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Bicycle transportation and air quality in Santa Clara County

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BICYCLE TRANSPORTATION AND AIR QUALITY IN SANTA CLARA COUNTY

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ABSTRACT

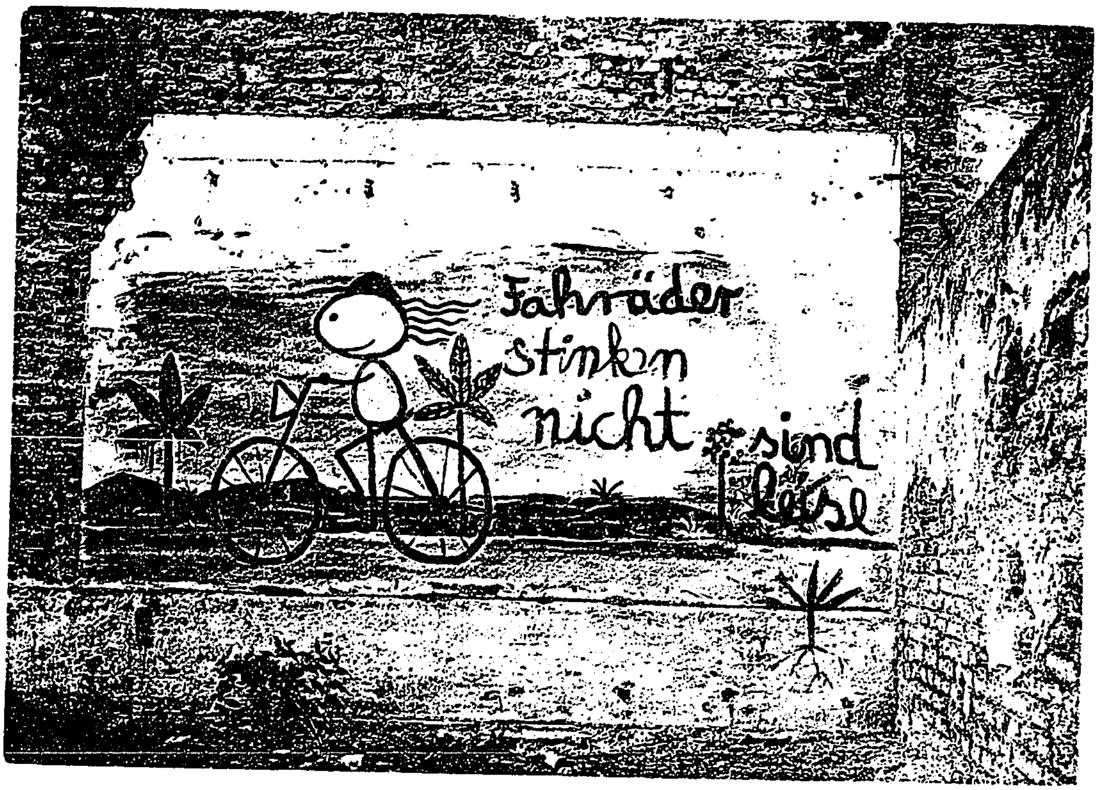
BICYCLE TRANSPORTATION AND AIR QUALITY IN SANTA CLARA COUNTY

by Karen Morvay

The purpose of this thesis is to evaluate whether improving bicycle facilities in Santa Clara County will significantly increase bicycle ridership and thereby reduce air pollution. The goals of this study are to quantify the effects of bicycle ridership on air quality in Santa Clara County and to determine what effect bicycle facilities have on the level of bicycle ridership.

The results of this thesis indicate that bicycle facilities--especially bicycle lanes--positively affect bicycle ridership levels.

This research also indicates that at current bicycle ridership levels, if bicycle commuter miles were motor vehicle miles, they would generate 7.34 tons per day of carbon monoxide, hydrocarbons, oxides of sulfur and nitrogen, and particulate matter. Also, motor vehicle-caused air pollution in Santa Clara County would increase between 1.16% and 1.36%, and total air pollution would increase between .04% and .85%.



("Bicycles don't stink and are quiet" -- a mural on a wall at a school in Aachen, Germany)

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CHAPTER 1
INTRODUCTION

The San Francisco Bay Area is situated in an area of rare natural beauty--rolling, golden hills, rich and varied vegetation, and lovely ocean bays and views. Unfortunately, as with most urban areas, this beauty has been marred by air pollution, one of today's most significant environmental problems. Air pollution problems include ground level ozone or "smog," particulate matter, various carcinogens, such as benzene, and carbon monoxide, to name just a few.

There are literally thousands of sources of air pollution in the Bay Area, ranging from paints and household cleaners to industrial smoke stacks. One major source of air pollution is motor vehicle emissions. On-road vehicles account for about 43% of all reactive hydrocarbons emitted (which contribute to ground level ozone), 57% of all nitrogen oxide emitted, and 82% of all carbon monoxide emitted in the Bay Area.[1] Gasoline and diesel fuel emissions are major contributors to global warming, acid rain, and the depletion of the ozone layer. Auto emissions are also linked to major health problems and cause about 30,000 premature deaths (excluding auto accidents) per year nationally.[2]

One way to ease this problem is bicycle transportation. Bicycles promote sustainable living: they use few finite resources, produce virtually no atmospheric or noise pollution, and reduce road congestion. With regard to energy, bicycles are one of the most effective means of transportation known to humans. Bicycles consume less energy per passenger mile than any other form of transportation,

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[1] Bay Area Air Quality Management District, Bay Area '91 Clean Air Plan (San Francisco, Ca., October 1991), 1:2.

[2] Jane Bosveld, "Can Bicycles Save the World?" OMNI, February 1989, 33.

including walking.[3] While a single occupancy vehicle requires 1,860 calories per passenger per mile, bicycles require only 35.[4] Besides environmental benefits, bicycling may also provide many benefits for the individual, such as health and financial benefits. This thesis will address only utilitarian bicycle trips, as opposed to recreational bicycle trips, and the focus of this study will be on bicycle transportation and air quality.

Some societies have recognized the growing problem air pollution and oil shortages and have turned to bicycles as part of the solution to these problems. The Netherlands is a good example of a country with a commitment to bicycle transportation. The government spent $230 million between 1975 to 1985 on constructing bicycle routes, parking, and other facilities.[5] By 1986, roughly 13,500 kilometers of bicycle routes spanned the Netherlands and "as a result, the share of trips made by bicycle in Dutch towns and cities is typically between 20 and 50 percent."[6]

The Bay Area, specifically Santa Clara County, is ideally suited to employing bicycles as a means of improving air quality. The weather is mild with little rainfall most of the year, the terrain is relatively flat, and most work and non-work trips begin and end within the county. Furthermore, making the county accessible for bicycle transportation is relatively inexpensive.

Funding for bicycle facilities is becoming more available on the federal and state levels, in part because "there has been a growing awareness on the part of government that cycling can be an aide in reducing traffic congestion and air

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[3] Marcia Lowe, The Bicycle: Vehicle for a Small Planet, World Watch Paper no. 90, (Worldwatch Institute, 1989), 20.
[4] Ibid., 21.
[5] Ibid., 35.
[6] Ibid.

pollution."[7] However, is the assumption that improved bicycle facilities will increase bicycle ridership correct? Will increased ridership significantly reduce air pollution? This thesis examines these questions in order to determine whether the current local, state, and federal policy direction--making funds available for bicycle facilities in order to improve air quality--will achieve what it promises.

First, this study will look at how bicycle commuters in Santa Clara County are currently affecting levels of motor vehicle-caused air pollution and total air pollution and will evaluate how much motor vehicle-caused pollution and total air pollution bicycle commuters are displacing.

Next, a simple model will be used to examine how different levels of ridership could affect both motor vehicle-caused and overall air pollution levels in Santa Clara County. Finally, this study will examine the influence bicycle facilities have on bicycle ridership and will evaluate whether bicycle facilities affect the level of bicycle ridership in Santa Clara County. It is hoped that the results of this thesis will be useful in determining transportation policy.

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[7] Santa Clara County Transportation Agency, Draft Santa Clara County Bicycle Plan (Santa Clara County Transportation Agency, January 1994).

CHAPTER II

AIR POLLUTION

TYPES OF AIR POLLUTION

Long before humans inhabited the earth, toxic substances were emitted into the air. There are hundreds of natural sources of air pollutants, from trees emitting smog-forming gases to forest fires to dust storms. This naturally occurring air pollution, however, has always been balanced by the atmosphere's cleansing processes: wind, rain, and chemical functions.[8]

Unfortunately, humans have begun to upset this balance by rapidly elevating the levels of air pollution. In the past, the main culprits have been wood and coal burning. Today, we produce both greater quantities of pollutants and a wider array. In general, air pollution is divided into two types: pollutant gases and particulate matter.[9] Table 1 describes the six main air pollutants in Santa Clara County as determined by the Bay Area Air Quality Management District, how they are generated and why they are significant.

AIR POLLUTION IN SANTA CLARA COUNTY

Santa Clara County is situated mainly within a valley, with the Santa Cruz Mountains to the west and the Diablo Range to the east. Because Santa Clara County is mostly in a basin, it can easily trap air pollutants which flow from northerly regions, such as San Mateo County. This is referred to as "transported" air pollution. Currently, the Bay Area Air Quality Management District (BAAQMD)

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[8] Bay Area Air Quality Management District, Air Quality Handbook (San Francisco, Ca., 1993), 3.

[9] Ibid., 4.

Table 1

AIR POLLUTANTS IN SANTA CLARA COUNTY

NAME	SOURCE OF POLLUTANT	SIGNIFICANCE OF POLLUTANT
Hydrocarbons (HC) (a)	Created from unburned or partially burned fuels or organic waste emitted from fuel systems and exhaust.(b)	Reacts with nitrogen oxides to form photochemical smog, or ozone, in the air near ground level. Can severally irritate the nose, throat, eyes, and respiratory system, and cause headaches, shortness of breath (c). Some studies have shown that ozone promotes development of tumors that may lead to cancer (d).
Carbon Monoxide (CO)	Emitted during the incomplete combustion of carbon containing substances, such as fossil fuels.	Combines with blood hemoglobin, reducing the blood's capacity to carry oxygen to body tissues, which strains the heart, brain, and other organs. May also produce chest pains and breathing difficulties (e).
Nitrogen Oxides (NOx)	Formed when fuel burns at high temperatures. Atmospheric oxygen combines at great temperatures and pressures with nitrogen to form NO and NO2.	Combines with hydrocarbons and sunlight to produce ground level ozone. Nitric acid can combine with water/ mist to form "acid rain" or "acid mist", which was been known to fall in small amounts in CA.(f) Can cause severe respiratory tract irritation, increased susceptibility to viral infections, and reduced lung functions (g).

NOTES:

(a) Includes total organic gases (TOG) and reactive organic gases (ROG).

(b) Andy Rowell and Malcolm Fergusson. Bike Not Fumes: The Emissions and Health Benefits of a Model Shift from Motor Vehicles to Cycling. Earth Resources Research, Ltd., October 1991, 6.

(c) The American Lung Association. Air Pollution: The Danger Continues. 1988.

(d) Ibid.

(e) The American Lung Association. The Health Effects of Ambient Air Pollution. 1989, 9.

(f) Bay Area Air Quality Management District. Air Quality Handbook, 1993, 5.

(g) Jim Beard. Environmental Impact of the Car. 1992, 26.

(Continued on next page)

Table 1
Air Pollutants in Santa Clara County

Sulfur Oxide (SOx)	Emitted during the heating and burning of fossil fuels such as oil and coal.	Reacts with water in the air (SO2 — SO3 + H20 -- H2SO4) to form acid rain. Exacerbates existing diseases and irritates the upper respiratory tract. Studies have shown that exposure over time can lead to lung disease.
Lead	Emitted primarily as a result of burning "unleaded" gasoline, which is still allowed to have 0.05 grams of lead per gallon of gasoline.	Tiny particles, emitted in great part by motor vehicles, can be inhaled, and once inside the body, this heavy metal can cause severe damage to the brain, kidneys, and nervous system, and can lead to birth defects (g).
Particulate Matter (PM) (h)	Emitted primarily in the Bay Area by motor vehicles either from the incomplete combustion of fuels or or from road dust kicked up into the air by autos (i).	The type of PM that causes the most damage, PM10, can be inhaled deeply into the lungs and can aggravate respiratory illnesses. Recent studies show that 50,000-60,000 deaths per year in the U.S. are are caused by PM pollution (j). One study linked an increase of lung cancer in California to PM10 (k).

NOTES:

(g) The American Lung Association. Air Pollution: The Danger Continues. 1988.

(h) PM that has a diameter of less than 10 microns is called PM10. PM is the umbrella term for dirt, dust, mist, and ash in air.

(i) Julie Morgan et al. Every Which Way: The Major Damage to Human Health and Bay Waters from Toxic Chemicals Emitted by Autos in the San Francisco Bay Region. Citizens for a Better Environment, 1991, 5.

(j) Philip J. Hilts. Soot Cites as a Big Killer in U.S.. San Jose Mercury News. July 19, 1993.

(k) Jim Beard. The Environmental Impact of the Car. 1992, 26.

data show that a small amount of air pollution is transported from San Mateo County to Santa Clara County (Figure 1); however, the exact amount is not known.[10]

The types of air pollutants, quantities of each kind, and sources for Santa Clara County are detailed in Table 3. Santa Clara County's contribution to the Bay Area's pollution is found in Table 4. Table 5 shows Bay Area pollution levels relative to the rest of California.

IS AIR POLLUTION A SIGNIFICANT PROBLEM?

How great a problem is air pollution? Overall, the air in the Bay Area has gotten cleaner over the past 20 years. The Clean Air Act of 1970 and the 1977 Amendments to the Act evaluated the air pollution problem and then legislated improvements. During the decade that followed the Clean Air Act, significant improvements in air quality were made. Some of the worst air pollutants were reduced by 20-30 percent.[11] The Bay Area Air Quality Management District reports that regulations have reduced reactive hydrocarbon emissions in the last twenty years by 35 percent.[12]

Despite all the progress made, air quality still remains a problem, especially in metropolitan areas. During the last ten years, the rate of progress in cleaning up some of these pollutants has slowed considerably or completely

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[10] The Bay Area Air Quality Management District has constructed a model of transported pollution from BAAQMD counties (such as Santa Clara County) to Monterey and San Benito Counties. However, no studies have been done to calculate the amount of air pollution that transports into Santa Clara County.

[11] The American Lung Association, Air Pollution: The Danger Continues (1988).

[12] Scott Thurm, "Smog levels in Bay Area show air of improvement," San Jose Mercury News (California), 6 August 1993, sec. B, p. 7.

