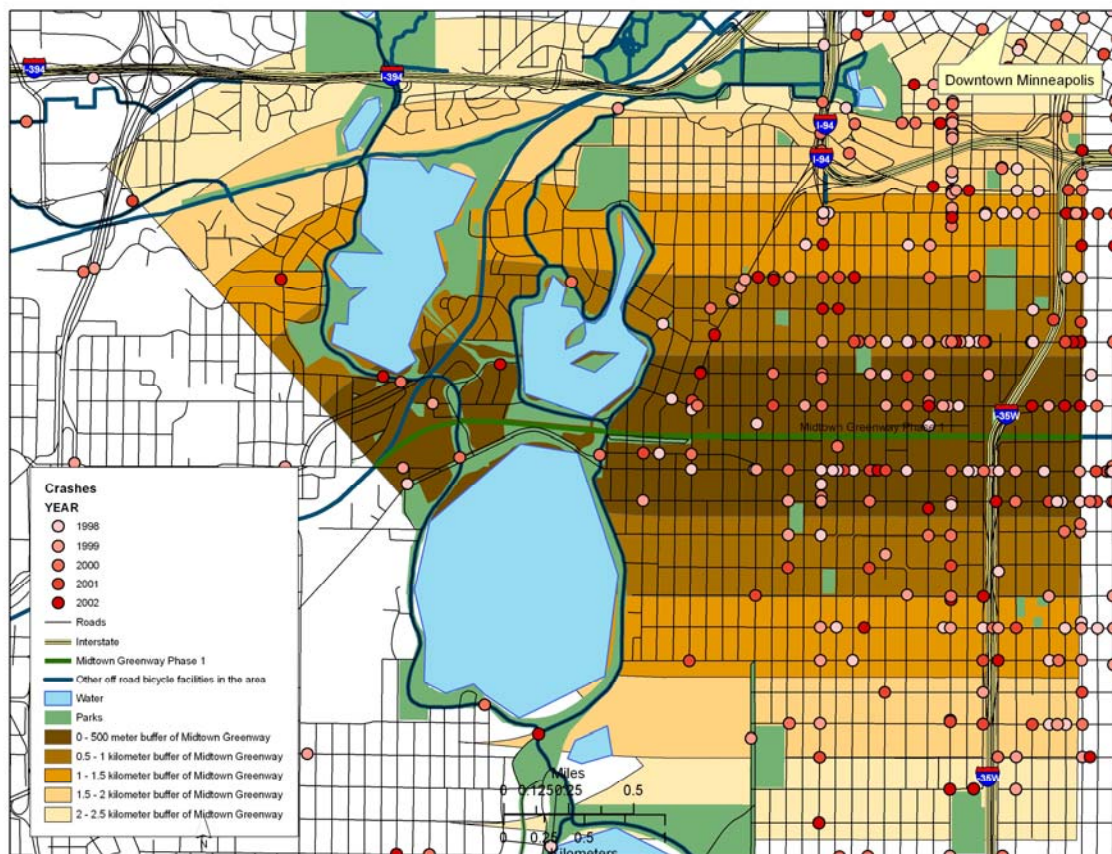
<sup>14</sup> Buffer does not include the areas beyond the ends of the Midtown Greenway because bicyclist traveling in this area did not have the option of using the Midtown Greenway for that portion of their trip.

The research team hypothesized that building Phase 1 of the Midtown Greenway will increase safety for bicycling, measured in crashes, in the area around the Greenway. The research team used a longitudinal method to determine if the number of crashes changed as a result of building Phase 1 of the Midtown Greenway. If the Midtown Greenway had no effect on the number of bicycle crashes, the number bicycle crashes should be within one standard deviation of the mean number of crashes within the buffer from the three years prior to the opening of the Midtown Greenway.

The average number of bicycle crashes a year within the 2.5 km buffer of the Phase-1 of the Midtown Greenway from 1998-2000 was 78.33 crashes a year with a standard deviation of 8.33. In each of the two years after the opening of the Phase-1 of the Midtown Greenway, there were 50 bicycle crashes within the buffer. This is a statistically significant decrease in the number of crashes.

