acknowledge the support by FHWA in this study and its permission to use these materials for this paper. The opinions and viewpoints expressed in this paper are entirely ours and do not necessarily reflect the policies or programs of FHWA or of any state or local agency.

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Transportation Control Measure Analysis: Bicycle Facilities

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The Clean Air Act Amendments of 1977 require that areas that have air quality problems examine their transportation system and implement measures to reduce automobile emissions. One of these measures is the improvement of bicycle facilities. The purpose of this paper is to determine the air quality impact and cost-effectiveness of bicycle facilities as a transportation control measure (TCM) for air quality in northeastern Illinois. A case study, based on a survey of the users of commuter bicycle parking at a commuter railroad station and a rapid transit station in a Chicago suburb has been used to determine these impacts. In addition to the air quality benefits and associated costs of current levels of commuter bicycling in Wilmette, some theoretical benefits and costs are calculated by extrapolation from the survey data and application of available ridership information for one of the stations. From the current level of bicycle trips to the station and the theoretical limit of potential trips, a range of possible emission reductions and costs are calculated. Actual potential air quality benefits and costs lie somewhere within this range. Bicycle facilities are implemented locally and bicycling activity varies considerably from one community to another. For these reasons, the impacts of bicycling are best considered at the local scale. For comparison to other TCMs, cost-effectiveness figures can be used. Even fairly expensive bicycle support facilities are found to be very cost effective for air quality improvement in relation to other measures. Each TCM must be evaluated for its socioeconomic as well as its air quality impact. This evaluation is also presented. Bicycle facilities are found to have few socioeconomic drawbacks.

Bicycle facilities are one of the transportation control measures (TCMs) identified by the Clean Air Act Amendments of 1977 for evaluation as a technique to decrease dependence on automobiles and thereby improve air quality. The Clean Air Act of 1970 requires that each TCM be evaluated for its feasibility for use by regions that have air quality problems. The common measure of feasibility used in northeastern Illinois (a six-county area that surrounds and includes Chicago) is the cost per ton of pollutant eliminated by a TCM. This report evaluates the cost-effectiveness for air quality improvement of bicycle facilities for commuters at transit stations. In addition, a socioeconomic impacts assessment required for all TCMs is included.

The analysis of air quality benefits potentially attributable to bicycling depends on estimates of existing and potential bicycling patterns in the region. Bicycle trips neither cause nor decrease air pollution--only when bicycle trips divert trips from other modes, primarily automobiles, can air quality improvements be credited to them. Buses cause pollution too, but an increase in bicycle use would have to be great before it caused a reduction of bus services. Therefore, it is the shift from automobiles to bicycles that must be quantified.

Transportation surveys have generally neglected to collect information on bicycle travel in this region, as well as elsewhere (1, p. 10). More specifically, the U.S. Environmental Protection Agency's (EPA) Bicycling and Air Quality Information Document, notes only one study (of a bicycle bridge in Eugene, Oregon) in which the modal shift from car to bicycle associated with a bicycle measure was quantified (1, p. 70). One other example is the Chicago Area Transportation Study's (CATS) analysis of new storage facilities installed by the Illinois Department of Transportation at commuter rail stations (2).

These studies represent the most direct way to forecast potential demand for bicycle facilities and resulting air quality improvements. The ideal study to forecast potential demand for bicycle facilities would combine the measurement of actual changes in use in response to new facilities with surveys that question users about mode change. If controlled for other variables, this information could then be generalized to similar locations where facilities are being planned.

In northeastern Illinois, general information on bicycle use was calculated in 1978 by the Northeastern Illinois Planning Commission (3). This study provides an estimate of regional bicycle use and potential modal shifts. By using a method developed by Carl Ohrn for Barton-Aschman Associates, it was determined that 10.4 percent of all home-based trips could be attracted to the bicycle if a complete grid of bikeways and appropriate support facilities were provided. By applying regional data developed by CATS, an estimate can be made of automobile vehicle miles of travel (VMT) that could be diverted to bicycles.

There are two major problems with this approach. First, Ohrn's percentages assigned to potential bicycle use are based on a comprehensive grid system of class 1 and 2 bikeways in the region. Such a system would be technically infeasible as well as economically and politically impossible in many parts of the region. Also, the idea that bikeway construction is generally the best way to encourage bicycling is a subject of controversy. Second, the costs associated with this regional estimate are impossible to determine. Since cost-effectiveness figures are needed to compare one TCM with another, a different approach is needed to establish air quality benefits attributable to bicycle facilities.