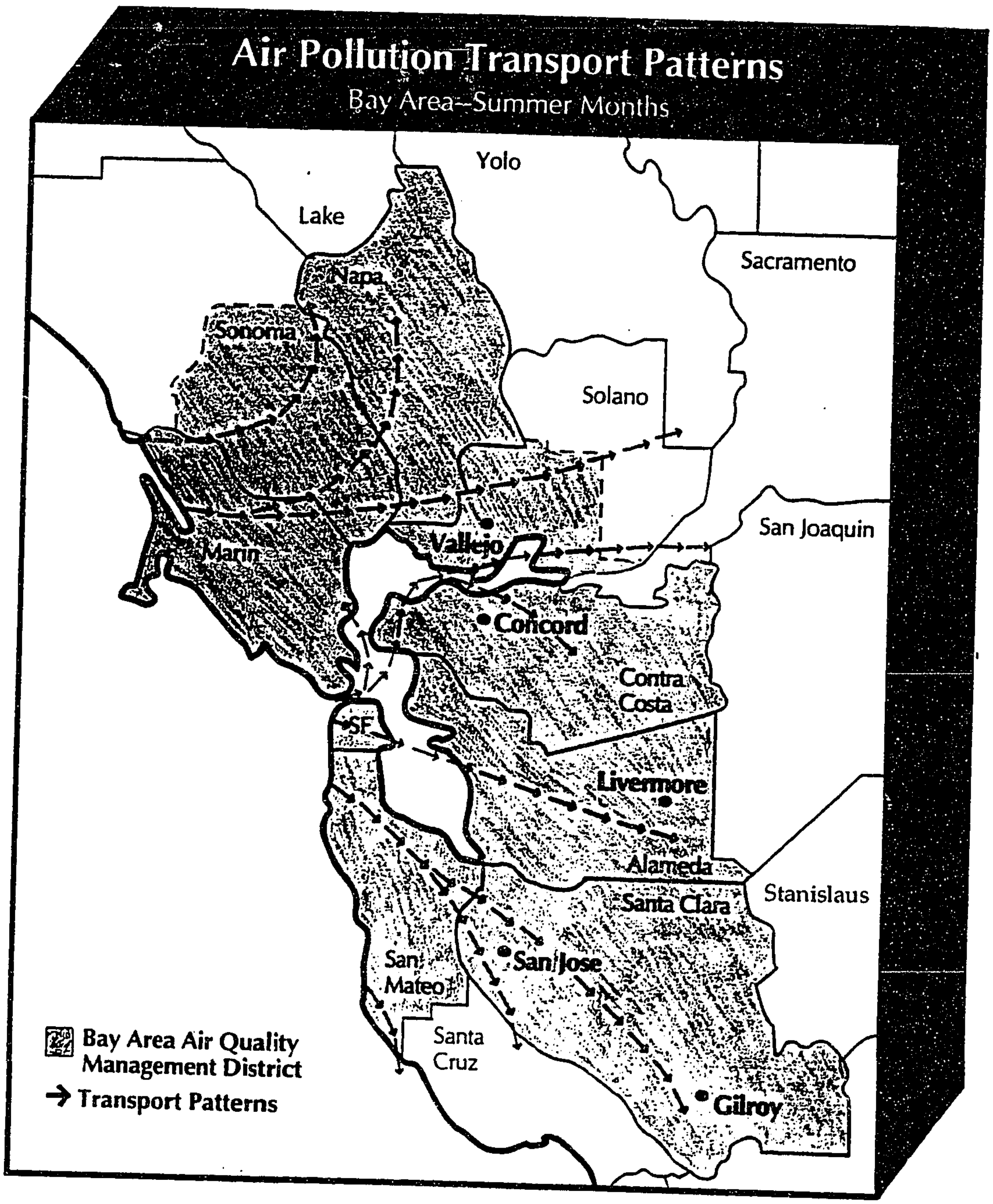

Figure 1. Air Pollution Transportation Patterns.
Source: Bay Area Air Quality Management District

Table 2
1989 Base Year Inventory:
Average Daily Emissions
Santa Clara County (a)
(tons/day)

	TOG	ROG(b)	CO	NOx	SOx	PM	PM10 (c)
Stationary Sources							
Fuel Combustion	11	4.1	50	22	1.3	7	6.5
Waste Burning	12	0.2	1	0.7	0.1	0.3	0.3
Solvent Use	43	39	*	*	*	*	*
Petroleum Process	12	6.1	*	*	*	0.2	0.1
Industrial Process	3.1	2.5	*	*	*	5.8	3.6
Misc. Process	280	52	2.8	*	*	230	120
Mobile Sources							
On Road Vehicles (d)	70	64	510	88	7.5	14	8.3
Other Mobile (e)	12	11	100	17	1.4	1.3	1.2
Total	430	180	660	130	10	260	140

NOTES:

* indicates that emissions estimates rounded off to less than 0.1 tons per day

(a) From the State of California Air Resources Board, Technical Support Division, Emissions Inventory Branch, Emissions Inventory 1989, August 1991, Table A-54.

(b) Sub-category of TOG

(c) Sub-category of PM

(d) Includes cars, light, medium and heavy-duty gasoline trucks, heavy duty diesel trucks, motorcycles, and heavy-duty diesel urban buses

(e) Includes off-road vehicles, trains, aircraft (government and others), mobile equipment, and utility equipment

List of Abbreviations:

TOG: Total Organic Gases
ROG: Reactive Organic Gases (a sub-category of TOG)
CO: Carbon Monoxide
NOx: Oxides of Nitrogen
SOx: Oxides of Sulfur
PM: Particulate Matter
PM10: Fine Particulate Matter (a sub-category of PM)

Table 3
San Francisco Bay Area
Emissions Summary 1989 (a)

County	TOG	ROG (b)	CO	NOx	SOx	PM	PM10 (c)
		Emissions (tons/day)					
Alameda	320	140	580	120	17	190	100
Contra Costa	260	120	390	140	48	160	86
Marin	75	37	120	19	1.5	58	30
Napa	76	48	56	9.4	0.7	31	16
San Francisco	61	48	210	44	9.5	76	41
San Mateo	200	74	320	58	4.3	110	59
Santa Clara	**430**	**180**	**660**	**130**	**10**	**260**	**140**
Solano	90	48	120	31	18	57	32
Sonoma	170	99	150	24	2	83	44
Total	1,700	790	2,600	580	110	1,000	550

NOTES:

(a) From Emissions Inventory 1989, State of California Air Resources Board

(b) Sub-category of TOG

(c) Sub-category of PM

Table 4
California Emissions Summary
1989 (a)

AIR BASIN	TOG	Emissions (Tons/Day) ROG (b)	CO	NOx	SOx	PM	PM10 (c)
Great Basin Valleys	10	9.4	59	11	1.6	140	81
Lake County	15	13	64	6.2	0.7	30	17
Lake Tahoe	7.8	6.8	52	2.7	0.3	17	9.3
Mountain Counties	85	71	490	70	8.2	290	170
North Central Coast	270	90	370	89	14	280	150
North Coast	120	62	400	78	14	200	120
Northeast Plateau	40	34	310	43	4.6	190	110
Sacramento Valley	430	280	1,500	270	24	880	480
San Diego	490	250	1,300	210	24	560	310
San Francisco Bay Area	**1,700**	**790**	**2,600**	**580**	**110**	**1,000**	**550**
San Joaquin Valley	1,200	630	1,800	550	76	2,100	1,100
South Central Coast	450	190	710	170	25	390	210
South Coast	2,100	1,200	4,800	1,100	120	2,100	1,200
Southeast Desert	300	150	700	290	26	2,600	1,300
State Total	7,100	3,800	15,000	3,500	460	11,000	5,800

NOTES:

(a) From Emissions Inventory 1989, State of California Air Resources Board

(b) Sub-category of TOG

(c) Sub-category of PM

stopped.[13] The San Jose Mercury News reported on August 6, 1993:

> ...The Bay Area already has violated the federal health standard for ozone more times and in more places than either of the past two years...and some of the regions worst pollution can occur in September and October, when summer fogs and breezes disappear.[14]

"Nonattainment areas" are areas that do not meet the National Ambient Air Quality Standards (NAAQS) for six of the most widespread and dangerous pollutants in the outdoor environment--ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM10, and lead--as set forth in the Clean Air Act and its amendments. The Bay Area is a non-attainment area for carbon monoxide, ozone, and PM10[15].

While in the 1980's, federal ozone standards were exceeded in the Bay Area 5 to 10 days per year, the 1990's have shown no more than one day per year that the federal ozone standards have been violated.[16] However, the more stringent state standards for ozone continues to be exceeded about 20 times per year, and the state carbon monoxide standard is even more frequently exceeded, especially in Santa Clara County.[17] In Bay Area cities in 1990, the state PM10 standard was continually exceeded, in some locations 20% of the days monitored.[18] Table 6 lists the air quality standards for the nation and the state of California.

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13 The American Lung Association, Air Pollution: The Danger Continues (1988).

14 Scott Thurm, "Smog levels in Bay Area show air of improvement," San Jose Mercury News (California), 6 August 1993, sec. B. p. 7.

15 The Bay Area is a non-attainment area for "24 hour" PM10 federal and state standards, but it does meet the state and federal annual PM10 standards.

16 Bay Area Air Quality Management District, Air Quality Handbook (San Francisco, Ca., 1993), 18.

17 Ibid., 19.

18 Julie Morgan et al., Every Which Way: The Major Damage to Human Health and Bay Waters from Toxic Chemicals Emitted by Autos in the San Francisco Bay Region (Citizens for a Better Environment, 1991), 5.

Table 5
Federal and California Air Quality Standards (a)

Pollutant	Average Time	California Standards	Federal Standards
Ozone	1 Hour	.09 ppm	0.12 ppm
Carbon Monoxide	8 Hour	9 ppm	9 ppm
	1 Hour	20 ppm	35 ppm
Nitrogen Dioxide	Annual Average		.05 ppm
	1 Hour	.25 ppm	
Sulfur Dioxide	Annual Average		.03 ppm
	24 Hour	.05 ppm	
Particulate Matter (PM10) (b)	Annual Mean	30µg/m3	50µg/m3
	24-hour average	50µg/m3	150µg/m3
Lead	30 Day	1.5µg/m3	
	Calendar Year		1.5µg/m3

NOTES:

(a) From Bay Area Air Quality Management District. Air Quality Handbook, 1993.

(b) The annual standards are based on an arithmatic mean for federal and a geometric mean for state.

THE HEALTH EFFECTS OF AIR POLLUTION

Air pollution has been found to have a significant effect on human health, including that of the population of the Bay Area. A large part of the air pollution in the Bay Area comes from motor vehicles. According to a document issued by the Citizens for a Better Environment (CBE), some of the health effects people in the Bay Area are experiencing from motor vehicle pollution include thousands of days of missed work and asthma attacks from ground level ozone smog, 40-60 deaths per year from exposure to particulate matter, risk of cancer deaths from motor vehicle emitted carcinogens, risk of lower intelligence for children from the lead that still remains in "unleaded" gas, and skin cancer deaths due to the destruction of the ozone layer over the next 50 years caused by chlorofluorocarbons (CFCs) emitted in great part by motor vehicles.[19]

THE ENVIRONMENTAL EFFECTS OF AIR POLLUTION

Air pollutants that are emitted in the Bay Area cause both local and global environmental damage. Locally, the most readily apparent effect of air pollution is visibility reduction, caused by nitrogen dioxide and particulate matter in the atmosphere. Air pollution also has a significant effect on materials and vegetation. Materials such as paint, rubber, fabrics, stone, and even metals all have been shown to suffer damage over time when exposed to certain air pollutants, especially sulfur dioxide and ground level ozone. Crop damage by air

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[19] Julie Morgan et al., Every Which Way: The Major Damage to Human Health and Bay Waters from Toxic Chemicals Emitted by Autos in the San Francisco Bay Region (Citizens for a Better Environment, 1991), 1.

pollution in California each year is estimated to be approximately $300 million.[20] Air pollutants have also been shown to contaminate water in the Bay Area, which damages wildlife as well. Globally, certain air pollutants which are emitted in the Santa Clara County--carbon dioxide, nitrous oxide, and chlorofluorocarbons--are "greenhouse gases" and contribute to global warming. CFC's are also the major cause of the destruction of stratospheric ozone, the protective layer of gases that shields the earth from harmful ultra-violet radiation.

[20] Bay Area Air Quality Management District, Air Quality Handbook (San Francisco, Ca., 1993), 14.

CHAPTER III

BICYCLE TRANSPORTATION

Given the effects of pollutants on people and the environment, one possible way to ease this problem is through bicycle transportation. In this chapter, the benefits and drawbacks of bicycle transportation, bicycle transportation facilities, and bicycle funding will be examined.

BENEFITS OF BICYCLE TRANSPORTATION

There are many benefits, both environmental and personal, that come from using bicycles as a means of transportation, especially when compared to the most commonly used mode of transportation in the U.S., the automobile. They include:

• **Bicycle transportation can help reduce the use of fossil fuels.** A recent study reports that "bicycling currently displaces between 120 and 680 million gallons of gasoline per year. This is equivalent to 0.1%-0.6% of fuel consumed by passenger vehicles, and 0.02%-0.13% of all energy used by the entire United States economy."[21]

• **Bicycles emit no air pollution**. On a national level, bicycle transportation has been estimated to displace between 106,000-579,000 metric tons of carbon monoxide per year, between 2,900-16,000 metric tons of nitrogen oxides per year, and between 7,900-43,000 metric tons of volatile organic compounds per

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[21] U.S. Department of Transportation, Federal Highway Administration, Case Study #15: The Environmental Benefits of Bicycling and Walking (Washington D.C.: GPO, 1993), 15.

year.[22] On a local level, the effect that bicycle transportation has on air pollution in Santa Clara County is detailed in Chapter 5 of this report.

• Bicycle transportation requires far less space per traveler than automobiles, which is due to both speed (faster moving vehicles need more space) and vehicle size. While the automobile in mixed traffic can carry 120-220 persons per hour per meter width of lane, and autos in a freeway can carry 750, the bicycle can carry 1,500 persons per hour per meter width of lane.[23]

• Bicycle transportation helps to ease noise pollution. One study estimates the annual United States health and productivity costs from motor vehicle noise to be approximately $22 billion, mainly from property values declining because of the noise from urban interstate highways.[24] Bicycles, on the other hand, produce little if any noise.

• Bicycle transportation reduces chlorofluorocarbons (CFCs) used in the United States. Air conditioning systems in cars and trucks account for about a quarter of all CFCs used in the United States, which help destroy the stratospheric ozone layer and contain gases which contribute to the "greenhouse effect."[25]

• Bicycle transportation reduces the amount of pollution--exhaust emissions, oil, grease, tire particles--that end up on roads because of motor vehicles. Pollutants from motor vehicles include lead, cadmium, polycyclic aromatic hydrocarbons (PAHs), and many others. These pollutants on the

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22 U.S. Department of Transportation, Federal Highway Administration, Case Study #15: The Environmental Benefits of Bicycling and Walking (Washington D.C.: GPO, 1993), 26.

23 Marcia Lowe, The Bicycle: Vehicle for a Small Planet, World Watch Paper no. 90, (Worldwatch Institute, 1989), 22.

24 Ibid., 36.

25 Ibid.

the ground can either be washed into the San Francisco Bay or ocean during the next rainfall or they can be kicked up by cars and inhaled by humans.[26]

• **Bicycling is relatively inexpensive**. Bicycles cost much less to purchase, operate and maintain than automobiles.