Using a series of buffers parallel to the Midtown Greenway, the research team examined the effect of varying distance from the Greenway on the number of crashes: 0-500 meters, 501 meters-1 kilometer, 1 -1.5 kilometer, 1.5 – 2 kilometers, and 2 – 2.5 kilometers (See Figure 15).

**Figure 15. Bicycle crashes by year in the area around the Midtown Greenway**



To compare the change in the number of bicycle crashes across the buffers, the research team looked at the change in the average number of bicycle crashes within each buffer annually using a Student's T-test, as shown below.

Where:

$C_i$  = Number of crashes in year "i"

$N_b$  = Number of years in sample before the opening of the Greenway

$N_a$  = Number of years in sample after opening the Greenway

$B$  = Average of crashes a year before the opening of the Greenway

$A$  = Average of crashes a year after the opening of the Greenway

$\sigma_b$  = Standard deviation of the annual number of crashes each year before the opening of the Greenway

$T_c$  = Threshold of statistical significance (T-critical)

$$B = 1/N_b * \sum_{i=98-00} C_i$$

$$\sigma_b = \sqrt{\sum_{i=98-00} (C_i - B)}$$

$$A = 1/N_a * \sum_{i=01-02} C_i$$

$$T_c = B - 2.92 * \sigma_b / \sqrt{N_b}$$

If  $A < T_c$

Then the difference is significant at a .05 level.

Looking at the number of crashes in the individual buffers shows the largest decrease in the number of crashes in the buffers closest to the facility (See Table 11). The decrease in the number of crashes was significant in both the 0-500 meter and 501-1,000 meter buffers. However, there was not a significant decrease in the buffers beyond 1 kilometer. This suggests that the Midtown Greenway is diverting more traffic from the streets immediately adjacent to the Greenway and the further the street is away from the facility, the less bicycle traffic is diverted.

**Table 11. Decrease in the number bicycle crashes at various distances from Phase-1 of the Midtown Greenway**

Buffer	Number of crashes a year 1998-2000		T-critical	Mean number of crashes a year from 2001-02	Significant
	Mean	St. Dev.			
0.0 - 0.5 Km buffer	26.67	5.69	17.08	12	Significant
0.5 - 1.0 Km buffer	17	1	15.31	15	Significant
1.0 - 1.5 Km buffer	15.67	8.5	1.33	8.5	Not Significant
1.5 - 2.0 Km buffer	13	4.36	5.65	8.5	Not Significant
2.0 - 2.5 Km buffer	6	2.65	1.54	6	Not Significant



### **4.3 Discussion**

The lack of a decrease in the number of crashes in the outer buffers maybe the result of a combination of factors. In addition to getting further away from the Midtown Greenway, the outer buffers become closer to other bicycle facilities (Southwest LRT Trail, Cedar Lake Trail, and Minnehaha Creek Trail). The presence of existing trails in the area provided bicyclists with bicycle facilities on which they could bicycle prior to the opening of the Midtown Greenway. People who live in the 2 to 2.5 Kilometer buffer north of the greenway are closer to other bicycle facilities; residents of the western portions of the buffer would have to cross the Southwest LRT Trail in order to get to the Greenway. Most of the residents of this buffer would also have to cross an Interstate (I-394 or I-94) to get to the Midtown Greenway. People who live in the 2 to 2.5 kilometer buffer to the south of the midtown greenway are about the same distance from the Minnehaha Creek Trail. Given the other options to bicycle, it is expected that the addition of the Midtown Greenway would not have as large an effect on people's bicycling behavior as those who now live closer to a high quality off-street bicycle facility. It may also mean that if these other facilities were not present the area in which the number of crashes was reduced by the opening of the Midtown Greenway would be larger.