For this study, a demonstration project was not possible and a review of the literature did not uncover a reasonable model for estimating modal shift from cars to bicycles. Instead, an existing facility in the region is analyzed by observing the bicycle use and by surveying bicyclists about their modes of transportation when they are not bicycling. This type of survey reveals the existing use patterns associated with this facility. Results of the survey are used to calculate VMT and associated pollution diverted by the users of this facility. The costs associated with this system and the cost per ton of emissions diverted are then calculated.

The survey results, however, do not indicate what the use pattern was before the present facilities were installed nor what further use could be stimulated by other facilities. One approach to the problem of estimating future use is to calculate a demand range. A demand range defines the lowest and highest possible bicycle use for a given purpose or facility (4). A reasonable estimate of the potential use that might be stimulated by measures to increase bicycle use lies somewhere between these extremes.

In this study, a demand range is used to identify these extremes and a range of emissions reductions and costs that are associated with bicycle use are then calculated. Potential demand is not identified because to do so would require as complete an analysis as possible of the many factors known to influence bicycle users. Also, a demand range can be generalized with greater confidence than can a potential level of use estimated for a specific community.

Twenty-seven factors associated with bicycle use have been identified by EPA (1, p. 16). One factor, climate, is relatively quantifiable and generally consistent throughout the northeastern Illinois region. Previous estimates of potential bicycle use for this region have not attempted to take account of weather. Since climate determines the number of cycling days for most bicyclists, it is an important factor in calculating use and therefore has been taken into account in calculations of the emissions saved in this case study. Climate is especially significant in relation to air quality. For example, although bicycling occurs primarily within just a seven-month period from April through October, this period coincides with the season of highest ozone readings.

We could argue that the air quality impact of a shift from cars to bicycles should be weighted to reflect this coincidence. This operation is beyond the scope of this report; however, note that the overall air quality benefits attributable to bicycling might be greater than those calculated due to the coincidence of the bicycling and ozone seasons.

METHODOLOGY

This report analyzes the air quality benefits attributable to bicycling by commuters who park their bicycles at the two commuter stations in Wilmette, a suburb of Chicago--the Chicago North Western Railroad (CNW) and the Chicago Transit Authority (CTA). The trip from home to transit station has good potential for diversion from automobiles to bicycles since it often involves a reasonable distance to bicycle by people who are carrying a light load.

The community of Wilmette was chosen because it has relatively better facilities than other communities for bicycle and transit commuters. Bicyclists were surveyed at both locations and emissions reductions attributable to bicycle use are calculated for trips to both. A demand range is calculated for only the CNW station because the necessary residential information was available for that station alone.

The bicyclists were surveyed at the two stations on May 7, 1980, during the morning-rush period (6:15-9:30 a.m.). Each cyclist answered three questions concerning bicycling to the transit stations:

1. How far does he or she cycle to get to the station?
2. How often does he or she cycle to the station? and
3. How does he or she get there when not bicycling--walk, bus, drive, automobile passenger, or drive to the city?

Virtually every cyclist was approached and out of a total of 96 bicycles parked at the two locations, 88 cyclists responded to these questions.

For those respondents who use a car for some or all of their trips (when not cycling) the VMT not traveled by car when the person cycled is calculated. Some of these trips involve automobile drivers (park-and-ride), some automobile passengers (kiss-and-ride), and some who drive to the city when not cycling to the station. The kiss-and-ride trips are assigned twice the VMT as the park-and-ride trips. Those who always bicycle and those who walk or take the bus when not cycling are not counted as having diverted automobile VMT when bicycling.

Wilmette has a large transit ridership and a good bus system. The bus service in some communities is not as good as in Wilmette. In Wilmette, even a very high level of bicycling would probably not affect bus ridership enough to cause a reduction of bus service. Therefore, diversions from bus to bicycle are not expected to have any air quality impact. In communities that have poor or nonexistent bus service, bicycle-support facilities might have a greater air quality impact because more trips per capita are currently being made by car that could be diverted to bicycles. For this reason, the VMT diversions and the air quality impacts for Wilmette as the transportation mix now exists and as it might be without a bus system are calculated. The automobile VMT that would be diverted by bicycling if no bus service existed is calculated by dividing the bus trips between park-and-ride and kiss-and-ride in the proportion represented by the survey responses.

CLIMATE

Weather was mentioned by many of the survey respondents, often spontaneously, when asked about the frequency of cycling to the station. The number of cycling days on which bicycle use could reasonably be expected are calculated and the yearly calculations of actual and potential emission reduction are based on that number of days.