• **Bicycling is good exercise**. Bicycling increases the heart rate, helping to reduce blood pressure and increase endurance; it increases strength and muscle tone; and it burns calories, which helps in weight control.[27]

• **Transit revenues could increase**. While people who switch to bicycle transportation from transit (light rail, buses or trains) could reduce the revenue these types of transit bring in, if access to transit was readily available to bicycles by allowing bicycles on buses, trains, and light rail and providing bicycle parking at transit stations, transit revenues could actually increase.[28]

NEGATIVE EFFECTS OF BICYCLE TRANSPORTATION

Bicycle transportation, however, is not without its negative effects. These include the following:

• **Negative effects on health**. Bicyclists, because they ride largely on the roads occupied by autos, are exposed to a certain degree of air pollution from motor vehicle exhaust. However, studies have shown that people in motor vehicles may suffer from even higher levels of pollution than bicyclists, particularly in

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[26] Julie Morgan et al., Every Which Way: The Major Damage to Human Health and Bay Waters from Toxic Chemicals Emitted by Autos in the San Francisco Bay Region (Citizens for a Better Environment, 1991), 7.

[27] U.S. Department of Transportation, Federal Highway Administration, National Bicycling and Walking Study (Washington D.C.: GPO, 1991), 43.

[28] Ibid., 48.

commuter traffic.[29]

• **Inconvenience for motorists**. Motorists and bicyclists generally share the road, which some motorists (and bicyclists) find inconvenient.

• **Costs of bicycle facilities**. Some examples of various costs of bicycle facilities include bicycle lockers (about $500 for two bicycles); widening of roadway ($2,750 for widening the roadway by three feet per 100 linear feet of roadway); and road signs ($60 per sign).[30]

• **Constructing bicycle facilities in environmentally sensitive areas**. Constructing bicycle facilities, such as bike paths, not only costs money to build, it also can take a toll on the wildlife and vegetation where it is constructed, unless great care goes into the designing, building and maintaining the facility.

• **Difficulty in going long distances**. Most non-recreational trips on bicycles are for relatively short distances. This is likely due to time, physical ability, and/or baggage constraints.

BICYCLE FACILITIES

Just as there are many different types of automobile transportation, there are many different kinds of bicycle facilities. Bicycling differs from automobile transportation, for while autos require facilities (i.e., roads) in order to travel, bicycles do not necessarily require special bicycle facilities (i.e., bike lanes) in order to travel; bicycles can and do travel on roads with no specific bicycling designation. About 80% of all bicycle travel is on roads with no specific bikeway

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[29] Andy Rowell and Malcolm Fergusson, Bikes Not Fumes: The Emissions and Health Benefits of a Model Shift from Motor Vehicles to Cycling (Earth Resources Research, Ltd., Surrey, U.K., 1991), 4.

[30] Ibid., 50-51.

designation.[31] Table 7 lists various types of bicycle facilities found in Santa Clara County.

FUNDING FOR BICYCLE FACILITIES AND PROGRAMS

Funding for bicycle facilities and programs is available from many different sources: federal, state, and local government agencies, and public and private businesses. Though funding for bicycle programs is available, sources for this funding are not widely known or publicized.

At the federal level, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 is the principle source of funding for bicycle projects (i.e. bike lanes and paths, traffic control devices, and parking facilities). At the state level, the Transportation Development Act (TDA) Article 3 Program, the State Transportation Fund Bicycle Lane Account, the State Flexible Congestion Relief (FCR) program, and Proposition 116 are some of the sources of funding for bicycle projects. Local funding by city and county agencies provide the largest source of funds for bicycle projects. Table 8 is a compilation of funding sources available for bicycle facilities and programs.

SUMMARY

This chapter has examined both the positive and negative effects of bicycle transportation. When looked at without the cost of bicycle facilities weighed in, bicycle transportation clearly has more significant positive effects than negative ones. However, with the costs of facilities factored in, further examination is needed. There are federal, state, and local tax dollars being

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[31] Joanne Collins, interview with author, San Jose, California, 22 June, 1993.

spent on bicycle facilities. Is this spending of tax dollars justified? To answer this question, we need to know:

1) What amount of air pollution is currently being displaced by bicyclists in Santa Clara County?

2) What amount of bicycle ridership results in significant air pollution displacement?

3) Can the installation of bicycle facilities allow us to reach this goal?

This thesis is devoted to answering these questions in order to determine if the current policy direction will be fruitful.

Table 6
Bicycle Facilities

TYPE	DESCRIPTION
Bike paths	Bicycle paths - Class I bikeways - are physically separated from roads and other facilities and have few, if any, cross flows with motor vehicles. (a) They are commonly multi-use trails, allowing bicycle, pedestrian, and occasionally, equestrian access, as well. Frequently located along creeks and ocean fronts, they are generally used more for recreation than commuting.
Bile lanes	Bicycle lanes - Class II bikeways - are separated along roadways specifically designated for bicycle use. Usually bike lanes are designated by stripes painted on the roadway, although occasionally low physical barriers delineate the bike lanes. Bike lanes are intended to increase safety for bicyclists and motorists by clearly showing the right-of-way for bicyclists.(b)
Bike routes	Bicycle routes - Class III bikeways - are simply roads that bicyclists share with other vehicles and are designated as such by signage. Bicycle routes were created to mark the best routes for bicyclists and as connectors to other facilities.(c)
Parking facilities	There are many different kinds of bicycle parking facilities, including bike racks and bike lockers. Bicycle parking can help protect bicycles from theft, unfavorable weather conditions and provides a convenient place to store the bike while engaged in other activities.

The following is a list of bicycle transportation services, amenities, and programs that can be found in various communities:

TYPE	DESCRIPTION
Financial Incentives	In order to encourage alternative transportation, employers can offer to pay employees a small stipend if they use bicycles to commute to work.
Locker rooms	Many businesses and agencies provide employees with locker room facilities, which means that employees can shower and change clothes after biking to work, or before biking home.

(Continued on the next page)

Table 6

Bicycle Facilities

TYPE	DESCRIPTION
Guaranteed Ride Home	Stanford University, and some local businesses, have a program that guarantees students, staff and faculty who ride a bicycle to work, a ride home (via taxi or rental car) if an emergency comes up.
Traffic Signals	Traffic signals can be adjusted to make them more "bicycle friendly": detection loops can be installed so that bicycles can trigger traffic signals and the amount of "green time" can be lengthened to ensure the safety of cyclists through major thoroughfares.
Access to transit	Bicycle transportation can be linked to public transportation by allowing bicycles on transit (which, to a limited extent, Santa Clara County Transit provides) and by providing safe bicycle storage at bus, light rail, and train stations.
Maintaining Bikeways for Cyclists	In order to ensure a safe road to ride on for cyclists, city governments can provide road, path and trail maintenance. This includes smoothing pavement in rough spots, especially after road repairs; filling potholes; smoothing railroad crossings; altering or replacing storm drain covers; careful pruning of plants that grow along bikeways and roads; and regular sweeping of debris off roads and bikeways.
Maps and Signs	Maps and bikeway signs provide a service to bicyclists by showing bike routes, lanes, and paths that bicyclists can use to travel on. They can also provide important information about connecting bikeways, bicycle/pedestrian bridges, and bicycle parking.
Bicycle Education Programs	Many cities offer bicycle education programs to their citizens in order to cut down on bicycle accidents and promote bicycle transportation.

NOTES:

(a) U.S. Department of Transportation, Federal Highway Administration. National Biking and Walking Study. (Washington D.C.: GOP, 1991), 29.

(b) Steve Colman. Bicycle Transportation Planning. 1992, 239.

(c) Ibid.

Table 7
Funding Sources for Bicycle Projects

FEDERAL SOURCES

• **Intermodal Surface Transportation Efficiency Act (ISTEA)**
This 1991 federal transportation bill authorizes the spending of $155 billion for fiscal year (FY) 1992-1997. (a) ISTEA programs for bicycles include:
1) Congestion Mitigation and Air Quality (CMAQ) Improvement Program: Enacted to help achieve 1990 Clean Air Act Amendment Goals; for construction of bicycle transportation facilities or projects related to bicycle safety.
2) Surface Transportation Program (STP): for improvements to roads, transit, safety, and environmental enhancements; includes construction of bicycle facilities or non-construction projects, such as route maps or education. (b)
3) National Highway System (NHS) funds: for construction of bicycle transportation facilities on land adjacent to any highway on the National Highway System, excluding the Interstate System. (c)
4) Federal Lands Highway Program: for construction of bicycle transportation facilities on certain public lands.
5) Transportation Enhancement Activities (TEA) program: for projects such as bicycle facilities and converting abandoned railroad corridors to trails.
6) Bridge Repair and Replacement Program: for bridge rehabilitation and replacement; bikeway improvements may be included when they exist on either side of the bridge. (d)
7) State Bicycle and Pedestrian Coordinators: ISTEA requires each state that receives federal funding to provide a bicycle/coordinator.
8) Interstate Construction and Maintenance: Monies that are not used to maintain a state's interstate system may be transferred to NHS and STP, which provide funds for bicycle facilities.
9) Scenic Byways Program Funds: funds that may be used to construct bicycle facilities along highways.
10) National Recreational Trails Fund: funds for recreational trails and trail-related projects.
11) National Highway Safety Act Funds (Section 402): though not a priority, some funding may be allocated to bicycle safety programs.

STATE SOURCES

• **Transportation Development Act (TDA) Article 3 Program:**
funds from 2% of 1/4 percent of the retail sales tax minus administrative and planning costs for bicycle and pedestrian projects (e).
• **California Bikeways Act - Bicycle Lane Account (BLA):**
funded by gasoline taxes, BLA funds are for improved bicycle facilities and safety.
• **Proposition 116 - Clean Air and Trans. Improvement Act, 1990:**
provides bond money for a variety of programs, including bicycle programs. (f)
• **AB 434:**
funds from a vehicle registration surcharge. (g)

Table 7
Funding Sources for Bicycle Projects

• **3% Bridge Toll:**
funding from 3% of 1989 bridge toll increase; for bicycle facilities. (h)
• **State Flexible Congestion Relief (FCR):**
funds from a 9-cent state gas tax; forbicycle transportation projects.

OTHER SOURCES

• **National Bicycle and Pedestrian Advocacy Campaign:**
funded by the Bicycle Federation of America, the advocacy campaign is designed to assist with ISTEA, the Clean Air Act, and to strengthen state and local bicycle advocacy. (i)
• **OFNAYIM Bicycle Philanthropic Fund:**
demonstration grants for non-profit groups advocating bicycle trans. and safety.
• **Rails-to-Trails Conservancy:**
assists groups with rails-to-trails conversions.
• **Resource Conservation and Development Program:**
funds projects that assist in resource conservation, economic development, and natural resource development. (j)
• **National Park Service Rivers and Trails Conservation Assistance Program:**
provides assistance with establishing and restoring river, trail, and greenway corridors. (k)

NOTES:

(a) Sacramento Area Council of Governments. Funding Working Paper for Bicycle and Pedestrian Related Projects. February 1993, 2.
(b) Santa Clara County Transportation Agency. SCC Bicycle Plan Draft. January1994, 38.
(c) Ibid.
(d) Sacramento Area Council of Governments. Funding Working Paper for Bicycle and Pedestrian Related Projects. February 1993, 5.
(e) Santa Clara County Transportation Agency. SCC Bicycle Plan Draft. January1994, 36.
(f) Ibid.
(g) Metropolitan Transportation Commission. State/Federal Funds Available for Bicycle Facilities. 1993.
(h) Ibid.
(i) Sacramento Area Council of Governments. Funding Working Paper for Bicycle and Pedestrian Related Projects. February 1993.
(j) Ibid., 39.
(k) Ibid., 40.

CHAPTER IV

HOW BICYCLE FACILITIES AFFECT LEVELS OF RIDERSHIP

This paper addresses three interrelated questions: 1) What effect does bicycle transportation have on motor vehicle-caused air pollution and total air pollution in Santa Clara County? 2) How would an increase or decrease in bicycle ridership levels affect air pollution levels in Santa Clara County? and 3) How do factors such as bicycle facilities affect levels of bicycle ridership. This chapter examines the third question.

This chapter will examine whether factors that can be "controlled" by state, county, and local governments and businesses affect levels of bicycle ridership. These factors--bike lanes, bicycle parking, accessibility of bikes on public transit--will be referred to, for the sake of simplicity, as "bicycle facilities." When appropriate, specific types of these facilities will be cited.

It is commonly assumed that bicycle facilities positively influence the level of bicycle ridership for a given area. This chapter will determine--using several methods--if this assumption is correct.

Numerous other social and economic factors may play a role in bicycle ridership. Such factors include income level, educational level, presence of a university, regional weather, and topography. Quantitatively assessing the importance of these is beyond the scope of this thesis but they will be considered in the discussion.

SURVEYS

It is currently theorized that "adequate facilities appear to play a vital role in the decision to walk or ride a bicycle rather than drive an automobile."[32] This theory is based, in part, on the results from surveys. Three surveys are examined in this thesis: a local survey of a Mountain View company's employees, a national survey conducted for *Bicycling* Magazine by Louis Harris and Associates, Inc., and a compilation of survey data from a national biking and walking survey.

The *Bicycling* survey, conducted in November of 1990, polled 1,254 people in households throughout the state. The results were weighted according to the U.S. Census Bureau's 1990 results. The survey first asked, "Have you ridden a bicycle in the last year?" Fifty-eight percent said they had not ridden a bicycle in the last year, and forty-two percent indicated that they had (Figure 2a). The survey then asked all adults who rode a bicycle in the last year but did not commute to work by bicycle in the last month if they thought they would sometimes commute to work by bicycle, if certain conditions were met. The results show that the respondents consider safe bicycle lanes on roads and highways to be the most important improvement, followed by financial incentives from their employer and shows/secure bike storage at their work. Figure 2b shows the results of these questions.

According to *Bicycling* magazine, these results mean that while currently 1 in 60 (1.7%) Americans ride a bike to work, "if better bicycle facilities were available," the proportion would be 1 in 5 (20%)."[33] (See Figure 2c).

The U.S. Department of Transportation Federal Highway Administration issued a report in 1993 on the reasons why bicycling and walking are not being

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[32] U.S. Department of Transportation, Federal Highway Administration, National Bicycling and Walking Study, Interim Report (Washington, D.C.: GPO, November 1991), 15.

[33] "A Trend on the Move: Commuting by Bicycle," Bicycling, 1991, 6.

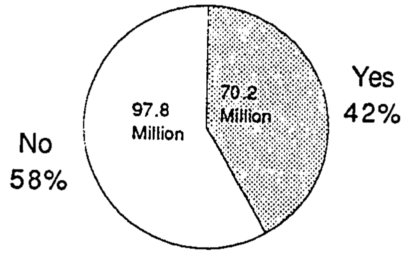
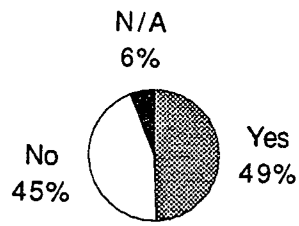
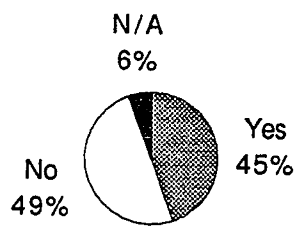


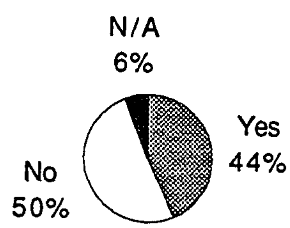
Figure 2a: Have you ridden a bicycle in the last year?