### **4.4 Conclusions**

This study shows that in the years following the opening of the Phase-1 of the Midtown Greenway there has been a decrease in the number of bicycle crashes in the area immediately adjacent to the Greenway. Although the transferability of the results of this study to other off-street bicycle facilities may be limited, it does present a methodology that can be used to measure the effect of building a bicycle facility on the safety of bicycling in the area. Questions remain about the safety of off-street bicycle facilities that force bicyclists to cross streets. However, the study should demonstrate that if off-street bicycle facilities are built similar to the Midtown Greenway, with few at-grade crossings, there will be a reduction in bicycle crashes in the area adjacent the facility.

In addition, the findings of the study suggest that high quality bicycle facilities, which allow bicycles to travel without crossing streets, should be located approximately every 2 kilometers. This interval is closer than Krizek, et al.'s previous findings "...that off-road bicycle facilities would ideally be located 2.41 to 3.21 km (1.5 to 2 miles) from one another (1)." That study looked at how far bicycle facility users travel to use a facility.

## **5. Summary of the impacts of the Midtown Greenway**

The Twin Cities Metropolitan Area has added several new bicycle facilities in the last 15 years, the most widely publicized of these bicycle facilities is the Midtown Greenway. The Midtown Greenway runs through several different neighborhoods, including the Chain of Lakes on the west end, the Uptown neighborhood, neighborhoods near I-35W, and along the Mississippi River.

The Greenway construction was spread over three phases. Phase-1, which opened in 2000, extends from the western edge of Minneapolis, between Lake Calhoun and Lake of the Isles, to 5th Avenue E. Phase-2, which opened in 2004, extends from 5th Avenue E. to Hiawatha Avenue. Phase-3, the most recent phase which opened in the fall of 2006, extends from Hiawatha Avenue to the Mississippi River.

The Greenway not only connects city parks and trail systems from the Chain of Lakes to the Mississippi, but is also an integral part of a larger system of regional bike facilities that stretches from Carver County to the Mississippi River that includes over 73 miles of continuous off-street facilities. Regional plans include expanding the network over the Mississippi river into St. Paul and east to the St. Croix River, the Minnesota-Wisconsin border. The Greenway is directly connected to the 17-mile network of on-street facilities located in Downtown and South Minneapolis.

As part of the project, the research team conducted a series of evaluations regarding the impacts of the Midtown Greenway. The Midtown Greenway was a key facility in three of the examinations included in this report: the examination of bicycle facilities on property values, the survey of neighborhood residents that was used to determine how far people were willing to travel to use a bicycle facility, and the examination of the relationship between bicycle facilities and safety in the corridor.

The Midtown Greenway is beginning to show some positive impacts on the surrounding community, even before the facility was completed. The largest of these is a decrease in the number of bicycle crashes on the streets immediately adjacent to the Midtown Greenway. This finding indicates that when off-street bicycle facilities provide bicyclists with the ability to travel extended distances without crossing streets, there is an increased level of the safety provided to the bicyclists.

Some of the indicators, such as property values, are not yet reflecting an impact from the Greenway. It should be noted that several new condominium projects are now under-construction along the Greenway. With the recent development pressure in the corridor, property values are something that should continue to be monitored over time. The change in development pressures is evident by the increase in the number of owner-occupied housing. Of the 33 census tracts that did not have 30 owner-occupied homes sales in either the 2 years before or after the completion of the Greenway, 27 of them were within three kilometers of the Midtown Greenway. All 27 of these tracts experienced an increase in the number of owner-occupied housing units from 1998-9 to

the 2004-5. As a whole, these 27 census tracts experienced an increase in the number of owner-occupied homes purchased from 354 in 1998-9 to 1,526 in 2004-5. This is an indication that area around the Midtown Greenway is experiencing a shift in the real estate market that was not picked up in the examination of property values, due to small samples. Over time, it is likely that this large influx of new homeowners to the neighborhoods will have an impact on the property values of the neighborhood. The impact of bicycle facilities on the real estate market is something that should be examined further in future studies.