April through October has been chosen as a reasonable bicycling season in the Chicago area. At least half of the days in these months have low temperatures no colder than 40°F. Low temperatures are usually late night or early morning readings so the daytime temperature on a day when the low is 40°F will usually be between 45° and 80°F. In addition to cold weather, precipitation is a deterrent to bicycle riding. Since this study deals with commuters, the probable monthly bicycling days based on 5 days per week, or an average of 21 days per month, are calculated.

The number of cycling days per year are determined by subtracting the number of days with measurable precipitation from these months. This number represents the minimum number of cycle days; a number of respondents indicated that they also cycle in inclement weather. A Boston survey found that cycling activity decreases when the temperature is below 40°F; however, the effect of temperature may be overestimated. The Boston survey found that 10 percent of the student population bicycled for 10-12 months of the year, and 22 percent bicycled for 6 to 9 months (1, p. 18).

Precipitation is probably more inhibiting than temperature (1, p. 18). The average number of days that have measurable precipitation for the seven-month bicycling season is 9.5 days/month. Therefore, the average number of cycling days per 217-day season is

31 - 9.5 = 21.5 x 7 months = 150.5 cycling days/year.

If this number is factored for a five-day workweek (21-day work month and 147-day season), the commuter cycling days can be determined as follows:

9.5 ÷ 31 = 0.306 x 21 = 6.43 rain days

21 - 6.43 = 14.57 x 7 months = 102 commuter cycle days/year.

The VMT per day diverted were multiplied by the number of commuter cycling days and the emissions diverted were calculated according to EPA Mobile 1 model for 1982 emissions. The same calculations were done for the without bus service scenario with the reported bus trips divided between the two types of automobile trips according to their actual distribution among those surveyed. These calculations are done for the CNW and CTA stations.

A demand range is calculated for the CNW station alone. The actual use observed and emissions eliminated by the present facilities serve as the low end of the demand range. The high end (or theoretical limit) for bicycle demand for this trip is calculated by using information on the percentage of CNW riders who live within average bicycling distance of the station (4). Emissions reductions and costs are calculated for the low and high ends of the demand range. The costs attributed to the lowest (current) level of bicycling to the station are those of the current parking facilities. Assigned to the highest level (theoretical limit) of bicycling are the costs of improved parking facilities and a rules-of-the-road enforcement program that, although not wholly attributable to commuter activity, would be necessary if bicycling increased greatly during the morning rush hour. The lowest level of bicycle demand (present actual use) and the theoretical limit for demand thereby define a range of potential demand, associated emissions reductions, and costs per ton of pollutant eliminated.

RESULTS

The number of bicycles in the racks at the end of the survey period was 75 at the CNW station and 21 at the CTA station. These numbers are consistent with the numbers counted on May 6 and are probably typical for a fair day at this time of year. The 75 cyclists at the CNW station represent 5.3 percent of the regular commuter riders at that station based on a daily average ridership of 1421 (5). The 21 cyclists parked at the Linden CTA station represent 0.85 percent of the morning rush-hour ridership (6). The average trips of the bicyclists surveyed were 1.33 miles at the CNW station and 1.7 miles at the CTA station. The longest trip to the CNW station was 3 miles and to the CTA station, 5 miles.

The survey answers also indicate that most of those commuters who bicycle to the station do so daily during the bicycling season. This finding indicates that bicycles are being used as a regular transport alternative.

Emissions Calculations

Most bicycle trips to commuter stations are less than 2 miles. Cold-start emissions, at an average speed of 18 mph, last for 505 s, in which time the car would travel approximately 2.5 miles. Therefore, most bicycle trips to commuter stations that replace automobile trips are replacing trips made in the cold-start phase. The calculations for diverted emissions are based on EPA 1982, 100 percent cold-start emission factors (7).

Calculations are made for the three dominant pollutants associated with automobile use: hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxide (NO_x). The calculations for the actual automobile VMT diverted (with and without bus service) by current bicycle trips to the two stations are summarized in Table 1. These calculations represent the air quality benefits attributable to the low end of the demand range. They are based on the number of automobile trips being diverted by the current bicycle trips to the commuter stations.

Table 1. Low estimate of demand range.