...there were safe bike lanes on roads and highways?



...there were financial incentives from your employer?



...there were showers and secure bike storage at work?

Figure 2b: Do you think you would sometimes commute to work by bicycle if...
(asked of all adults who did ride a bicycle in the last year, but did not commute to work by bicycle in the last month)

(From Bicycling, "Communting By Bicycle," 1991)

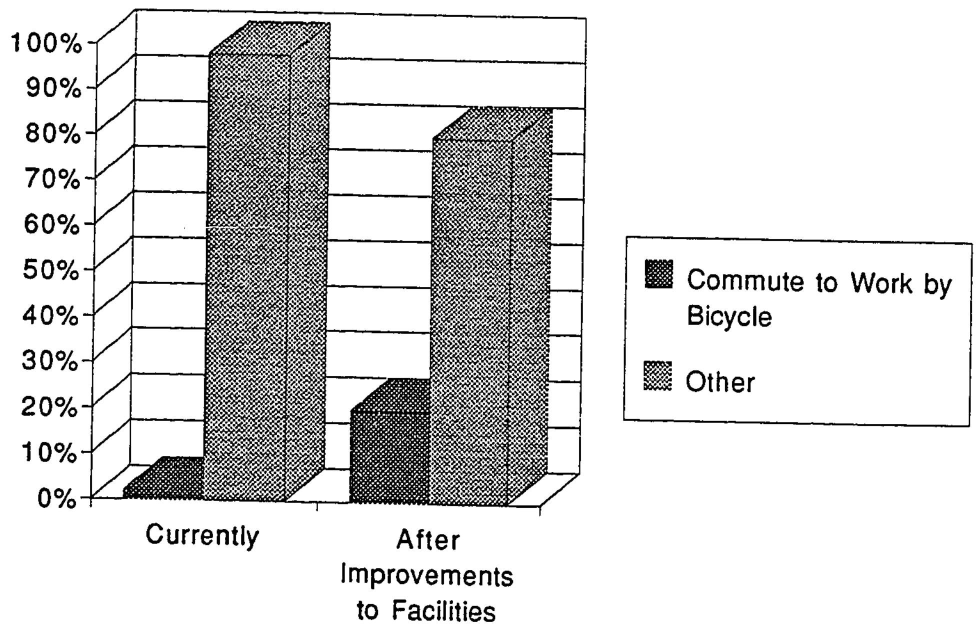


Figure 2C. "Commuting by Bicycle" Survey Results
(From Bicycling, "Commuting by Bicycle," 1991)

used more extensively as travel modes. The study compiled survey data from various cities in the U.S. One survey asked respondents to state why they do not ride a bicycle to work (Table 8a). The most popular reason was "too far to ride," followed by "too dangerous." Lack of facilities was the third most popular answer. Other reasons included the need of a car for work, inconvenience, and the weather.[34]

The report also cites a survey which asked people in three cities what improvements could be made to encourage them to ride a bicycle to work (Table 8b). Like the Harris Poll, the survey respondents list such improvements as safer routes, shower facilities, and improved parking.[35] However, unlike the Harris Poll, the category of "nothing could encourage use of this mode" was added, and this choice received the most votes in all three cities (37% in Davis, CA, and Seattle, WA, 72.7% in New York), with selections such as "safer routes," "shower facilities," and "improved parking" receiving the rest of the votes. This shows that while improvements to facilities are important, overriding considerations (such as distance of commute) may be more important to most people.

The Federal Highway Administration study also includes a survey taken in Seattle that asked respondents to rank three sets of policy options--expand/improve facilities; educate cyclists and motorists; and enforce bicycling traffic laws--in order of importance (Table 8c).[36] "Expand/Improve facilities" was cited in the survey as the most important bicycle policy.

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34 U.S. Department of Transportation, Federal Highway Administration, Case Study No.1: Reasons why bicycling and walking are and are not being used more extensively as travel modes (Washington D.C.: GPO, 1993), 20.

35 Ibid., 22.

36 Ibid., 23.

Table 8a Percentage Active Bicyclists Citing Following Reasons For Not Bicycle Commuting (a)

Reason	Phoenix	Seattle	Portland	Orange County
Too far to ride	31%	41%	21%	45%
Too dangerous	19%	22%	12%	N/A
Lack of facilities	17%	15%	12%	N/A
Need car for work	14%	8%	N/A	7%
Inconvenient	6%	8%	17%	4%
Weather	N/A	11%	7%	N/A

Table 8b Results of the survey question: "What would induce you to bicycle to work?" (b)

Improvement	Davis	Seattle	New York
Safer Routes	11.70%	41%	1%
Shower Facilities	9.40%	5%	3.10%
Improved Parking	11.90%	4%	0.90%
all of the above	N/A	N/A	28.3
Nothing could encourage	37%	37%	72.70%

Table 8c Results of the survey question: "Rank Importance of the following policy options to increased bicycling" (c)

Policy Option	Most Important	2nd	3rd
Expand/Improve Facilities	67%	17%	16%
Educate Cyclists & Motorists	21%	45%	34%
Enforce bicycle traffic laws	19%	35%	46%

NOTES:

(a) U.S. Department of Transportation, Federal Highway Administration. Case Study No.1: Reasons Why Bicycling and Walking are and are not being used more extensively as Travel Modes. (Washington D.C.: GPO,1993), 20.

(b) Ibid., 22.

(c) Ibid., 23.

A Bay Area survey was conducted by Michelle Sullivan at a Mountain View company called Metaphor, Inc. The survey, conducted in the spring of 1991, was distributed via electronic mail. It was sent to 200 employees and of the 181 employees who completed this survey, about 10% bicycled to work at least once a week. The survey asked those who regularly cycled what it would take to make them bicycle more often. Two thirds of them indicated that improved facilities (bike lanes and paths, allowing bikes on transit, parking, etc.) would make them bicycle more often. [37] (see Figure 3).

The survey also asked those who do not bicycle to work what would make them do so. Roughly one-third said that improved bicycle facilities would make them bicycle more, but the majority of those surveyed stated reasons that are not related to bicycle facilities, especially distance from home to work.[38]

This survey indicates that if bicycle facilities were improved, the numbers of employees who bicycle to work and those who use another mode, 10% and 90% respectively, would change to 44% cycling and 56% using another mode of transportation. However, surveys of hypothetical use generally are not very accurate: what people indicate they would do and what they actually do when presented with the opportunity may be two different things. Rather than an accurate indicator of how commuting habits would change if circumstances changed, these surveys are good indicators of what people want and don't want in terms of bicycle transportation.

Several methods have been used to more accurately determine how bicycle facilities affect bicycle ridership levels: bicycle counts and site comparisons.

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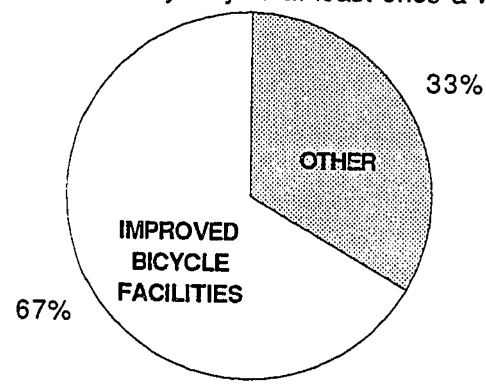
[37] Michelle Sullivan, "Metaphor Bicycling Survey," (unpublished data, 1991).
[38] Ibid.

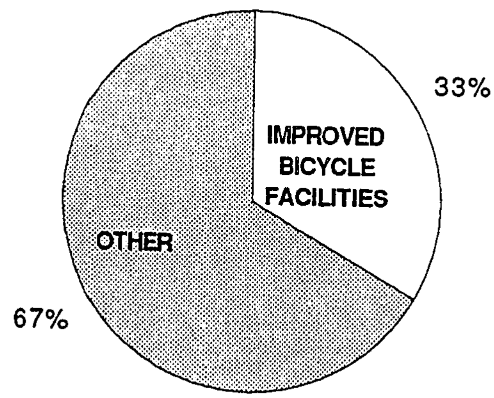
Part 1

Of those surveyed who commute to work by bicycle at least once a week, what would make them ride more often:



Part 2

Of those surveyed who do not commute to work by bicycle, what would make them bicycle to work:



Part 3

Changes in bicycle ridership levels, after improvement to facilties:

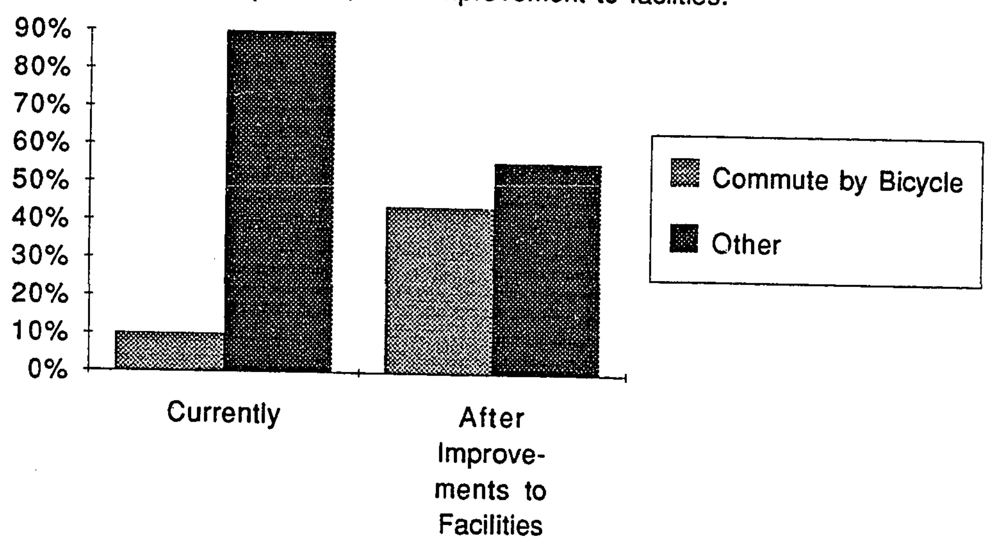


Figure 3. Metaphor Bicycle Survey Results
(From Metaphore Bicycle Survey by Michelle Sullivan, 1991)

BICYCLE COUNTS

One of the ways to determine whether or not factors such as bicycle facilities affect the level of ridership for a given area is to use bicycle counts. Bicycle counts are defined as counting the number of bicyclists for a given area, at a given time of the day and year, and repeating this process in the same area at a later time. To help determine whether ridership is increasing because of improvements to bicycle facilities, counts should be taken before and after improvements to bicycle facilities in that area.

Unfortunately, not many examples of bicycle counts before and after facility improvements exist. Of the studies that were done, probably the most well-known were done in Palo Alto, CA. In the late 1960's, Palo Alto started to plan its bikeway system. Palo Alto's Planning Commission began the process of developing a bicycle route system by consulting with local bicyclists.[39] Together, city officials and bicyclists developed the Bikeways Master Plan. Currently, Palo Alto's bikeway system includes a nearly 40 mile network of bike paths, bike lanes, bike bridges or underpasses, bicycle parking, a bicycle boulevard (closed to automobile traffic), and signed bike routes. In September 1973, the Palo Alto bikeways system was officially dedicated. Bicycle counts were conducted at twelve locations on the bikeway system streets in 1972, before the bikeway system was implemented and again in 1973, after much of the 40+ planned miles of both bike lanes and paths had been completed. In 1972, the total volume of bicyclists at the twelve locations was 11,972. In 1973, after improvements to the bicycle facilities, the total volume was recorded as 13,519, an increase of 13%.[40]

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[39] Ellen Fletcher, "Palo Alto: A Bicycle Friendly City," Bicycle USA, February 1989, 16.
[40] City of Palo Alto City Council, Staff Report: Bicycle Route System: Evaluation and Status Report (Palo Alto, Ca., January 17, 1974), 2.

Bicycle counts were also conducted along Palo Alto's "bicycle boulevard", a two mile long stretch of road in central Palo Alto that is off-limits to cars. In late 1981, before the bicycle boulevard was implemented, the Palo Alto City Council approved a demonstration study of the boulevard. The study consisted of bicycle counts taken in two main areas along the boulevard itself and along certain parallel and cross streets. Base counts were taken at these locations from 7am to 7pm, during weekdays, in May 1981 and April 1982. The bicycle boulevard was then put through a trial run from May to the end of October, 1982.[41] Bicycle counts were taken a final time during October, while the boulevard trial was occurring.

The results of the bicycle counts show a significant increase in bicycle traffic along the boulevard, and a decrease in bicycle traffic in areas adjacent to the boulevard. The data from the counts indicates that bicycle ridership increased overall by about 25%.[42] It cannot be determined from this study whether the increase in bicycle traffic along bikeways in Palo Alto after improvements to facilities is an increase in total bicycle ridership or if the increase is merely from re-routed bicyclists. To accurately determine this through bicycle counts, counts would have to be taken city-wide both before and after improvements to bicycle facilities--an enormous undertaking. Although the 1982 bicycle boulevard evaluation showed shifts from parallel roads to the boulevards, the entire ridership level for the areas counted had increased. This shows that, at least in the vicinity surrounding and including the bicycle boulevard, the ridership levels increased after bicycle facilities improved.

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41 City of Palo Alto, Staff Report: Bicycle Boulevard Demonstration Study - Evaluation (Palo Alto, Ca., December 9, 1982), 7.

42 Ibid., exhibit #3.

Stanford University also conducted alternative transportation mode counts, which include bicycle transportation. Seven counts were taken from 1987 to 1992. The counts for bicycles were taken at 11 locations on campus. Though the numbers have fluctuated from year to year (and month to month), overall from December 1987 (when the counts began) to October 1992 (the date of the last count), there has been a rise in the level of ridership of about 20%[43]. Again, it is difficult to determine exactly what is responsible for the rise in the level of ridership, but because bicycle facilities on and surrounding the campus continued to improve during those years, the conclusion may be drawn based on the bicycle counts that the rise in the level of bicycle facilities may be at least partially responsible for the rise in the level of ridership.

The City of San Diego's bikeways program was started in 1965. In that year, the city installed 2.4 miles of Class II bike lanes and 4 miles of Class III signed bicycle routes. By 1991, more than 250 miles of bikeways were constructed.[44]

In order to determine where bicyclists were riding and how many bicyclists there were, the San Diego Association of Governments conducted bicycle counts over the last decade or so, most recently in 1990. Bicycle counts were taken at 71 locations throughout San Diego.[45] The results of the counts show that since 1980, cycling has increased in volume by approximately 10-15%, although there have been large fluctuations from year to year in the exact number of cyclists,

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43 Stanford University, Alternative Transportation Mode Counts (November 1992).

44 City of San Diego, Traffic Engineering Department, Bicycle Facilities in San Diego (San Diego, Ca., n.d.).

45 San Diego Association of Governments, Bicycle Counts at Selected Intersections in San Diego County, 1990 (San Diego, Ca., February 1991), 3.

probably due to factors such as demographics, counting methods, and the weather.[46] During this time, 1980 to 1990, approximately 65 miles of bikeways in San Diego were constructed (Figure 4a).[47]

More recently, in comparing the data from the counts in 1987 and 1990, a 6.9% increase in the total number of cyclists was recorded.[48] From 1987 to 1990, 54.6 miles of bike lanes, 1 mile of bike path, and 4.4 miles of bike routes were constructed in San Diego (Figure 4b).[49]

Similar to Palo Alto, Eugene, Oregon, began its bicycle program in the early 1970's. The city began by forming a bicycle committee to encourage bicycle use. The committee set about to determine where bicycles were being ridden, where cyclists would ride if barriers or impediments were removed, and how these barriers or impediments could be removed. They distributed questionnaires, held public meetings, and conducted bicycle counts at key points throughout the city.

