Analyzing the Effect of Bicycle Facilities on Commute Mode Share over Time

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Abstract: This study employs United States census data to analyze changes in bicycle commuting between 1990 and 2000 in the Minneapolis-St. Paul, Minn. area. A variety of perspectives are used to understand the impact of newly created facilities. The evidence suggests that bicycle facilities significantly impact levels of bicycle commuting, although the results are not totally free of uncertainty. For example, areas near new bicycle facilities showed considerably more of an increase in bicycle mode share than areas farther away. Observing increased cycling due to these physical interventions provides a starting point to which future research could add detail that would be needed to guide infrastructure investment.

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Introduction

A central theme in recent planning and public health policy discussions aims to spur bicycle and pedestrian travel and overall levels of physical activity (Transportation Research Board 2005). A key dimension to such discussions revolves around the role of facilities. Such facilities come in the form of sidewalks, on-street bicycle lanes, off-street bicycle facilities, or some combination of the three. Several key transportation acts passed in the 1990s provided the resources to construct many such trails in urban areas. For example, the $286.4 billion transportation bill, SAFETEA-LU, provides substantial funds devoted exclusively to construct bicycle facilities. An implicit argument—and assumption—in such legislation is that building bicycle facilities will increase levels of bicycling. Such assertions are often bantered about by planning agencies and advocacy groups.

Providing research that can reliably support such an assertion is important, at least for policy purposes (Librett et al. 2003; Rietveld and Daniel 2004). However, this proves to be a task that has yet to be satisfactorily tackled in much of the academic literature for a variety of reasons because most applications have lacked clear conceptualization of the issues, been unable to employ sound research design, and have struggled with issues of measurement and sampling (see Krizek et al. 2009). The research presented herein aims to do so using longitudinal data from the United States census focusing on bicycle commute rates in the cities of Minneapolis and St. Paul, Minn. To our knowledge, our investigation is unique because it is longitudinal in nature, measuring rates of cycle commuting at two points in time (1990 and 2000) in relation to a series of interventions that happened between the two measures. The text that follows describes existing theory and literature related to this endeavor, the data used in our analysis, results, and a summary of the findings.

Background

There is considerable enthusiasm about the merits of bicycle trails and paths to induce use (Pucher et al. 1999). For example, existing studies have examined the use of particular trails (Troped et al. 2001; Lindsey and Doan 2002; Merom et al. 2003) or their impact on route choice decisions (Tilahun et al. 2004). Other research was among the first to explore such questions examining correlations between aggregate levels of bicycle infrastructure and commute rates (Nelson and Allen 1997); this work was later updated and enhanced by adding additional control measures (Dill 2003). Additional research has examined cycling use relative to proximity of facilities (Krizek and Johnson 2006). Other researchers have offered more general theories to explain induced cycling use (Pikora et al. 2003) and have even tested such claims (Cervero and Duncan 2003).

The bulk of existing work—if not all of it—tries to get at this question using cross-sectional data. The urban planning community is learning, not surprisingly, that things are not as simple as relying on findings from cross-sectional research. Analyzing a single policy or environmental change without fully capturing other important influences may lead to errant conclusions; in some cases it may even overstate outcomes about a particular policy or environmental change. Such factors hold particularly true for matters related to understanding the factors leading to people's decision to cycle. Trying to unravel such a decision-making web by isolating the specific role of cycling facilities is a complex endeavor.

Put another way—as any reliable textbook on statistics suggests—correlation does not mean causation. It is important to distinguish between the following: (1) documenting correlations

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between bicycle facilities versus (2) claiming that bicycle facilities will induce use. The majority of previous work on the subject has not adequately differentiated between the two. For example, residents (or families) often select locations to match their desires for certain behaviors, such as cycling (Krizek 2003). The locations have attractive options (e.g., bicycle paths) they prioritize in their home location. This suggests that differences in rates of cycling between households in different areas of the city with different access to cycling facilities should *not* be credited to facility alone; the differences should be attributed to self-selection. In other words, people who are likely to cycle choose to locate in a given neighborhood where they have a better chance of cycling.

The above considerations are particularly vexing for researchers aiming to shed light on debates and discussions around causality. Two phenomena can move together due to chance, or there could be bidirectional causality. What is the researcher of cycling behavior left to do? How can one reliably say that cycling facilities will increase levels of cycling? Is there an element of causality in such assertions and how strong is that assertion?