Item	CNW Station (n = 71)	CTA Station (n = 17)
VMT/day by bicycle	181.4	51.8
VMT/day diverted from automobile	54.08	47.6
VMT/day that would be diverted from automobile if no bus service available	155.3	87.4
Air quality benefits with bus service (tons/year)		
HC[a]	0.035	0.031
CO[b]	0.472	0.415
NO_x[c]	0.015	0.014
Air quality benefits for similar community without bus service (tons/year)		
HC[a]	0.102	0.057
CO[b]	1.35	0.762
NO_x[c]	0.044	0.025

[a]Calculated by multiplying estimated hydrocarbon emissions (5.83 g/mile) by estimated VMT/day diverted from automobile travel by number of commuter cycling days/year (102).
[b]Calculated by multiplying carbon monoxide emissions (77.57 g/mile) by estimated VMT/day diverted from automobile travel by number of commuter cycling days/year (102).
[c]Calculated by multiplying nitrogen oxide emissions (2.54 g/mile) by estimated VMT/day diverted from automobile travel by number of commuter cycling days/year (102).

Reductions in automobile emissions due to bicycle use depend on the level of bicycle use and how many bicycle trips are replacing automobile trips. Estimates of potential reductions in emissions depend, in turn, on estimates of potential bicycle use or demand. Walsh (4) has suggested that a demand range be calculated by using a low estimate based on actual use and a high estimate based on the number of trips that could be made by bicycle. The length of the trips in the high estimate would be that of the average current trip made by bicycle.

The emissions diverted by the Wilmette bicycle trips represent the smallest benefit potentially attributable to that facility, the low estimate. The quantity of emissions diverted by all possible trips within the average trip-generating radius represents the highest benefit theoretically possible for that facility, the high estimate. Potential benefits lie somewhere in between.

A demand range can be calculated for the CNW bicycle commuters by using information on the residential distribution of CNW commuters. The average length of a one-way bicycle trip to the CNW station is 1.33 miles. Twenty-one percent of the regular commuters live within approximately 0.5 mile of the CNW station (8). These riders are most likely to walk to the station. [Seven of our respondents bicycled only 0.5 mile, but this must be compared with the 49 bicyclists within the 1- to 1.5-mile radius. Ohrn and others also identified 0.5 mile as a walking radius (9).] Almost 41 percent of the ridership live within the quarter-sections adjacent to the CNW station, which places them within the 0.5- to 1.5-mile radius associated with cycling by this survey and other studies (1, p. 17; 9). Daily ridership at the Wilmette station is 1421; 40.8 percent of this ridership (580 riders) would live within the average bicycling radius. Thus, the demand range varies between a low of 75 riders (71 surveyed plus 4 bicycles already parked) or 5.2 percent and a high of 580 riders or 40.8 percent ridership. Potential demand lies somewhere within the demand range. Walsh suggests that 50 percent of potential short-distance trips could be diverted to bicycles (4); in this case, 20.4 percent of the ridership. This is by other estimates a high figure. Bikeways in Northeastern Illinois suggests that 7.5 percent of trips to transit stations could potentially be diverted to bicycles (3, p. 39). In Madison, Wisconsin, 13 percent of all vehicle trips are made by bicycle (1, p. 10).

For the purposes of this analysis, the emissions that could be diverted at the high end of the demand range are calculated and, together with the low end calculations, serve as a range of emissions diverted. Some of the costs associated with approaching that limit are also computed and annualized. Minimum improvements needed for maximum bicycling activity would include increased storage facilities and a bicycle rules-of-the-road enforcement program.

If 5.2 percent of the CNW ridership diverts 54.08 miles of automobile traffic/day, then 40.8 percent of the CNW ridership would divert approximately 418.2 miles of automobile traffic/day with bus service. Were there no bus service, 155.3 miles would be diverted by current bicycling; 40.8 percent of the CNW boardings would divert approximately 1218 miles of automobile traffic/day without bus service. The high range of emissions associated with these VMT are summarized in the calculations below. These figures represent a theoretical limit rather than a potential estimate.

For the Wilmette CNW Station with bus service,

HC emissions = 5.8 g/mile x 418.2 mile = 2425.56 g/day x 102 days = 247 407.12 g/year = 0.273 tons/year.

CO emissions = 97.57 g/mile x 418.2 mile = 32 439.77 g/day x 102 days = 3 308 856.9 g/year = 3.65 tons/year.

NO_x emissions = 2.54 g/mile x 418.2 mile = 1 062.23 g/day x 102 days = 108 347.3 g/year = 0.119 tons/year.

For a similar community without bus service,

HC emissions = 5.8 g/mile x 1218 mile = 7064.4 g/day x 102 days = 720 568.8 g/year = 0.794 tons/year.