By 1975, the Eugene Bikeways Master Plan, comprising 120 routes covering about 150 miles, was approved by the City Council.[50] Though over the years the plan has been changed and modified, the goals have remained the

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46 San Diego Association of Governments, Bicycle Counts at Selected Intersections in San Diego County, 1990 (San Diego, Ca., February 1991), 8.

47 City of San Diego, Traffic Engineering Division, Bicycle Facilities in San Diego (San Diego, Ca., n.d.).

48 San Diego Association of Governments, Bicycle Counts at Selected Intersections in San Diego County, 1990 (San Diego, Ca., February 1991),19.

49 From 1980 to the present, there has been a per year increase of 1.5% for all roads, 2.2% for the population, and 1.8% for bicycle ridership. From San Diego Association of Governments, Dennis Thompson, October, 1993.

50 Bikeways Oregon, Inc., Bicycles in Cities: The Eugene Experience, 12 vols. (Eugene, Ore., 1981), 2.

Figure 4a City of San Diego: Results of Bicycle Counts Before and After Improvements to Facilities (1980-1990) (a)

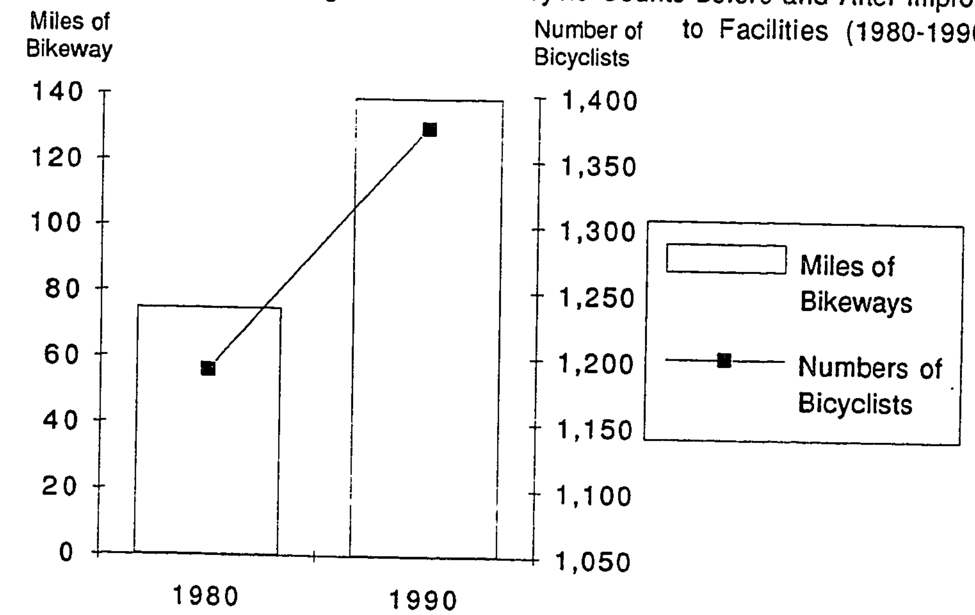
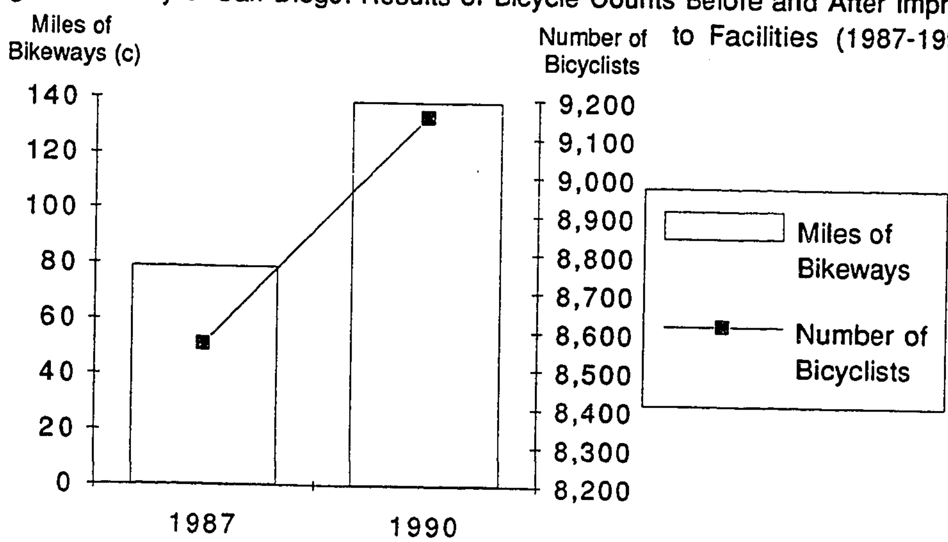


Figure 4b City of San Diego: Results of Bicycle Counts Before and After Improvements to Facilities (1987-1990) (b)



NOTES:

(a)From San Diego Association of Governments. Bicycle Counts at Selected Intersections in San Diego County, 1990. February, 1991. Counts taken at 18 locations.
(b) Ibid. Counts taken at 71 locations.
(c) Bikeway information from City of San Diego, Traffic Engineering Division.

same: to construct facilities and make policies that would integrate bicycles into the transportation system. In the years following the Plan's approval, 70 miles of paths, on-street lanes, and signed routes have been constructed.

When about 50 miles of the bikeways had been constructed, the city hired independent consultants to come to Eugene to evaluate the program. The consultants found that the city's bicycle commuters were using the routes to a great extent. Bicycle counts taken in 1978 (after construction and improvements to bicycle facilities), when compared to similar counts taken in 1971, showed a 76% increase in bicycle ridership.[51] Since then, bicycle counts have not been done frequently or at many locations. However, counts taken in 1992 at 14 locations around the city show that the level of ridership recorded in 1978 has, for most locations, increased slightly or remained steady. This shows that the jump in ridership from 1971 to 1978, after improvements to facilities, has either remained consistent or increased.

Trying to gauge whether bicycle facilities influence the level of bicycle ridership by conducting bicycle counts is a difficult task. In order to achieve accurate results, the bicycle counts must be done before and after construction and/or improvements to bicycle facilities. The counts must be taken at numerous locations, not just along bikeways, but throughout the area. This way it can be determined if, for example, an increase in ridership levels along a specific bike lane is due to new bicyclists (thus a true increase in ridership levels for the area) rather than a re-routing of cyclists from one route to another (no net increase in ridership levels for the area). Finally, the counts must be taken at consistent

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51 Bikeways Oregon, Inc., Bicycles in Cities: The Eugene Experience, 12 vols. (Eugene, Ore., 1981), 12.

times and locations. For example, counts taken in February and again in June might have different results, strictly because of a factor such as the weather.

The bicycle counts that were taken in Palo Alto, San Diego, and Eugene for the most part adhere to the above specifications. The data from these surveys do not always lend themselves to statistical evaluation but do indicate that the level of bicycle ridership increases after bicycle facilities are improved.

SITE COMPARISONS

Another way of determining how bicycle facilities affect ridership levels is by comparing bicycle facilities and bicycle ridership between cities and towns. While bicycle counts look at the number of bicyclists for an area before and after improvements to bicycle facilities to that area, site comparisons examine the relationship between the percentage of bicycle commuters and the amount and type of bicycle facilities for given areas. The objective of site comparisons is to determine whether or not there is a correlation between bicycle facilities and bicycle ridership.

In 1993, the U.S. Department of Transportation's Federal Highway Administration issued a report, Case Study No.1: Reasons why bicycling and walking are and are not being used more extensively as travel modes. This report examines bicycle facilities and ridership levels in many different U.S. cities.

Figures 5a and b are from this study. Figure 5a shows the ratio of bikeways (bike lanes and bike paths) to street miles (excludes state and county-owned highways and expressways) versus the percentage of bicycle commuters for a variety of cities. This chart appears to show a relationship between

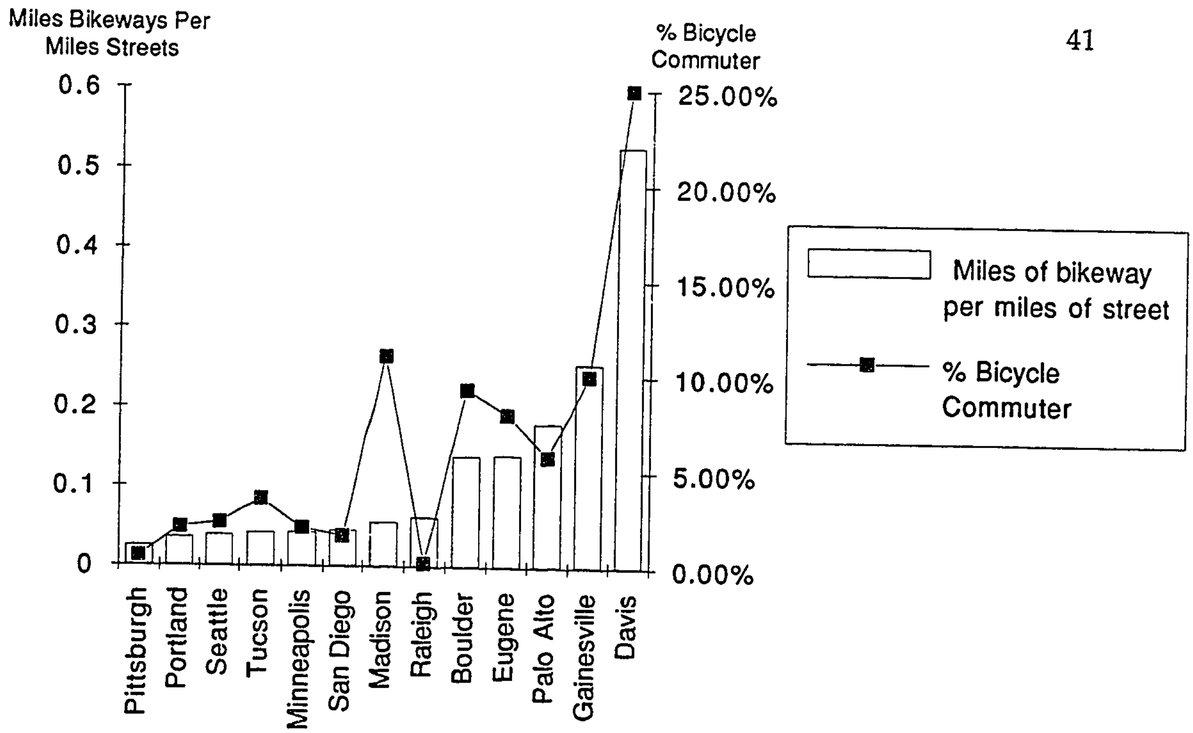

Figure 5a Ratio of Bikeways to Street Miles vs. Percentage of Bicycle Commuters (a)

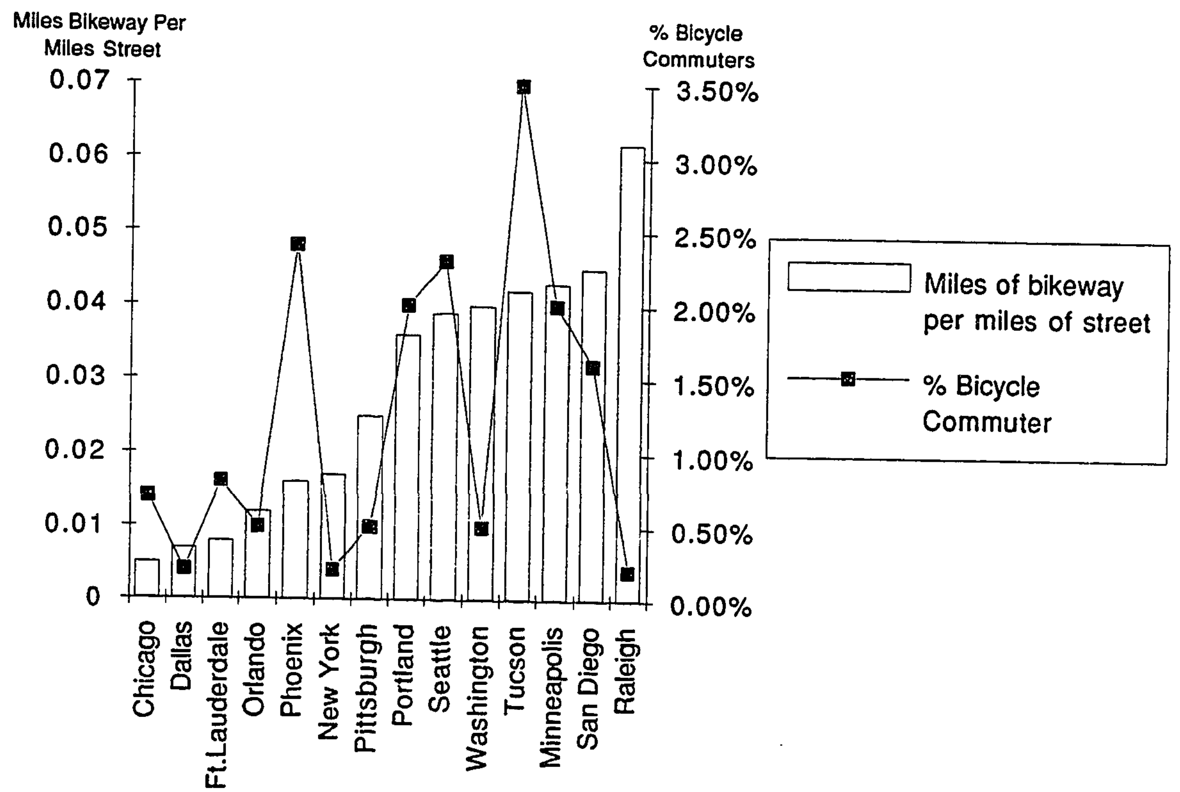

Figure 5b Ratio of Bikeways to Street Miles vs. Percentage of Bicycle (University towns excluded)

NOTES: (a) U.S. Department of Transportation, Case Study No.1, 38-41.

bikeways and ridership levels. However, when university towns are excluded from this chart (Figure 5b) , the relationship is weaker, revealing that universities (usually in small towns with a young, healthy population) greatly influence ridership levels. In fact, when the data from these two charts was tested using the Pearson product-moment correlation, no correlation between the ratio of bikeways to street miles versus the percentage of bicycle commuters was found. The Pearson product-moment correlation results for Figure 5a are $r=.9242$, $n=15$, α 0.05. For Figure 5b, the results are $r=.320$, $n=14$, α 0.05.

Figures 6a and 6b are also from the U.S. Department of Transportation study. Figure 6a shows the ratio of bike lanes to arterial miles (includes city-owned streets and state and county-owned highways and expressways) versus the percentage of bicycle commuters for a number of cities. Figure 6b shows the same data, except it leaves out university towns. Unlike the data from Figures 5a and 5b, the data in Figures 6a and 6b were found, using the Pearson product-moment correlation test, to have a definite correlation. The Pearson product-moment correlation results from Figure 6a are $r=0.702$, $n=13$, α 0.05. The results for Figure 6b are $r=0.929$, $n=16$, α 0.05.