The issue of causality is undoubtedly a polemical one among social science researchers. Several texts prescribe various rules of thumb to follow to best infer elements of causality (Lieberson 1985; King et al. 1994), but there remains a formal prescription for doing so. In fact, in the social sciences and any research employing quasi-experimental research designs, it is often stated that one can never really prove causality (see Chap 9 in Lieberson 1985). However, the closest and most agreed upon guidelines that help move researchers further to inferring causality were reportedly first provided by John Stuart Mill (Mill 1843) who suggested that at least three conditions need to be met:

1. Concomitant variation is the extent to which a cause, X, and an effect, Y, occur together or vary together in the way predicted by the hypothesis under consideration (i.e., rates of cycling and the presence of a cycling facility);
2. The time order of occurrence condition states that the causing event must occur either before or simultaneously with the effect; it cannot occur afterwards (i.e., the cycling facility came before heightened levels of cycling); and
3. The absence of other possible causal factors means that the factor or variable being investigated should be the only possible causal explanation. This condition is the most difficult to satisfy. (For example, an additional causal explanation leading to heightened levels of cycling may be a result of what is commonly referred to as the “Lance Armstrong” factor. This is in reference to the fact that the United States experienced an overall cycling boom in 1999 and 2000—and hence increased rates of bicycle commuting—because of the increased popularity American Lance Armstrong brought to cycling after winning his first of seven races of the Tour de France).

The methodological approach described in this paper is based on premises outlined by the first two of these conditions *with an eye* toward understanding the third condition—a condition that is almost impossible to meet in social science research. This work employs a longitudinal method to determine the effect of constructing bicycle facilities in Minneapolis-St. Paul, Minn., on journey to work bicycle mode share. During the 1990s a number of new facilities were constructed 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 to existing facilities. As such, the central question in our research is: did constructing new bicycle facilities lead to an increase in bicycle commute rates to work between 1990 and 2000?

The analysis presented below compares bicycling commute rates in 1990 and 2000, primarily as a function of proximity or access to the new facilities. The first part of our analysis describes the new facilities, their service areas, and two buffering methods that characterize the area of influence of the facilities. The next section describes changes in bicycle commuting from several perspectives. The final section summarizes the analysis and offers suggestions for further work in this regard.

Methods

Describing New Facilities

Our research covers the cities of Minneapolis and St. Paul, which border one another and are the central downtown areas in the Twin Cities metropolitan area. The central business districts are about 16 km apart. Both cities are well endowed with on-street and off-street bicycle paths—a combined 96 km of on-street bicycle lanes and 198 km of off-street bicycle paths. Local residents use these trails heavily.

We identified bicycle facilities installed in Minneapolis and St. Paul during our study period, focusing on larger facilities likely to enhance accessibility to major employment centers (Fig. 1).

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 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 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 12.5 km through a former rail corridor from downtown Minneapolis to the southwest. The Kenilworth Trail is a 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 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 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,