The distance decay curves that were developed from the survey of residents of the area around the Greenway had the same general shape as those of the other study areas. However, it showed a lower overall percent of the residents using the facility. This raises interesting questions as to why the curve is shifted downward 20%-40%. It is most likely the result of a combination of factors. One reason is that there other regional bicycle facilities in the area around the Midtown Greenway (including the Chain of Lakes Trail system) providing bicyclists, in particular recreational bicyclists, with another location to bicycle. The Chain of Lakes Trails would generally be considered a more scenic place to ride with its views of lakes and Downtown Minneapolis' skyline. As the Greenway is located in a more urban environment, there is a greater mix of land uses along with a grid network of streets in the area, providing bicyclists who are bicycling for commuting or shopping purposes with multiple routes to bicycle to their destination without using the Greenway. The newness of the Midtown Greenway may also be a factor in that not all bicyclists in the area have begun to shift their routes to incorporate the Midtown Greenway. The interesting aspect is that although the percent of residents using the facility is lower it appears that the curve has the same shape. This indicates that there is some potential for being able to predict how many of the residents who live at various distances from the facility will use a bicycle facility if they know how many people use the facility at another distance.



## 6. Application—Classroom Exercise

In an effort to coordinate the University's research efforts with the teaching aspects of the University, the research team engaged students from a graduate Planning and Civil Engineering course, focused on land use and transportation. The 25 students in the class were asked to incorporate the on-line tool as part of a land bridge assignment. The students used the on-line tool to evaluate the benefits and costs of incorporating a bicycle facility into their study areas.

The assignment requires the students to create a development plan for a land bridge over an urban freeway, including appropriate links to the surrounding community. The land bridge assignment provides students with the opportunity to be creative and work from a clean slate as they design for development; however, at the same time it provides them with the challenge of blending the new development in the existing surroundings. We asked the students to use the on-line tool to examine the feasibility of adding a bicycle facility to their proposed land bridge assignment and to write a memo regarding their impressions regarding the on-line tool. The memo was to include their overall impressions, its ability to help them in an academic setting, and recommended improvements to the on-line tool. Their feedback, collected by a survey and a one-page memo, on the on-line tool was refreshing and provided the research team with issues that they had not previously considered.

The majority of the students, (83%) thought that the on-line tool was an extremely useful or useful way to learn about the planning and construction of a bicycle facility. In addition, 75% of the students felt that the on-line tool was extremely useful or useful in completing their land bridge assignment. The students found that certain aspects of the on-line tool added a great deal to the usefulness of the on-line tool. The glossary of terms and the Primer on Design were two attributes that the students repeatedly found to be beneficial as they worked through their assignment. The students liked that the Primer on Design used the technical and industrial terms, and that the terms were defined in the glossary. They found that the combination of both the Primer and glossary helped them to expand their knowledge of bicycle facilities planning.

Several of the students mentioned that they appreciated how detailed the cost worksheet was. The detail of the tool forced them to think about what it would take to look at all aspects of the design. The students saw the value of working through the details of a project. Several of the students commented on the detailed planning that is involved in planning a transportation facility.

In general, students reported that they found the tool to be navigable and intuitive. Some of the students commented that they would appreciate having information from the Primer on Design at various steps in the cost matrix. However, other students commented that the lack of clutter on the screen was much appreciated. The students also discussed three other concerns or potential improvements that could be made to the website.

1. They reported having difficulty tracking down population density and median sale price of homes for the area around their facility. Many of the students recommended adding a link to the Census Bureau's website.
2. Students found the use of various units of measure to be confusing.
3. The students recommended adding mapping capabilities, most likely using a Geographic Information Systems (GIS) base. Mapping capabilities would allow the user to add the proposed bicycle facility and the computer would then determine the length and attributes of the area around the facility, based on census data.

The research team incorporated their concerns into the modifications to the on-line tool. The research team removed the questions about population density and median sale price from the input form; they were not being used in calculations. However, the students reported difficulty in collecting this information raises questions about potential users' willingness to gather necessary data.