It is clear from this data that bike lanes have a much stronger relationship than bikeways (bike lanes and bike paths) do on the level of bicycle ridership. However, the study warns against making too many conclusions based on this data because there are many factors that may be influencing the data for each city that are not readily apparent, such as street layouts, land use, and traffic patterns. Furthermore, comparing different sites in the U.S. is itself problematic, because of economic, cultural, climatic and geographic differences between the cities. Therefore, a comparison of different cities and towns within one region

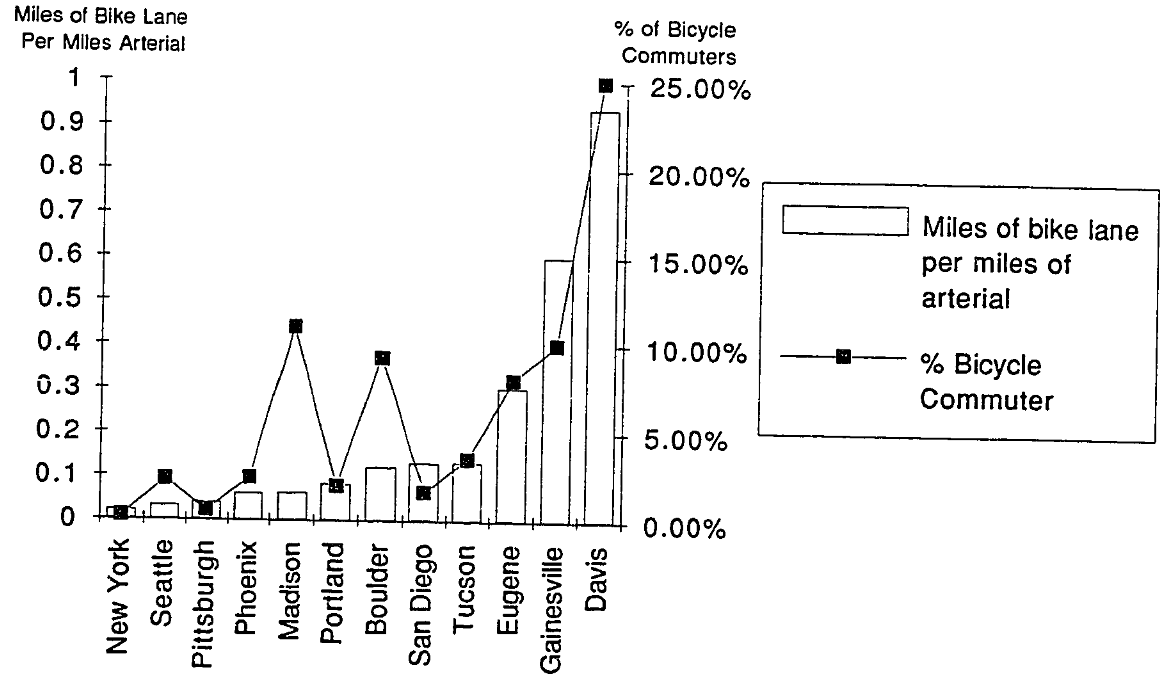

Figure 6a Ratio of Bike Lanes to Arterial Miles vs. Percentage of Bicycle Commuters (a)

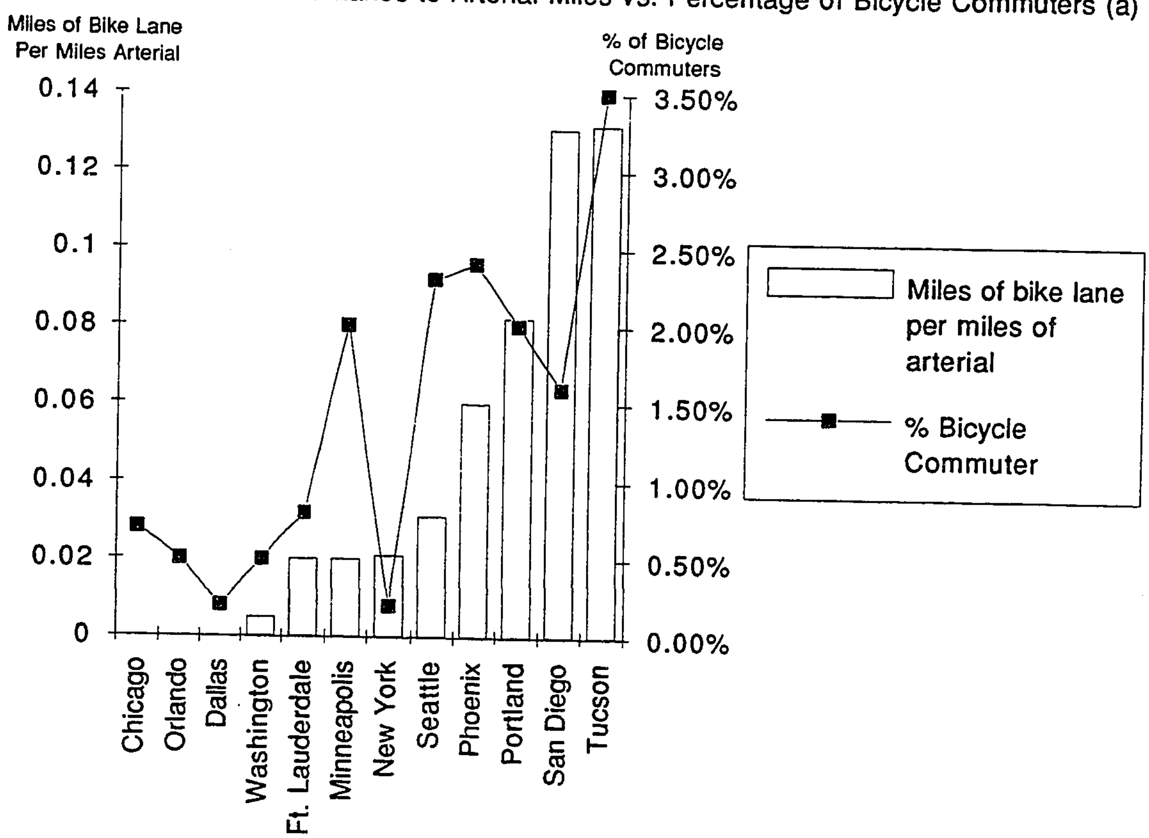

Figure 6b Ratio of Bike Lanes to Arterial Miles vs. Percentage of Bicycle Commuters (without university towns)

NOTES: (a) U.S. Department of Tranpsportation, <u>Case Study No.1</u>, 38-41.

may be more accurate.

Figures 7a and 7b compare bicycle facilities and bicycle ridership levels for towns and cities within Santa Clara County, an analysis similar to that in the U.S. Department of Transportation's report. Figure 7a shows the relationship between the ratio of bikeways--bike lanes and paths--to street miles versus the percentage of bicycle commuters for cities in Santa Clara County. Figure 7b shows the relationship between the ratio of bike lanes to street miles versus the percentage of bicycle commuters for cities in Santa Clara County. Each town/city provided the information on the number of miles of streets for their area, but the data on the number of miles of bikeways came, in some cases, from estimations using city bikeways maps or the Santa Clara County Transportation Agency Bikeways map (May 1993). The data on bicycle commuter percentages came from the 1990 Census.

The data in Figure 7a was tested using the Pearson product-moment correlation, with and without the data from Palo Alto. Palo Alto is a university town which, as shown by the U.S. Department of Transportation study, tends to skew results. The results of the Pearson product-moment correlation test for Figure 7a are, including Palo Alto, $r=0.611$, $n=15$, α 0.05, and, without Palo Alto, are $r=0.75$, $n=14$, α 0.05. These results show that, when Palo Alto is excluded, there is a strong relationship between bikeways and bicycle ridership in Santa Clara County.

The data in Figure 7b, which test the relationship between bike lanes and bicycle ridership show a slighly stronger correlation than between bikeways and

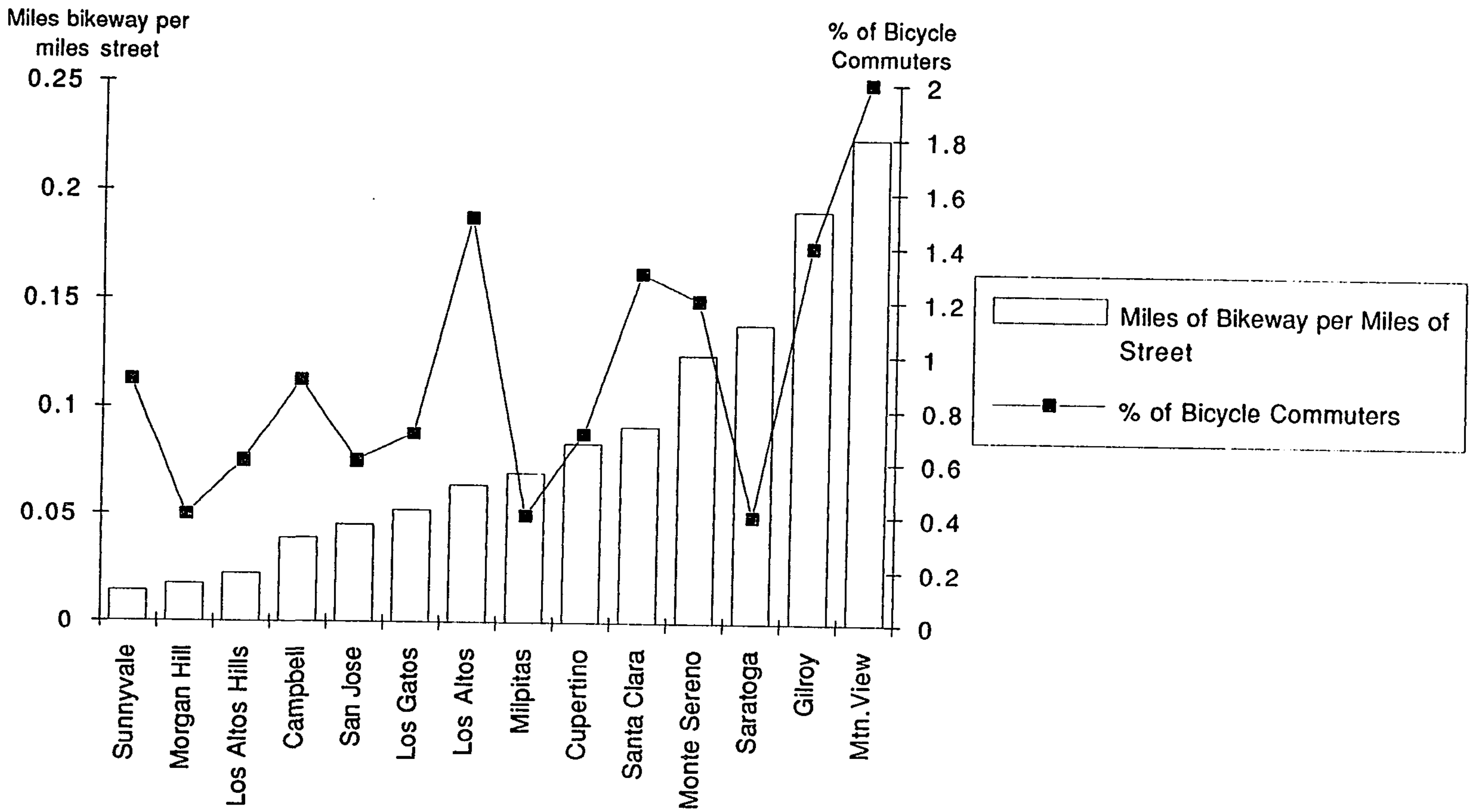

Figure 7a Ratio of Bikeways (a) to Street Miles vs. Percentage of Bicycle Commuters (b)

NOTES:
(a) Includes bike lanes and bike paths only.
(b) Information from 1990 Census, Santa Clara County Transportation Agencys Bikeways map, May 1993, and city offices within Santa Clara County. Excludes Palo Alto.

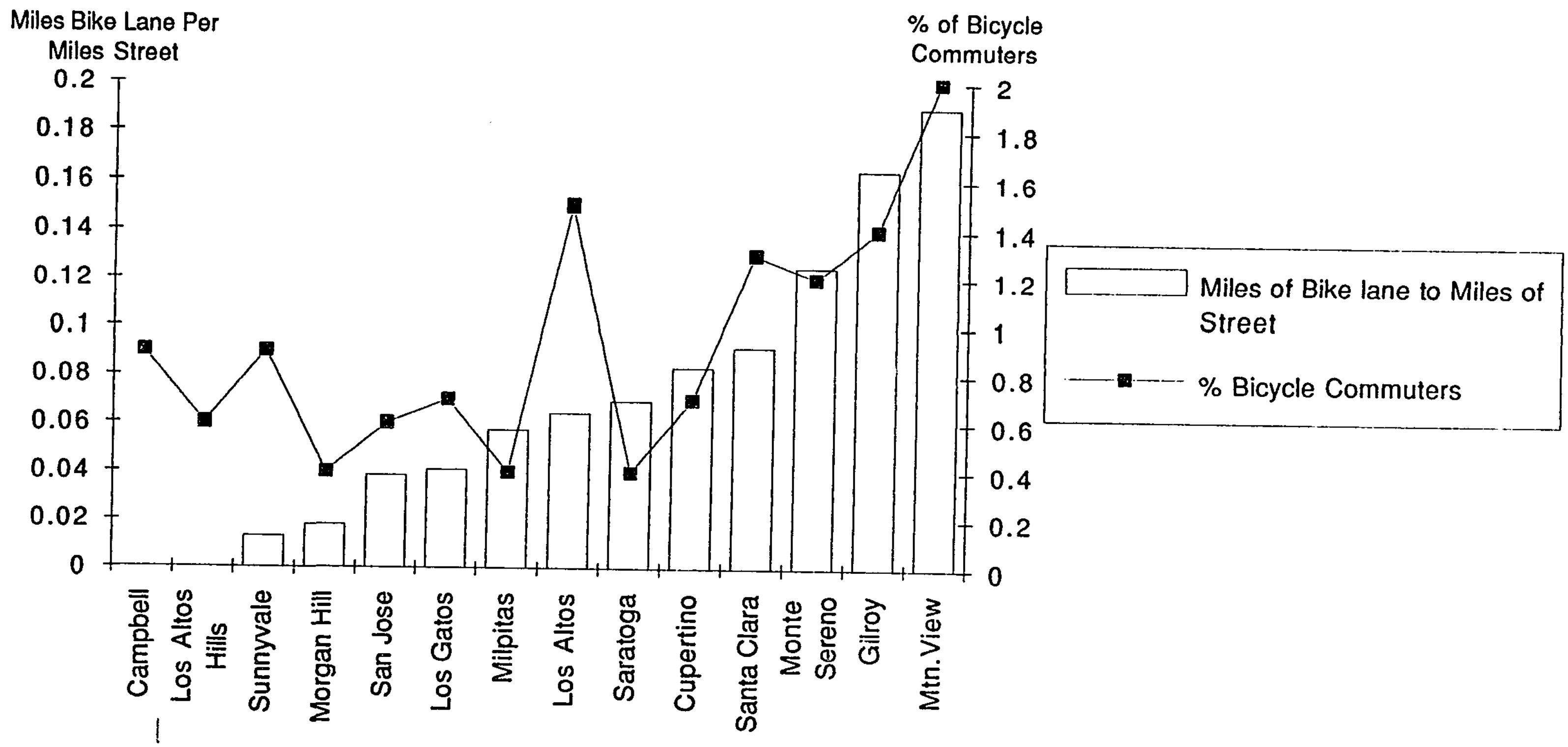

Figure 7b Ratio of Bike Lanes to Street Miles vs. Percentage of Bicycle Commuters (a)

NOTES:
(a) Information from 1990 Census, Santa Clara County Transportation Agency Bikeways map, May 1993, and city offices within Santa Clara County. Excludes Palo Alto.

bicycle ridership in town sand cities within Santa Clara County. The results of the Pearson product-moment correlation for Figure 7b are (with Palo Alto) r=0.56, n=13, α 0.05, and (without Palo Alto) r=0.76, n=12, α 0.05.