CO emissions = 77.57 g/mile x 1218 mile = 94 480.26 g/day x 102 days = 9 636 986.5 g/year = 10.62 tons/year

NO_x emissions = 2.54 g/mile x 1218 mile = 3093.72 g/day x 102 days = 315 559.44 g/year = 0.348 tons/year.

The range of emissions that can be saved by bicycling to the Wilmette CNW station and a similar station not served by bus are summarized in the list below.

The range of emissions eliminated in Wilmette with bus service is as follows:

HC, from 0.035 tons/year to 0.273 tons/year;
CO, from 0.472 tons/year to 3.76 tons/year; and
NO_x, from 0.015 tons/year to 0.119 tons/year.

For a similar community without bus service, the following range of emissions would be eliminated:

HC, from 0.102 tons/year to 0.794 tons/year;
CO, from 1.35 tons/year to 10.62 tons/year; and
NO_x, from 0.044 tons/year to 0.348 tons/year.

Cost-Effectiveness

Many costs and benefits can be attributed to bicycling. If the proportion of all bicycling for different purposes is known, then a portion of the costs of the entire bicycle support system (e.g., bicycle routes, automobile, parking, education, and promotion) can be assigned to each purpose. The amenities of the entire Wilmette bicycle system--on-street routes, signing and improvements, parking facilities, and a modest promotion and education program--serve commuters, but the cost of these facilities cannot be solely attributed to commuter bicycling. The costs of parking facilities at the two commuter stations are the main costs attributable to commuter bicycling.

Item	Cost ($)
CNW station parking	
Shelter for bicycle racks	14 000
Bicycle racks, two locations	1 200
	15 200
CTA station parking	
Bicycle racks	600
Total	15 800

If we assume a 10-year life for these facilities, the costs are annualized by using a 12 percent discount rate and a capital recovery rate of 0.177:

CNW: $15 200 x 0.177 = $2690.4/year.
CTA: $600 x 0.177 = $106.2/year.

The costs of eliminating air pollution with commuter bicycling to Wilmette's commuter rail and public transit stations are summarized in Table 2.

The minimum costs associated with provision for the 580 bicycles associated with the high end of the demand range would include 430 new parking spaces and a bicycle rules-of-the-road enforcement program such as was implemented in Niles, Illinois, to help alleviate some of the traffic conflicts that might occur with a large increase in bicycling (1, p. 48).

Niles adopted an enforcement program in which summer wardens stopped 6000 cyclists and issued warnings and instructions about proper bicycling techniques. Bicycle-related accidents in the town went from 17 to 3 during the summer of 1975. The cost of this program was the salary of the officer in charge of the program and approximately $14 000 for summer wardens and their uniforms. The $14 000 (inflated for 1980 dollars) can be solely attributed to bicycling improvement. An inflated cost of $22 400 for enforcement could justifiably be attributed to the high end of the demand range, but the police officer's time would probably be used in some other way were there no enforcement program. That salary will not be attributable to bicycling improvements.

If we assume that the new parking was comprised of 30 bicycle lockers and sheltered rack spaces for 400 bicycles, the costs of the high end of the demand range would be as follows:

Item	Cost ($)
30 bicycle lockers at $300/bicycle	9 000
400 bicycle rack spaces at $14 000/100	56 000
Enforcement program at $22 400/year	224 000
Total	289 000

Again, assuming a 10-year life for these facilities and a capital recovery factor of 0.177, the cost-effectiveness figures would be based on a cost of $53 843.40/year. These costs would be added to the costs already incurred at the CNW facility in Wilmette to determine the cost-effectiveness of the high end of the range:

$289 000 + 15 200 = $304 200.

The costs of eliminating one ton of each pollutant at the high end of the demand range are summarized in comparison to the low-end figures in Table 3.

Socioeconomic Impacts

The socioeconomic impacts for all of TCM evaluations for this region were prepared by James Jarzab of the Northeastern Illinois Planning Commission (10).

Improved bicycle facilities have few negative socioeconomic impacts associated with them. Improvements may entail the provision of racks and lockers, bicycle paths, and safety education programs; however, few of these activities can be considered drawbacks to the TCM. The two important factors that must be considered when contemplating improved bicycle facilities are safety and traffic operations. Increased bicycle use may cause additional safety problems and traffic might be disrupted if automobile and bicycle operators do not obey state vehicle operating procedures. A bicycle rules enforcement program and improved drivers' education about the bicyclist's rights and responsibilities are appropriate complements to improved facilities.

Positive impacts include greater amenities to residents in terms of reduced air pollution, increased recreational potential, the availability of an alternative mode of transportation, improved motorist awareness of bicycle users, and related social benefits (10). Little capital expenditure need be involved in the provision of bicycle facilities, and aggregate benefits appear to far outweigh project costs.