We believe that the second concern, confusion regarding the various units of measure, stemmed from 2 separate issues. The first being that some of the students did not realize the program has a toggle switch. To address this issue, metric will be the default unit of measure for both the cost and demand calculations. The second issue comes from the question regarding population density. The demand inputs screen asks the user to enter the population density within 800 m of the facility and requests population density be given in people per sq. mile. Although the research team understands the confusion, each unit was selected for a reason. Meters were selected because the underlining research that the calculations are based in uses the metric system. The research team chose to request population density in square miles because this is how the U.S. Census Bureau reports population density and it was decided the on-line tool could do the conversion more efficiently than most of the users.

The idea of having an interactive map that would allow the user to map out possible facility routes, similar to those found on Google's pedometer <http://www.gmap-pedometer.com/> would greatly enhance the on-line tool. Unfortunately, building this type of capabilities into the on-line tool at this time is just beyond the scope of work. However, as technology becomes more and more accessible, it is likely that in the future, mapping capabilities can be built into the on-line tool.

## 7. Modifications to the Online Tool

The online tool, “Benefit-Cost Analysis of Bicycle Facilities,” seeks to quantify the impacts of building a new bicycle facility on the overall community. One of the most important elements in quantifying the impacts of a bicycle facility is determining how many additional bicyclists there will be in the community, as a result of the facility. The number of new cyclists is used in several of the other equations used to quantify the impacts of a bicycle facility.

### 7.1 Number of Induced Bicyclists

When the guidelines were originally created, the formula for determining the induced ridership was based on work by Krizek and Johnson (5). This work looked at the effect that living in proximity to trails has on a person’s likelihood to bicycle. The article concluded that those who lived within 400 meters of an on-street bicycle facility are more likely to bicycle than those who live more than 1,600 meters from the facility. In all other cases, both distance and types of facility, residents were more likely to ride a bicycle but not at a statistically insignificant level than those who lived more than 1,600 meters from a facility<sup>15</sup>. Since this was one of the first attempts at trying to quantify the impact of a bicycle facility on bicycle ridership, it provided the best guide for the number of induced bicyclists at the time. By liberally interpreting the confidence intervals used from this study, the tool uses the suggested direction and magnitude of the likelihood of residents of the area around the bicycle facility to cycle. The tool employs the following formulas:

New commuters = existing commuters · ( $L-1$ )

New adult cyclists = existing adult cyclists · ( $L-1$ )

New child cyclists = existing child cyclists · ( $L-1$ )

Where:

$$L_{400m} = 2.04$$

$$L_{800m} = 1.54$$

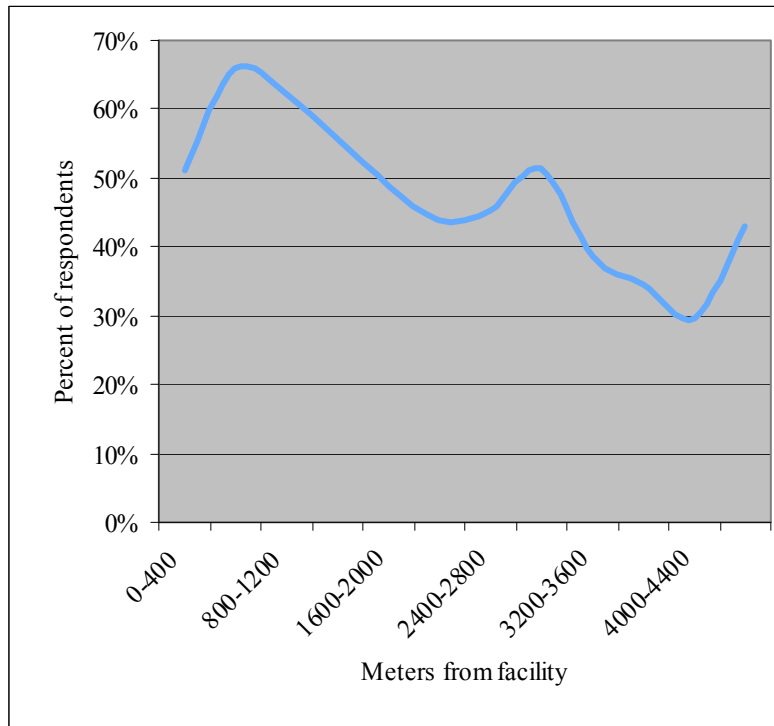
$$L_{1200m} = 1.21$$

Through further research, a longitudinal study (38) and a survey of residents, it became possible to more accurately predict the likely number of induced bicyclists. A mail-out survey was administered to people who lived in one of three study areas that were identified by their proximity to a bicycle facility. Each study area had differing development patterns: dense urban, inner-ring suburban and outer suburban. The survey respondents were asked about their use of the bicycle facility closest to their home (See Figure 16). The resulting curve showed a clear pattern for respondents who live within 2,400 m of the facility. Beyond 2,400 m, there seemed to be little correlation with the distance to the facility and the percent of respondents who use the facility. This finding is

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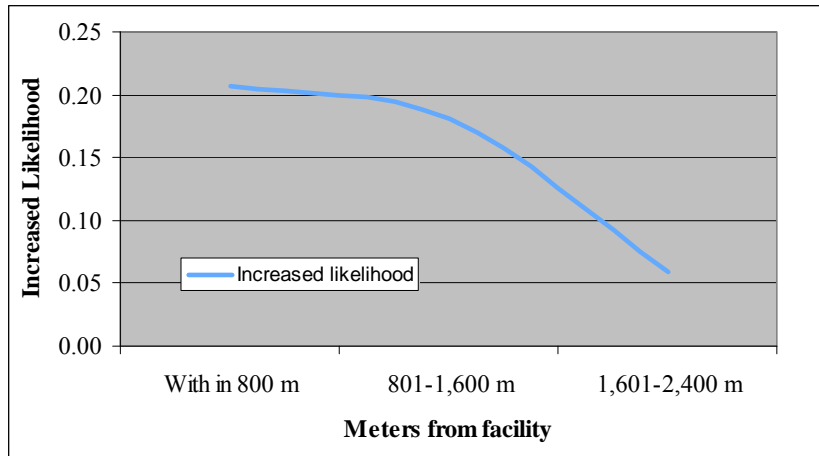
<sup>15</sup> This may be partially explained by the later work of Krizek et al. that found that bicyclists would travel up to 2,500 km (or just over 1.5 miles) to use a facility (37). The later evidence indicates that bicycle facilities have an effect on the behavior of people who live further from the facility than originally suspected.

similar to the results of a survey administered to trail users that found more than half of the users cycled less than 2,500 m to reach the facility (37).



**Figure 16. Percent of survey respondents who use facility closest to their home by distance they live from facility**

The survey seems to indicate that the geographic area that the facilities are inducing riders from is larger (2,400 m) than was assumed in the original online tool (1,200 m). However, the survey did indicate everyone within 2,400 m of the facility would not be affected to the same degree. Looking at the respondents who lived beyond 2,400 m, under the assumption that their decision to cycle is not dependant on proximity to the facility, we determine what percent of the respondents use the facility. Using the people who live beyond 2,400 m for comparison, we determine how much more likely people who live closer to the facility are to bicycle by subtracting the rate that they use the facility from the rate of use of those who live beyond 2,400 m (See Figure 17).



**Figure 17. Increase in likelihood of using a facility based on residential proximity to the facility**

Using these new likelihood factors creates a new equation for induced bicycle ridership:

New commuters = existing commuters  $\cdot (L_i)$

New adult cyclists = existing adult cyclists  $\cdot (L_i)$

New child cyclists = existing child cyclists  $\cdot (L_i)$

Where:

$$L_{800m} = 0.21$$

$$L_{1600m} = 0.18$$

$$L_{2400m} = 0.06$$

In addition to the survey of people who live near a bicycle facility a longitudinal analysis was done to look at the changes in bicycle commute share in TAZs near bicycle facilities constructed during the 1990's (38). This was done by comparing the bicycle commute mode share in 1990 and 2000 for TAZs which have their center within 1 mile (1.61 km) of a new bicycle facility in Minneapolis or St. Paul. The study showed increases in the bicycle commute mode shares in the TAZs near the new bicycle facilities (See Table 12).