ANALYSIS OF THE DATA

This chapter presented several methods to gauge whether bicycle facilities affect bicycle ridership levels. The results from the national and local surveys tend to support the hypothesis that bicycle facilities support bicycle ridership. A large percentage of survey respondents indicated that they would use bicycle transportation more if bicycle facilities were improved. Surveys, however, have been found to not be very accurate. Therefore, more accurate methods to determine the answer to this question were used.

Two methods to quantitatively assess whether or not factors such as bicycle facilities affect the level of ridership for a given area are bicycle counts and site comparisons. The results from both the bicycle counts and the site comparison data indicates that improved facilities encourage bicycle ridership.

The bicycle count results from Palo Alto showed a 13% increase in ridership after improvements to the bikeway system. There was also an increase in ridership levels after the "bicycle boulevard" was created, though only the area surrounding and including the bicycle boulevard was surveyed. Stanford University, too, has shown an increase in ridership levels as its bicycle facility levels increase. From 1987-1990, the City of San Diego saw a 6.9% increase in ridership levels after 54.6 miles of bike lanes, 1 mile of bike path, and 4.4 miles of bike routes were constructed. Finally, Eugene, Oregon showed a large increase in ridership after their bikeways were constructed or improved.

Though bicycle counts, as a method for determining whether bicycle facilities influence bicycle ridership levels, are problematic, the pattern that develops when examining the data from these bicycle counts is that bicycle facilities appear to encourage bicycle ridership.

Site comparisons provide another approach to testing the relationship between bicycle facilities and bicycle ridership. Several comparisons indicate a positive correlation. Although no correlation was found when comparing the U.S. Department of Transportation's data on bikeways and level of ridership for various U.S. cities, there was a definite correlation when comparing bike lanes only and level of ridership for various U.S. cities. This may be because bike lanes are generally placed on a more direct route from residents' homes to their work places. However, because of many factors such as the different climate, topography, and demographics for these areas, comparing such diverse regions is not a very accurate method. Comparing towns and cities within a region is expected to be a more accurate method.

As with the national, the Santa Clara County data showed that the presence of a university town skewed the data. The young population of such towns is more likely to bicycle ride whatever the facilities. When Palo Alto is removed from the Santa Clara County data, there is a strong positive correlation between both bikeways and bike lanes and ridership, though the correlation between bike lanes and level of ridership is slightly higher.

CHAPTER V

HOW BICYCLE TRANSPORTATION AFFECTS AIR QUALITY IN SANTA CLARA COUNTY

Analysis from the last chapter indicates that bicycle ridership can be increased if bicycle facilities are increased. However, does this increase in bicycle ridership have a significant impact on air pollution? This chapter examines what effect work trip-oriented bicycle transportation has on motor vehicle-caused air pollution and total air pollution in Santa Clara County. To determine this effect, many factors had to be taken into consideration. The purpose of this chapter is to calculate, step by step, bicycle transportation's effects on air quality. This study calculates impacts from work commute trips only, not trips to school or to another destination. Nor does it include recreational trips of any kind. This study focuses on the impact of bicycle commuters in Santa Clara County.

Figure 8a is a flow chart of this model. It demonstrates the methodology for determining how bicycle commuters affect air pollution in Santa Clara County. Figure 8b is the corresponding equation.

In the first step, total daily emissions and daily motor vehicle emissions for Santa Clara County are calculated. This information is derived in part from data collected by the State of California Air Resources Board.[52] Emissions Inventory 1989 is an inventory of the types, quantities and sources of air pollutants in air

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[52] Another source of information about emissions in the San Francisco Bay Area is the Bay Area Air Quality Management District's 1987 Emissions Inventory. The data from the State of California Air Resources Board Emissions Inventory 1989 was used instead of 1987 Emissions Inventory because the information in it was more current.

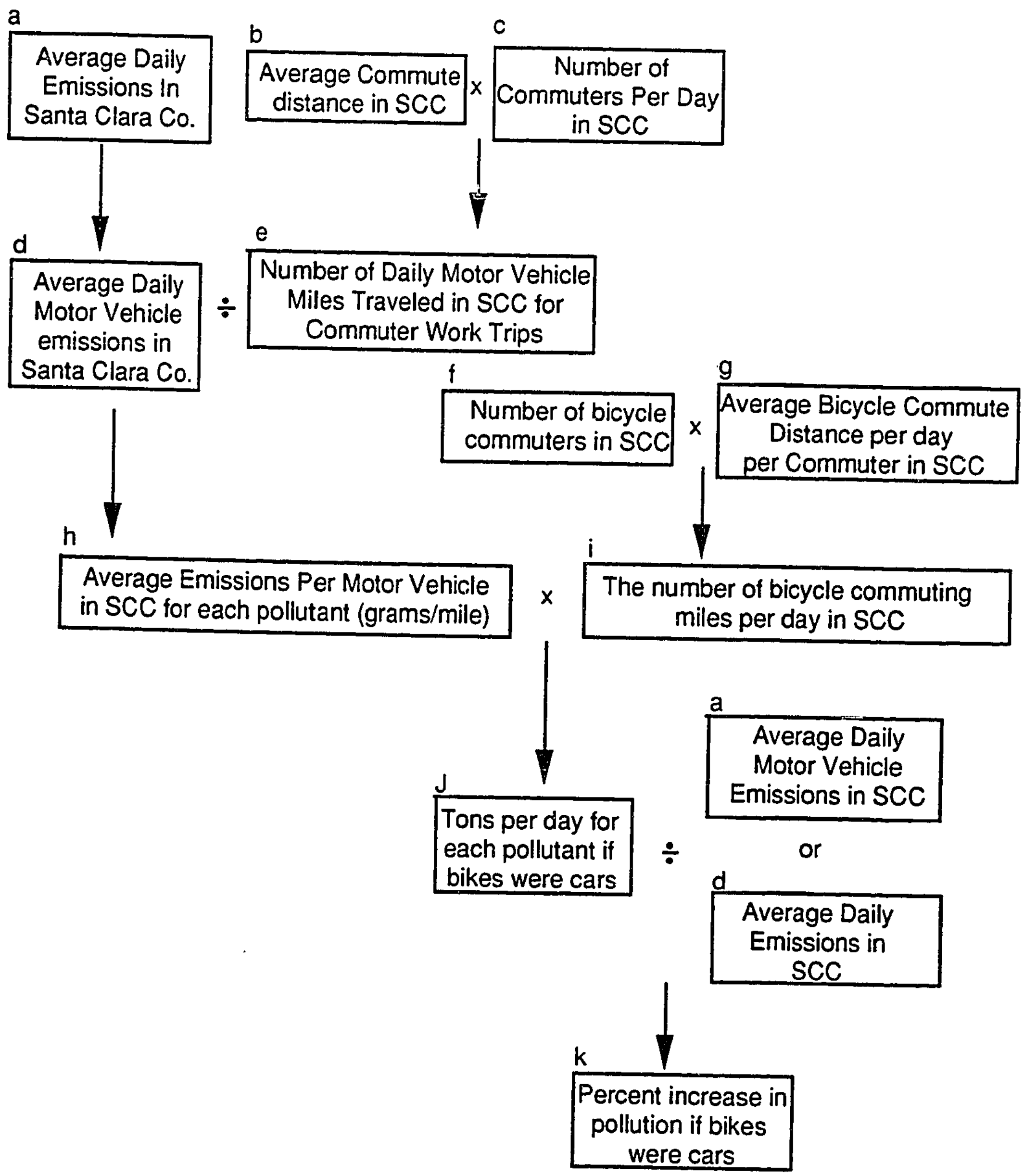

Figure 8a Flow Chart of Model: How Bicycles Affect Air Quality in Santa Clara County

Figure 8b Equation to the Model

$$\frac{\left(\left(\frac{d}{c \times b}\right) \times \left(f \times g\right)\right)}{a \text{ or } d} = k$$

basins in the state of California.[53] The California Air Resources Board (CARB) compiled this inventory using data from a variety of sources, such as air quality management districts, governmental agencies, consulting firms, literature, and research studies.[54]

Table 3 (on page 10) shows the 1989 Base Year Inventory, Average Daily Emissions for Santa Clara County in tons per day. This table lists the following seven criteria pollutant categories: particulate matter (PM) and fine particulate matter (PM_{10}), a sub-category of PM; total organic gases (TOG); reactive organic gases (ROG), a sub-category of TOG; oxides of nitrogen (NOx); oxides of sulfur (SOx); and carbon monoxides (CO). This table shows how much and what kind of pollution is emitted each day in Santa Clara County, and what its source is.

Table 10 is derived from Table 3. It shows how much and what kind of pollution is emitted every day in Santa Clara County from motor vehicles according to the California Air Resources Board. This table includes emissions from cars, light-duty and medium-duty gasoline trucks, and motorcycles, all of which constitute "motor vehicles" in this thesis. Emissions from heavy-duty diesel or gasoline trucks or buses are not included as this thesis focuses on individual commuter vehicles, and not on heavy-duty trucks.

Next, the number of bicycle commuter miles per day in Santa Clara County was determined by multiplying the average number of bicycle commuters in Santa Clara County per day by the average number of miles these bicycle commuters ride per day. To find the number of bicycle commuters, two main

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53 State of California Air Resources Board, Technical Support Division, Emissions Inventory Branch, Emissions Inventory 1989 (August 1991), ii.

54 Ibid., IV-1.

Table 9
1989 Base Year Inventory:
Average Daily Motor Vehicle Emissions in
Santa Clara County (a)
(tons/day)

	TOG	ROG (b)	CO	NOx	SOx	PM	PM-10 (c)	TOTAL (d)
Cars	50	46	350	46	2.4	6.6	3	
Light & Medium Trucks	13	12	98	14	0.9	1.7	0.8	
Motorcycles	1	0.9	3	0.3	*	*	*	
Total	64	58.9	451	60.3	3.3	8.3	3.8	586.9

(a) From the State of California Air Resources Board, Technical Support Division, Emissic Inventory Branch, Emissions Inventory 1989. August 1991. Table A-54.
(b) Sub-category of TOG
(c) Sub-category of PM
(d) Total does not include the sub-categories, ROG and PM
*indicates that emissions estimates rounded off to less than 0.1 tons per day

sources were used: the 1990 Census and Commute Profile '92, a survey of Bay Area commuters conducted by RIDES for Bay Area Commuters, Inc. While the 1990 Census surveyed all residents in Santa Clara County, in which one in eight people responded, Commute Profile '92 was a random sampling of residents in the Bay Area, including Santa Clara County.[55]

Table 11a shows the number of commuters in Santa Clara County, as determined by the 1990 Census. This chart has been broken down according to the following transportation modes: drive alone, carpool, transit, walk, and other. Table 11b shows the number of bicycle commuters in Santa Clara County and the percent of the total they make up, according to the 1990 Census and Commute Profile '92. Because the Commute Profile '92 is a random sampling survey, it did not provide the number of commuters, bicycling or otherwise, for Santa Clara County. However, it did provide a percentage of bicycle commuters of the total, which is 2%. Thus, the number of bicycle commuters was calculated by taking 2% (the Commute Profile '92 figure) of the total number of commuters (excluding telecommuters) in Santa Clara County (the 1990 Census figure). The resulting number is in Table 11b.

It is the Commute Profile '92 bicycle commuter number that is used in this report, rather than the 1990 Census bicycle commuter number, for a number of reasons. The "long form" of the 1990 Census, which contained questions regarding work commute modes, was sent to about 1/8th of the households in Santa Clara County, and the rest of the households received the "short form." Commute Profile '92 conducted a random telephone survey of Bay Area

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[55] For the 1990 U.S. Census, in households overall, 1 in 6 responded. For urban areas specifically, 1 in 8 households responded.

Table 10a

Number of Commuters in Santa Clara County (a)		
Drive Alone	618,995	
Carpool	98,163	
Transit	23,727	
Walk	16,509	
Other	19,225	
Total (b)	756,633	

Table 10b

Number of Bicycle Commuters in Santa Clara County		
	Bicycle Commuters	Percent Bicycles
Commute Profile '92	15,133 (c)	2.00%

NOTES:

(a) From 1990 Census

(b) Excludes telecommuters

(c) Figure derived by calculating 2% of the total number of commuters according to the 1990 Census. (See Chapter 5 for details) commuters, using a computer generated list of telephone numbers.[56] A total of 1600 telephone surveys were completed, 400 of which were done in Santa Clara County. The data that was obtained was then weighted according to the size of the working population in Santa Clara County.[57] The Commute Profile '92 results from Table 11b were used in this study because the questions asked in this survey about commute modes were more pertinent than the ones asked in the Census. Also, Commute Profile '92 is more current than the census data by two years.

However, Table 11b uses census data from Table 11a to derive the number of bicycle commuters. This is because the most current data on the total number of commuters in Santa Clara County is from the 1990 Census. In sum, Table 11a uses data from the 1990 Census because it is the most current data on the total number of commuters in Santa Clara County. Table 11b uses data from Commute Profile '92 because it is more accurate and current than data from the 1990 Census.

The next piece of data required is the average number of miles per day that individual bicycle commuters travel in Santa Clara County. This information is from a survey conducted by Michelle Sullivan at a Mountain View company, Metaphor.[58] The survey asked those who regularly cycle to work at least once a week how many miles (approximately) their one-way journey is from home to work. The average number of miles (7.4) was then doubled to determine the round-trip mileage.[59]

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[56] Valerie Brock York, Commute Profile '92 (RIDES Planning and Research, July 1992), 1.
[57] Ibid., 2.
[58] Other data from this survey is used in this study. See Chapter IV for details on methodology.
[59] No official studies have been conducted in Santa Clara County to determine how many miles the average bicycle commute is. However, the data from the Metaphor survey seems to

To determine the average number of daily bicycle commuter miles in Santa Clara County, the number of bicycle commuters in Santa Clara County (Table 11b), 15,133, was multiplied by the average number of bicycle miles per day per commuter, 14.8. The resulting number is 223,968.4 miles.