Table 2. Costs of eliminating air pollution with commuter bicycling facilities.

Pollutant	Amount/Year (tons)	Low Cost Estimate ($/ton) CNW[a]	CTA[b]
With bus service			
HC	0.0312	86 230.77	3425.80
CO	0.415	6 482.89	255.90
NO_x	0.0136	197 823.53	7273.97
Without bus service			
HC	0.057	47 200.00	1863.15
CO	0.762	3 530.70	139.37
NO_x	0.025	107 616.00	4248.00

[a]Calculation based on cost of $2690.40/year.
[b]Calculation based on cost of $106.20/year.

Table 3. Facilities for bicycle commuters to CNW station in Wilmette: summary of demand range.

Demand Range	Automobile Range (VMT/year diverted)	Emission Range (tons/year diverted) HC	CO	NO_x	Cost Range ($/year)	Cost-Effectiveness Range ($/ton) HC	CO	NO_x
With bus service								
Low estimate	5 516.06	0.035	0.472	0.015	2 690	86 231	6 483	197 824
Potential high estimate	42 656.4	0.273	3.65	0.119	53 843	197 229	14 752	452 466
Without bus service								
Low estimate	15 840.6	0.102	1.35	0.044	2 690	47 200	3 531	107 616
Potential high estimate	124 236	0.794	10.62	0.348	53 843	67 813	5 070	154 722

Table 4. Direct socioeconomic impacts due to implementation.

Sector Affected	Impact	Unit of Measurement	Preliminary Impact Assessment[a]	Description of Change from Existing Conditions
Residential	On no. of dwelling units	Dwelling units demolished; potential for new units	0	This TCM is expected to require neither the taking of nor the development of dwelling units
	On no. of households	Households added or dislocated	0	Same as above
	On existing residences	Positive or negative effects on use and enjoyment of residences	+	Provision of bicycle facilities should reduce the amount of vehicle noise and air pollution on and around residential areas, and thereby improve conditions in areas of implementation
Business	On no. of businesses	No. of businesses dislocated or potential for additional businesses	0	No significant impacts are anticipated
	On existing businesses	Potential increase or decrease in business activity	0	No significant impacts are anticipated
Parking	On availability of off-street parking	Gain or loss of parking spaces	+	Some off-street parking space availability should result because of decreased automobile use
	On availability of on-street parking	Gain or loss of parking	+ 0 -	Some on-street parking may be lost due to curb lane dedication to bicycle use; however, also possible is that other spaces would be freed by bicycle users diverted from automobiles
Employment	On no. of temporary jobs	Gain or loss of temporary jobs	+	Some temporary jobs may be created for the purpose of public information, marking and installation of facilities, and bicycle safety promotion
	On no. of permanent jobs	Gain or loss of permanent jobs	0	No impacts are anticipated
Goods movement	On efficiency of goods movement	Positive or negative impact	+ 0	Goods movement will be affected to the extent that automobile traffic is reduced (positive impact) or truck traffic will be delayed (negative impact); in any case, the impact is expected to be small
Municipal services	On delivery of municipal services	Positive or negative impact	+ 0 -	Same factors that affect goods movement may affect delivery of municipal services
Land use	On sensitive land uses	Increase or decrease in number of acres of sensitive land uses	+	Bicycle use is consistent with a policy of road improvement rather than road and highway expansion; use of bicycles as an alternative to automobile use might, therefore, contribute to land preservation
	On land use	Change in land use from a higher-value use to a lower-value use or from a lower-value use to a higher-value one	+	Bicycle facilities increase value of land by increasing its usefulness for recreation and transportation
Land values	On surrounding land values	Increase or decrease in land values	+	Additional amenities like bikeway facilities can influence land values by making property more attractive
Taxes	On local assessed valuation	Increase or decrease in assessed valuation due to property added to or removed from tax rolls and change in land use patterns	+	Areas that have bicycle facilities will be more attractive to home buyers; this should be reflected in increased property value and subsequently assessed valuation
Taxi service	On service availability and safety	Positive or negative impact	0	Taxi service may be affected somewhat because of the availability of bicycle facilities for short trips in good weather; however, this diversion is expected to be small; traffic movements will be affected as any other vehicle would be affected

[a]+ = positive, - = negative, and 0 = no impact.

As a TCM measure, improved bicycle facilities have few socioeconomic drawbacks and, for the most part, are supportive of regional socioeconomic policies, goals, and objectives. The socioeconomic impacts of bicycle facilities are summarized in Tables 4 and 5 (10, pp. 35-44).