**Table 12. Longitudinal change in bicycle commute mode share**

Distance from facility	1990 Bicycle commute mode share	2000 Bicycle commute mode share	Difference in commute mode share
Minneapolis facilities 1,600 m	0.02423	0.02557	0.00134
St. Paul facilities 1,600 m	0.00855	0.01125	0.0027
All facilities 1,600 m	0.01859	0.02051	0.00192
TAZs beyond 1,600 m (still in central city)	0.00428	0.0052	0.00092
Suburban area	0.00187	0.00164	-0.00023

Each of these three studies measured the induced number of bicyclists using a slightly different method. In order to be better able to compare the results of the original method and survey method with the results of the longitudinal study, the calculations are worked out below. For the original method and survey method, assume a uniform population distribution and a bicycle commute share of 0.01 for the change in bicycle commuters (See Table 13, Table 14 & Table 15).

**Table 13. Original method for calculating induced cyclists**

Distance from facility	Population	Bicycle commute share	% of population that commutes	Existing commuters	L-1	Total # commuters	New commuters	New bicycle commute mode share	Difference in commute mode share
400 m	4,000	0.01	0.4	16	1.04	32.64	16.64	0.0204	0.0104
800 m	4,000	0.01	0.4	16	0.54	24.64	8.64	0.0154	0.0054
1,200 m	4,000	0.01	0.4	16	0.21	19.36	3.36	0.0121	0.0021
Total	12,000	0.01	0.4	48		76.64	28.64	0.016	0.00597

**Table 14. Survey method for calculating induced cyclists**

Distance from facility	Population	Bicycle commute share	% of population that commutes	Existing commuters	L	Total # commuters	New commuters	New bicycle commute mode share	Difference in commute mode share
800 m	8,000	0.01	0.4	32	0.21	38.72	6.72	0.0121	0.0021
1,600 m	8,000	0.01	0.4	32	0.18	37.76	5.76	0.0118	0.0018
2,400 m	8,000	0.01	0.4	32	0.06	33.92	1.92	0.0106	0.0006
Total	24,000	0.01	0.4	96		110.4	14.4	0.0115	0.0015

**Table 15. Comparing the different methods for calculating the induced bicycle commute mode share**

Method	Difference in commute mode share
Original method	0.00597
Survey method	0.0015
Longitudinal method Central Cities	0.00192
Longitudinal method Minneapolis	0.00134
Longitudinal method St. Paul	0.0027

The change in bicycle commute mode share created by the survey method of .00150 is similar to the rates identified in the longitudinal study (38). The survey method allows for differences in population density at different distances from the facility and the existing level of bicycling affecting the predicted number of induced bicyclists. The survey method predicts results similar to those discovered by the longitudinal study. For these reasons, the survey method has been incorporated into the online tool. Replacing the original method with the survey method has two effects on the results. It doubles the geographic area that is affected by the bicycle facility from 1,200 m to 2,400 m and decreases the rate at which residents closest to the facility are induced to bicycle. Figure 18 shows the difference in the geographic area that each of the methodologies includes in its area affected by the bicycle facility.

## 7.2 Mobility and Externality Benefit

When creating the original online tool, an assumption was made that the average bicycle commuter works 5 days a week, 50 weeks a year. Through further exploration into likely

amounts that bicycle commuters will work, the assumption was changed to 47 weeks. This assumption is based on 10 days of holiday and 15 days of vacation and/or sick leave.

### **7.3 Property Values**

Initially, the research team intended on including an impact of the bicycle facility on sale prices of residential real-estate. However, as Section 3. Effect of Bicycle Facilities on Housing Prices illustrated, our longitudinal analysis indicated that building bicycle facilities did not have a significant impact on sale prices of residential properties. For this reason, we did not add property values' benefit to the list of benefits calculated by the online tool.