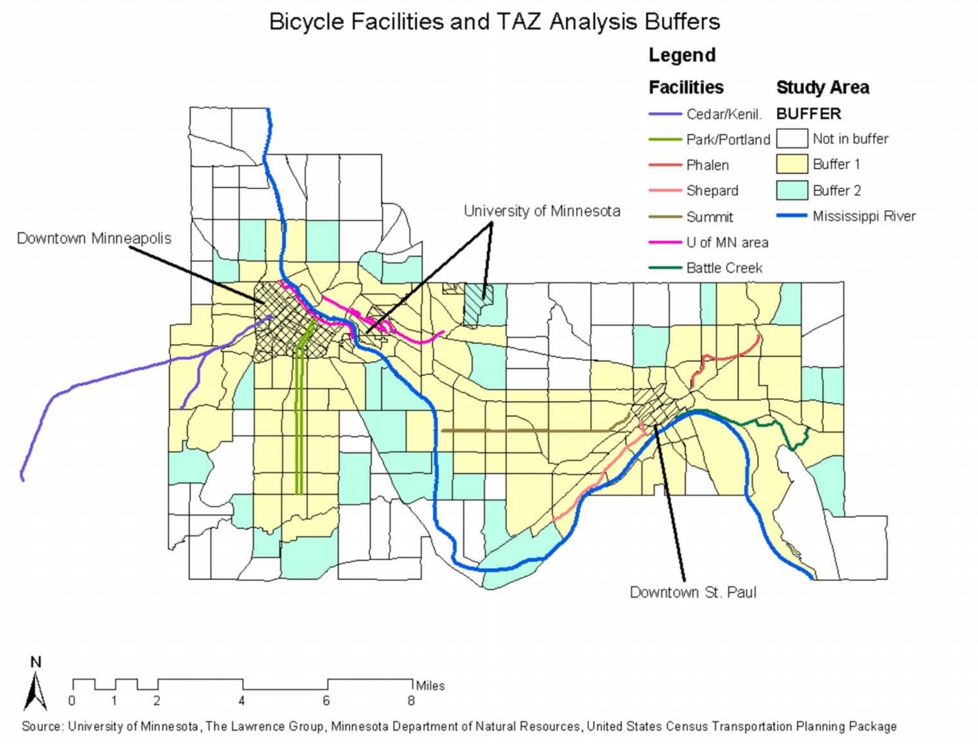

Fig. 1. Bicycle facilities and TAZ analysis buffers

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 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 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 Avenue/4th Street. University Avenue and 4th Street SE are parallel one-way streets near the University of Minnesota campus in Minneapolis. The facility on University is 2.5 km, while the lane on 4th St. SE is just 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 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.

University 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 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

The above list is relatively comprehensive in accounting for the full range of facilities constructed in the 1990s. However, it is necessary to mention that other—more minor—improvements were also made in select areas. Such improvements, however, were not included in this analysis for two reasons. First, we sought to examine facilities that were long enough to have an impact over a fairly large area. This eliminated a number of relative "spot" improvements (e.g., short lane stripings) or treatments to select intersections. Second, our longitudinal use data are limited to commuting trips. We therefore restricted the analysis to facilities that provided route access to employment sites, either directly or by linking to existing facilities. For example, new or upgraded facilities in parks or around lakes that did not provide access to any major employment sites were not included.

There were also facilities, both on and off street, created in the suburban areas in 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 not to serve major employment concentrations.

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 100–400 m across. We first selected TAZs for analysis if their geographic centroids lay within 1.6 km (1 m) of a facility (referred to here as Buffer 1). The second technique extended Buffer 1 by an additional 0.8 km (0.5 m) 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 areas 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 the 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 even more complexity.

For purposes of this analysis, 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 we do not suspect they affect an analysis based on where people live, since both commuters who live in facility buffers and those that do not 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:

1. Shares for TAZs in facility buffers versus those that are not;
2. Shares for the areas around individual facilities;
3. Share for trips crossing the Mississippi River; and
4. 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) (Census 1990 and 2000) reports mode choice at the TAZ level from three different perspectives. 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. 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 these are suppressed due to confidentiality issues, as point-to-point flows are often quite small.

Calculating Bicycle Mode Share and Statistical Significance

In this analysis, 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 of proportion of bicyclists—the number of bicycle commuters divided by the total number of commuters. The standard deviation of this distribution is provided by Eq. (1) (represented below as the raw standard deviation, not the proportion)

$$\text{standard deviation} = (\mathrm{N}^*\mathrm{p}^*(1-p))^{(1/2)} \tag{1}$$

…where N=total sample size; and p=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. The above analysis strategy is represent in the tables in this paper in its own column; a “2” means that the observed number exceeds the 1990 rate by at least 2 SD, “1” exceeds by at least 1 SD, and “0” is less than 1 SD.

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 showed a statistically significant increase in bicycle mode share, the areas in the facility buffers showed a larger increase (Table 1).

Viewing St. Paul and Minneapolis separately, somewhat differing results emerge. Minneapolis has a higher bicycle mode share than St. Paul, probably owing a large extent to the presence of students at the University of Minnesota campus. Both cities showed increased bicycle mode share, with the areas in facility buffers showing generally larger increases (Table 2). An interest-

Table 1. Twin Cities Metro Area Bicycle Commute Share, 1990–2000

	1990 bicycle mode share (%)	2000 bicycle mode share (%)	Significance	2000 sample size
All Metro	0.442	0.462	1	212,963
Noncentral city TAZs	0.187	0.164	−2	161,090
Central city TAZs	1.153	1.386	2	51,873
TAZs in Buffer 1	1.563	1.775	2	28,325
TAZs in Buffer 2	1.023	1.491	2	8,007
TAZs outside buffers	0.510	0.627	2	15,541

ing 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.

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 (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 almost 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.

River Crossings

Some of the above facilities (University/4th Ave., Summit, West River Parkway) touch and incorporate a number of Mississippi

Table 2. Minneapolis and St. Paul Bicycle Commute Share, 1990–2000

	1990 bicycle mode share (%)	2000 bicycle mode share (%)	Significance	2000 sample size
St. Paul	0.528	0.681	2	21,262
TAZs in Buffer 1	0.559	0.797	2	12,616
TAZs in Buffer 2	0.493	0.408	0	2,824
Zones outside buffers	0.476	0.566	1	5,822
Minneapolis	1.596	1.876	2	30,611
TAZs in Buffer 1	2.423	2.557	1	15,709
TAZs in Buffer 2	1.309	2.081	2	5,183
TAZs outside buffers	0.530	0.664	1	9,719