DISCUSSION OF RESULTS

The high end of the demand range serves as a theoretical limit to the air quality benefits obtainable through the promotion of bicycling to transit stations in Wilmette. The value of the demand range is that the low end of the range illustrates that feasible bicycle support facilities can produce air quality benefits at a low cost. The high end of the demand range demonstrates the limit within which bicycle use for a given purpose can be expected to produce air quality improvements.

Given our assumption about costs associated with bicycling, air quality improvements appear to become more expensive as bicycle use increases. The major reasons for this are (a) the addition of an enforcement program (as in Niles) because of the increased need to integrate bicycle and automobile traffic and (b) the addition of storage lockers that are roughly twice as expensive as the sheltered racks at the CNW station. The higher cost per ton of the more-extensive system still represents a cost efficiency well above that of many other TCMs evaluated. The emission reduction cost-effectiveness varies from \$13 319 to \$985 349/ton for public transportation improvements and from \$98 918 to \$731 250/ton for park-and-ride lots (11). At the high end of the demand range the cost-effectiveness of commuter bicycle facilities as a measure to reduce hydrocarbons varies from \$67 813 to \$197 229/ton. As bicycling increases for purposeful trips, various road and traffic improvements, such as signs, special signalization, storage facilities, lane markings, and enforcement personnel, may become necessary. At the same time, money might be saved by having to provide fewer parking spaces for automobiles. The use of the bicycle as a transportation vehicle necessitates

Table 5. Indirect socioeconomic impacts due to implementation.

Variable	Impact	Unit of Measurement	Preliminary Impact Assessment[a]	Description of Change from Existing Conditions
Land use	On long-term land use patterns	Change in land use, from a higher-value use to a lower-value use, or from a lower-value use to a higher-value one	+	Bicycle facilities increase value of land by increasing its usefulness for recreation and transportation
Safety	On vehicular and pedestrian safety	Potential increase or decrease in vehicle and pedestrian accidents	+	Increased bicycling on public highways may result in an increase in automotive-bicycle and pedestrian-bicycle accidents; accidents may, however, be decreased by implementation of appropriate education programs and traffic management
Health	On susceptible population groups	Positive or negative impact due to improvement or deterioration of air quality	+	Automobile trips diverted to bicycle trips will reduce emissions and thereby improve community health
Accessibility	On accessibility for mobility-limited persons	Increased or decreased accessibility	0	Accessibility for the mobility-limited will not be affected
	On neighborhood accessibility	Increased or decreased accessibility to adjacent neighborhoods	+	Increased bicycle trips should be generated both intra- and inter-community due to increased bicycle facilities
Traffic	On amount of traffic in sensitive areas	Increase or decrease in traffic in sensitive areas	+	Positive impact would be expected from the diversion of some automobile trips to bicycles
Buildings	On buildings in vicinity of TCM	Positive or negative impact on building maintenance due to air quality changes and building vibrations	+	Reduced emissions should result in reduced building maintenance costs

[a]+ = positive, – = negative, and 0 = no impact.

and justifies costs more consistent with the costs of other modes.

It is possible to speculate on some of the reasons for the large difference in the number of bicycle riders at the CTA and CNW stations. Only 21 bicycles were parked at the CTA station; 75 were parked at the CNW. The survey responses show that cyclists to the Linden CTA ride longer distances than those at the CNW stations (CTA average was 1.7 miles; the longest trip was 5 miles; CNW average was 1.33 miles; the longest trip was 3 miles). The Linden CTA stop is the end of the line and those North Shore riders who wish to take the CTA rather than the CNW come to the Linden or Evanston stations. The North Shore corridor is, on the other hand, served by many CNW stations. The longer trips to the Linden station might discourage bicycle use. Another, and more probable contributory factor to the difference in bicycle ridership is that the parking facilities at the CNW station are superior and more numerous. The CNW station has 100 spaces covered by a roofed structure and 50 additional spaces south of the station. The CTA has conventional unprotected racks that provide parking for up to 40 or 50 bicycles.

The case study can be generalized to other communities with commuter rail stations. If each of these communities were to provide parking facilities like Wilmette's, then the percentage of commuters who ride their bicycles to the station might be expected to be the 5 percent observed at Wilmette. Inducements and deterrents other than these facilities would, of course, affect ridership. It is probably fair to suggest that communities that have land use patterns similar to those in Wilmette would gain a similar bicycle ridership given similar facilities. This could mean a fairly significant increase for some communities where moderate inducements might remind and encourage residents to exercise the bicycling option. The air quality benefits would be especially significant in communities that currently have poor bus service.