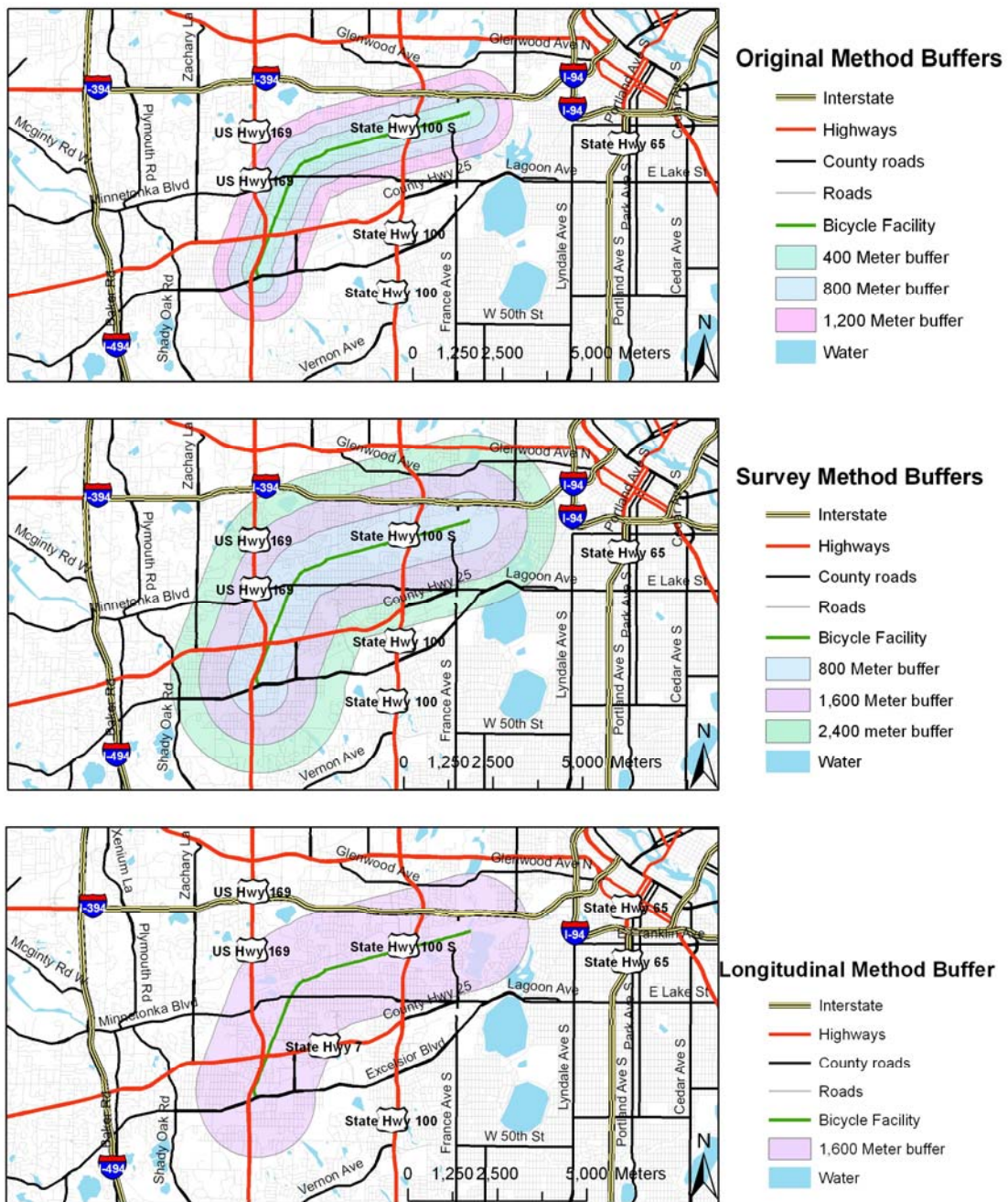


Figure 18. Difference in the Geographic Area influenced by the Bicycle Facility: by Method



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