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

Facility buffer	1990 bicycle mode share (%)	2000 bicycle mode share (%)	Significance	2000 sample size[a]
Battle Creek	0.206	0.392	2	4,051
Cedar Lake-Kenilworth	1.497	2.138	2	9,291
Park-Portland	1.493	1.830	2	8,800
Phalen	0.181	0.403	2	4,645
Shepard	0.265	0.443	2	5,208
Summit	0.664	1.275	2	8,894
Univ. of Minnesota	3.515	3.280	0	8,308

[a]Major areas of buffer overlap near downtown Minneapolis were assigned to Univ. of Minnesota facility and excluded from others. Other, smaller areas of overlap remain and cause the total sample size for facilities to be larger than the overall total.

Table 4. Minneapolis and St. Paul River Crossing Bicycle Commute Share, 1990–2000

	1990 bicycle mode share (%)	2000 bicycle mode share (%)	Significance	2000 sample size[a]
Trips crossing south-flowing portion of Mississippi River	3.021	4.604	2	1,606
Trips originating and terminating west of the Mississippi River	2.228	2.585	1	4,465
Trips originating and terminating east of the Mississippi River	1.982	2.775	2	4,148

[a]Sample sizes here are much smaller than the central city residential totals because not all residents work in the central cities, and because many small flows are not reported in the Part 3 data from which this table was derived.

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 (Table 4).

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

The last part of our 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 (Table 5).

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 some may prefer 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

The most difficult guideline to satisfy for inferring causality—the absence of other causal factors—is the topic on which we now briefly comment. As mentioned above, claiming to *completely* rule out confounding explanations in social science research is borderline impossible. Indeed, there are a seemingly countless array of factors that could also be at work. These range from relatively large sways in gentrification, influx of residents of certain socio-demographic characteristics, ambitious public awareness campaigns by the city and advocacy groups, people changing their employment locations, warmer weather, worse congestion, increasing anticar sentiments—the list goes on.

The most likely candidate of the explanations is that the demographic and economic composition of the areas studied may 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, the analysis suggests that demographic variables are not as important to cycling rates as they are often asserted. For

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

Trips to major employment/activity centers	1990 bicycle mode share (%)	2000 bicycle mode share (%)	Significance	2000 sample size[a]
Univ. of Minnesota—Minneapolis campus	2.820	3.313	2	4,855
Downtown Minneapolis	0.788	0.841	1	21,111
Downtown St. Paul	0.335	0.279	−1	9,016

[a]These numbers are taken from the Part 2 data and thus include commuters who live outside the central cities.

Table 6. Age and Income by Area

	Percent with peak income (%)	Percent with peak age (%)	Percent with both (%)
All Metro	44	64	26
Noncentral city TAZs	45	62	25
Central city TAZs	41	71	28
TAZs in buffers	43	72	30
TAZs outside buffers	37	69	24

age, income, and education level, the range in cycling rates is only a factor of two (Barnes and Krizek 2005). In other words, even if people of the "right type" (e.g., relatively affluent, male, and between the ages of 18 and 40) were 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, the areas studied in this analysis had differences many times larger.

A more telling point is that there are only small demographic differences across the 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.

The suburbs have slightly fewer commuters in the peak age group, but more commuters in the peak income category than in 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 nonbuffer areas. Given that the rate of bike commuting is about four times higher in the nonbuffer 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.

Conclusion

The evidence here suggests that bicycle facilities significantly impacted levels of bicycle commuting. In the aggregate, areas closer to 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 also require a somewhat nuanced understanding. 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 immediate downtown areas showed little or no gain in bicycle commuting, although they were the targets of most of the new facilities, and the areas around the facilities showed substantial increases.

Furthermore, and as cautioned by any interpretation trying to infer causality, the relative impact of the facility is just one part of the story. The already heightened levels of cycling, pre-1990, in many of the areas suggest there is a strong cycling ethic in select pockets. Thus, it is possible that facilities might be the effect, rather than the cause, of high bicycle use because the people lobbied for the construction of such facilities. 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. This research could be used to further refine methods and approaches urged in the past (Porter et al. 1999) but offered by other recent work (Lindsey et al. 2007) to predict levels of use vis-à-vis the onset of new facilities.

There are a number of further lines of work that could add more insight to this analysis. One would be experimenting with alternative 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. The problem with robustly analyzing is that it requires extremely large sums of data to appropriately document the extremely low levels of cycling use currently in the suburbs.

While there are several opportunities to strengthen this approach in other settings, the fact that this straightforward analysis demonstrates a clear 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.

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