In addition to generalizing the findings at the Wilmette CNW station, communities could reproduce the survey used in this case study for any trip generator. To calculate a demand range, some data would be necessary on the residential distribution for those who travel to the trip generator under consideration.

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Bicycle Traffic Volumes

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This paper provides information on bicycle traffic volumes in the metropolitan Boston area. This information allows a better understanding of factors that affect this mode and their relative importance to the bicyclist. The data reported here were collected between 1974 and 1981. All bicycle counts were done manually, mainly during weekday peak periods. The volumes have grown at a 7.5 percent annual rate compounded over the past six years. Volumes varied significantly according to season of the year and weather. These two influences operated independently of each other to some extent. Twelve-hour counts indicated definite peaks in the morning and evening. The morning peak hours occurred in a narrower time band; the evening-peak-hour volumes were an average of 20 percent higher. Bicycle traffic increased by 300 percent on a day when transit was unexpectedly out of operation. During an evening-peak-period count, half of the cyclists used a bicycle path and half used three adjacent arterials. Average daily bicycle traffic volumes in the inner metropolitan area are presented for 1976. Possible correlations between volumes and the number of reported bicycle accidents are discussed.

This paper reports on bicycle traffic volumes collected in the metropolitan Boston area since 1974. Some implications of the data, including the need for further research, are discussed.

BICYCLE TRAFFIC DATA

A number of bicycle traffic counts have been conducted in the Boston area since 1974, most of them by the Central Transportation Planning Staff of the Boston metropolitan planning organization (MPO).

The majority of the counts have been done in Boston and Cambridge, just north of Boston. Counts have also been done in Brookline and Newton, west of Boston, and in Somerville, Arlington, Belmont, Lexington, and Bedford, north and northwest of Boston (see Figure 1).

The impetus for the collection of bicycle traffic volumes was the U.S. Environmental Protection Agency's transportation control plan for Boston. This 1975 document required that encouragement of bicycle use be included in the area's attempt to reduce pollution. Virtually no information was available on actual bicycle traffic volumes, so some was collected in 1975 and 1976. Data have continued to be collected since then to improve our understanding of the issues discussed in this paper.

Bicycle counts have been done at more than 50 locations in the Boston area. Most of the counts were on weekdays, during the morning or evening peak period. The emphasis was on commuter, not recreational, traffic. Unless otherwise noted, precipitation neither occurred on nor was forecast for the days of the counts.

All counts were done manually, included turning movements, and were calibrated in 15-min segments. All of the data reported here were collected by staff members or adult volunteers and are considered to be reliable.

GROWTH IN BICYCLE TRAFFIC

Bicycle volumes were collected at 11 intersections on Thursday, October 9, 1975, as part of the transportation control plan work. Bicycle volumes at 9 of the intersections were collected again exactly five years later, on Thursday, October 9, 1980. The weather was similar--temperatures were in the low 50°s at 7:00 a.m. and the wind was approximately 10 mph on both days; it was partly cloudy in 1975 and sunny in 1980.

The volumes for each day are shown in Figure 2. The evening-peak-hour volume was higher at all nine intersections in 1980; the increase varied from 5 to 60 percent. The total evening-peak-hour volume for the nine intersections was 1922 bicycles in 1980 40 percent higher than in 1975.

Volumes are compared in Figure 3 for four intersections at which counts were done on Wednesday, May 5, 1976, and five years later on Wednesday, May 13, 1981. The weather on these two dates was identical--at 7:00 a.m., temperature was 51°F, wind was 15 mph, and skies were mostly sunny.

The increases in the morning peak-hour volume at the four intersections varied from 35 to 236 percent. The total morning peak-hour volume for the four intersections was 575 bicycles in 1981, 57 percent higher than it was five years before.

The October 1975 and May 1976 volumes added together and compared with the total for October 1980 and May 1981 yield an average increase of 44 percent. This is an average annual compound increase of 7.5 percent. A 7.5 percent increase would be considered a high annual increase for automobile traffic. Because the bicycle's share of traffic is lower, a high annual increase is relatively less significant. For example, assume that the bicycle's share of commuter traffic was 1 percent in 1980. If a 7.5 percent annual compounded growth rate were to continue for 20 years, the bicycle's share would only be 4.2 percent by 2000. A 7.5 percent annual increase does suggest, however, that the bicycle is not just holding its share of the commuting market but steadily increasing it.