After calculating the average number of bicycle commute miles per day in Santa Clara County, the next step was to determine what the average vehicle emits per mile. Vehicle emissions in grams per mile were calculated using data specific to Santa Clara County. The number of daily commuter vehicle miles traveled in Santa Clara County was calculated using the 1990 Census and Commute Profile '92. Commute Profile '92 states that the average auto commute distance is 13.48 miles, one way.[60] This number was doubled to give the average total commute distance per day in Santa Clara County, about 27 miles. This number was then multiplied by the number of commuters in Santa Clara County, according to the 1990 Census (See Table 11a). The number of commuters includes those who drive alone (618,995) and those who carpool, divided by 2.3, since this is the average number of occupants in a carpool (98,163 divided by 2.3 is 42,680).[61] The resulting number--661,675--is the number of non-mass transit commuter vehicles on the road each day in Santa Clara County. This number multiplied by the average number of commuting miles per day is the number of daily commuter vehicle miles traveled in Santa Clara County. The resulting number is 17,865,213 miles commuted by autos per day.

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agree with surveys conducted by CalTrans, who asked bicycle commuters what length they considered a reasonable commute. Commuters in Marin County, where the terrain is hilly, said 2-3 miles, while commuters in Santa Clara County, where the terrain is relatively flat, said 12 miles (round trip).

[60] Valerie Brock York, Commute Profile '92 (RIDES Planning and Research, July 1992),36.

[61] Ibid.

The average motor vehicle emissions, shown on Table 12, were calculated using Table 10 and the figure for the number of daily commuter vehicle miles traveled in Santa Clara County, about 17.9 million. The average daily motor vehicle emissions for Santa Clara County (in tons per day) were divided by the average number of daily vehicle miles traveled (VMT) in Santa Clara County for commuter work trips (in miles per day). The resulting sum is shown in grams per mile.

Table 13 is the calculation of what bicycle commuters would generate in terms of tons of pollutants per day if they were to stop commuting by bicycle and instead use motor vehicles for their commute. To calculate this, the number of bicycle commuting miles per day in Santa Clara County (223,968.4 miles) was multiplied by what the average motor vehicle emits per mile in Santa Clara County (Table 12) for each criteria pollutant. The results are shown in tons per day for each criteria pollutant (Table 13). The data shows that if bicycle commuter miles were motor vehicle miles, they would generate 7.34 tons per day of carbon monoxide, hydrocarbons, oxides of sulfur and nitrogen, and particulate matter.

At this point, it can be determined what the percentage increase in motor vehicle caused pollution and total air pollution in Santa Clara County would be if bicycle commuters used motor vehicles as their transportation mode to work instead of bicycles. Table 14a shows what the percentage increase in motor vehicle caused air pollution in Santa Clara County would be if bicycle commuter miles were motor vehicle commuter miles. This was calculated by dividing the results of Table 13 (what bicycles would generate in terms of pollution if they were motor vehicles) by the data from Table 10 (motor vehicle emissions for

Table 11
Average Emissions Per Motor Vehicle
in Santa Clara County
(grams/mile)

Type of Pollutant	Tons/Day for all motor veh. (a)	Daily commuter VMT* (in millions) (b)	Grams/mile emitted per motor vehicle (c)
CO	451	17.9	22.86
ROG (d)	58.9	17.9	2.99
TOG	64	17.9	3.24
SOx	3.3	17.9	0.17
NOx	60.3	17.9	3.06
PM	8.3	17.9	0.42
PM-10 (e)	3.8	17.9	0.19
TOTAL (f)	586.9		29.75

NOTES:

(a) See Table 9
(b) See Chapter 5 for details about calculations
(c) See Chapter 5 for details about calculations
(d) Sub-category of TOG
(e) Sub-category of PM
(f) Includes CO, TOG, SOx, NOx, and PM)
* Indicates vehicle miles traveled

Table 12
What Bicycles would generate in
Santa Clara County if they were motor vehicles (a)

Pollutant	Tons Per Day
CO	5.64
ROG (b)	0.74
TOG	0.80
SOx	0.04
NOx	0.76
PM	0.10
PM10 (c)	0.05
Total (d)	7.34

NOTES:

(a) See Chapter 5 for details about calculations
(b) Sub-category of TOG
(c) Sub-category of PM
(d) Does not include ROG and PM10

Table 13a

Increase in motor vehicle caused air pollution if bicycle commuter miles were motor vehicle miles			
Pollutant	tons/day if bike miles were mot.veh. miles (b)	Motor vehicle emissions in Santa Clara County in tons/day (c)	% increase (a)
CO	5.64	451.00	1.25%
TOG	0.74	64.00	1.16%
ROG (d)	0.80	58.90	1.36%
SOx	0.04	3.30	1.21%
NOx	0.76	60.30	1.26%
PM	0.10	8.30	1.20%
PM10 (e)	0.05	3.80	1.32%
TOTAL(f)	7.34	586.90	1.25%

NOTES:

(a) Calculated from Table 9 and Table 12. (See Chapter 5 for details)
(b) From Table 12
(c) From Table 9
(d) Sub-category of TOG
(e) Sub-category of PM
(f) Does not include PM10 and ROG
(g) Average percentage increase of all criteria pollutants

Table 13b

Increase in total air pollution if bicycle commuter miles were motor vehicle miles			
Pollutant	tons/day if bike miles were mot.veh. miles (a)	Total emissions in Santa Clara County in tons/day (b)	% increase (c)
CO	5.64	660.00	0.85%
TOG	0.80	430.00	0.19%
ROG (d)	0.74	180.00	0.41%
SOx	0.04	10.00	0.40%
NOx	0.76	130.00	0.58%
PM	0.10	260.00	0.04%
PM10 (e)	0.05	140.00	0.04%
TOTAL (f)	7.34	1490.00	0.49%

NOTES:

(a) From Table 12
(b) From Table 2
(c) Calculated from Table 2 and Table 12 (See Chapter 5 for details)
(d) Sub-category of TOG
(e) Sub-category of PM
(f) Does not include PM10 and ROG
(g) Average percentage increase of all criteria pollutants

Santa Clara County). The results for each criteria pollutant indicate the percentage increase in motor vehicle-caused air pollution for Santa Clara County. The results show that if bicycle commuter miles were motor vehicle miles, motor vehicle caused air pollution in Santa Clara County would increase by approximately 1.25%.

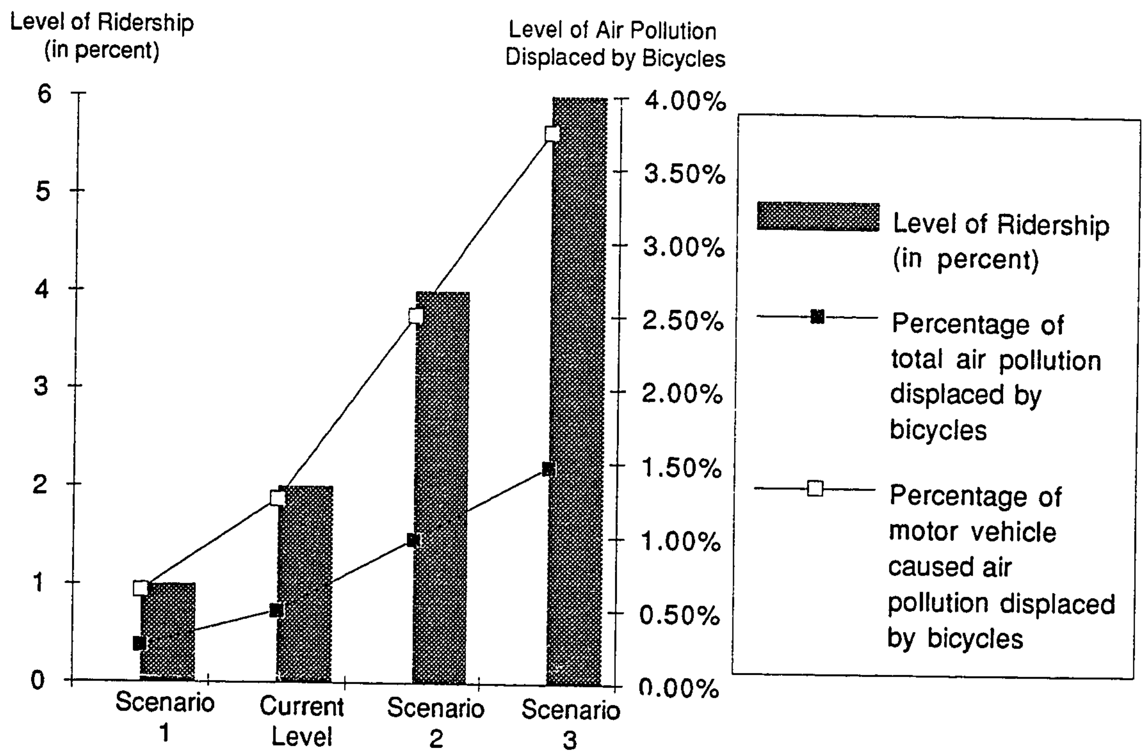
Table 14b shows the increase in total air pollution if bicycle commuter miles were motor vehicle miles. It was calculated using the same method as described above for Table 14a, except it uses Table 3 (total air pollution in Santa Clara County) instead of Table 10. The results show that if bicycle commuter miles were motor vehicle miles, total air pollution in Santa Clara County would increase by approximately .49%.

The data shows that if bicycle commuter miles were motor vehicle miles, they would generate 7.34 tons per day of pollutants. This would increase the motor vehicle caused air pollution by 1.25%, and the total air pollution by 0.49%. Furthermore, if bicycle ridership levels doubled or tripled, these numbers would double and triple as well. For example, if bicycle ridership levels climbed to 6%, total air pollution in Santa Clara County would decrease by 1.47%. Figure 9 is an illustration of three different scenarios:

•Scenario 1: what would happen to air quality if there were a 50% decrease in bicycle ridership levels in Santa Clara County.

•Scenario 2: what would happen to air quality if there were a doubling in bicycle ridership levels in Santa Clara County.

•Scenario 3: what would happen toair quality if there were a tripling of bicycle ridership levels in Santa Clara County.



Scenario 1: What would happen to air quality if there were a 50% decrease in bicycle ridership levels in Santa Clara County

Scenario 2: What would happen to air quality if there were a doubling of bicycle ridership levels in Santa Clara County

Scenario 3: What would happen to air quality if there were a tripling of bicycle ridership levels in Santa Clara County

Figure 9 How an Increase or Decrease in Bicycle Ridership Levels Would Affect Air Quality in Santa Clara County

Each scenario level represents various ridership levels in different towns in Santa Clara County. Overall, the county's ridership level is about 2 percent. Figure 9 demonstrates what would happen to air pollution if the county's bicycle ridership level was at, for example, Sunnyvale's level (about 1%) or Palo Alto's level (5.8%). As discussed in the next chapter, halving, doubling or tripling the bicycle ridership level for Santa Clara County is certainly possible.

ANALYSIS OF THE RESULTS

What do these results mean, in terms of air quality in Santa Clara County? Is displacing 7.34 tons of various air pollutants per day significant to overall air quality? Are these results significant in the long term? In the short term? Certainly, keeping any amount of pollution from being produced is beneficial, but it is important to examine this data's significance in terms of overall air quality for Santa Clara County and the Bay Area.

When first looking at the results, it may appear that displacing 1.25% of the county's motor vehicle-caused air pollution and about 0.5% of the county's total air pollution is not significant. However, several factors must be considered.

First, the Bay Area Air Quality Management District's goals are to meet state and federal government air quality standards for certain criteria pollutants. The Bay Area is a non-attainment area for ozone, carbon monoxide, and PM10. The Bay Area's air quality is improving, but it is doing so very slowly. The BAAQMD expects for the next several years to reduce air pollution in the Bay Area by about 2% each year. As the population increases in the Bay Area, this is becoming more difficult to do. Bicycle transportation is helping to achieve this goal by displacing at least 0.5% of Santa Clara County's total air pollution, a quarter of the BAAQMD's annual goal for this county.

Second, because the data necessary was not available, the numbers here are probably an underestimate of bicycle transportation's real impact on air quality. The amount of air pollution displaced by bicycle commuters in Santa Clara County is probably twice as high as the data indicates, and consequently much more significant in terms of overall air quality for Santa Clara County.

The data has also shown that bicycle transportation has the potential to displace far more air pollution if bicycle ridership levels increase. If ridership levels double or triple, the amount of displaced air pollution becomes much more significant (see Figure 9).

The data on bicycle transportation's effect on air pollution levels represents the closest approximation of the current situation in Santa Clara County, given the data available. However, the actual numbers are likely to be higher. This is important because, as bicycles tend to displace auto trips at shorter lengths and slower speeds, and these are the trips that cause the most air pollution, bicycles are actually displacing a disproportionately higher amount of air pollution than their numbers would suggest. According to a 1994 report by the Santa Clara County Transportation Agency:

> ...Replacing short automobile trips with bicycle trips is particularly effective in reducing automobile pollution, because nearly 70 percent of emissions occur in the first mile of a typical seven-mile trip when the engine is too cold to operate efficiently.[62]

Table 14, which demonstrates this point, is a hypothetical case study of net reductions in carbon monoxide emissions due to a shift to bicycle usage.

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[62] Santa Clara County Transportation Agency, Draft Santa Clara County Bicycle Plan (San Jose, Ca., January 1994), 23.

This data, from the EPA, shows average carbon monoxide emissions in grams per mile for light duty passenger vehicles in urban areas, at various speeds. The table also shows how many vehicle miles are traveled at each of these speeds per year in this urban area and the total metric tons per year of carbon monoxide in this urban area, at various speeds. The table then presents a hypothetical situation: what would happen if 2.4% of the total vehicle miles traveled per year were shifted from autos to bicycles? Then it further assumes that the shift would tend to take place at lower speeds. The last two columns show the amount of carbon monoxide displaced in terms of metric tons per year and as a percentage reduction. This table demonstrates that a shift of 2.4% from autos to bicycles could potentially bring a reduction of 5.1% in carbon monoxide emissions. Figure 10 is a flow chart of this model.

Therefore, it can be assumed that though the data in this thesis gives a conservative estimate of the impact Santa Clara County bicyclists are having on the county's air quality, the actual numbers are very likely to be higher.

Table 14
Hypothetical Case Study of Net Reduction in Carbon Monoxide
Emissions Due to a Shift to Bicycle Use (a)

	Average Speed Category	CO (grams/ VMT) (b)	Annual VMT (c)	CO metric tons/yr.	% Modal Shift (d)	Reduction CO metric tons/yr.	% Reduction in CO
	5	140	25,000	3.65	15%	0.55	15%
	10	100	65,000	6.50	10%	0.65	10%
	15	70	320,000	22.40	5%	1.12	5%
	20	55	300,000	16.50	0.50%	0.08	0.50%
	25	45	200,000	9.00	0.50%	0.05	0.50%
	55	25	310,000	7.75	0%	0	0%
Total			**1,221,000**	**56.8**	**2.40%**	**2.91**	**5.10%**

NOTES:

(a) From the EPA, Office of Transportation and Land Use Policy, Bicycling and Air Quality, Information Document, September 1979, 75

(b) Carbon monoxide emitted per light passenger vehicle, in terms of grams per vehicle mile traveled at various speeds

(c) Annual vehicle miles traveled for all light passenger vehicles in an urban area, according to speed

(d) Hypothetical percentage shift from light passenger vehicles to bicycles in terms of total transportation, according to speed

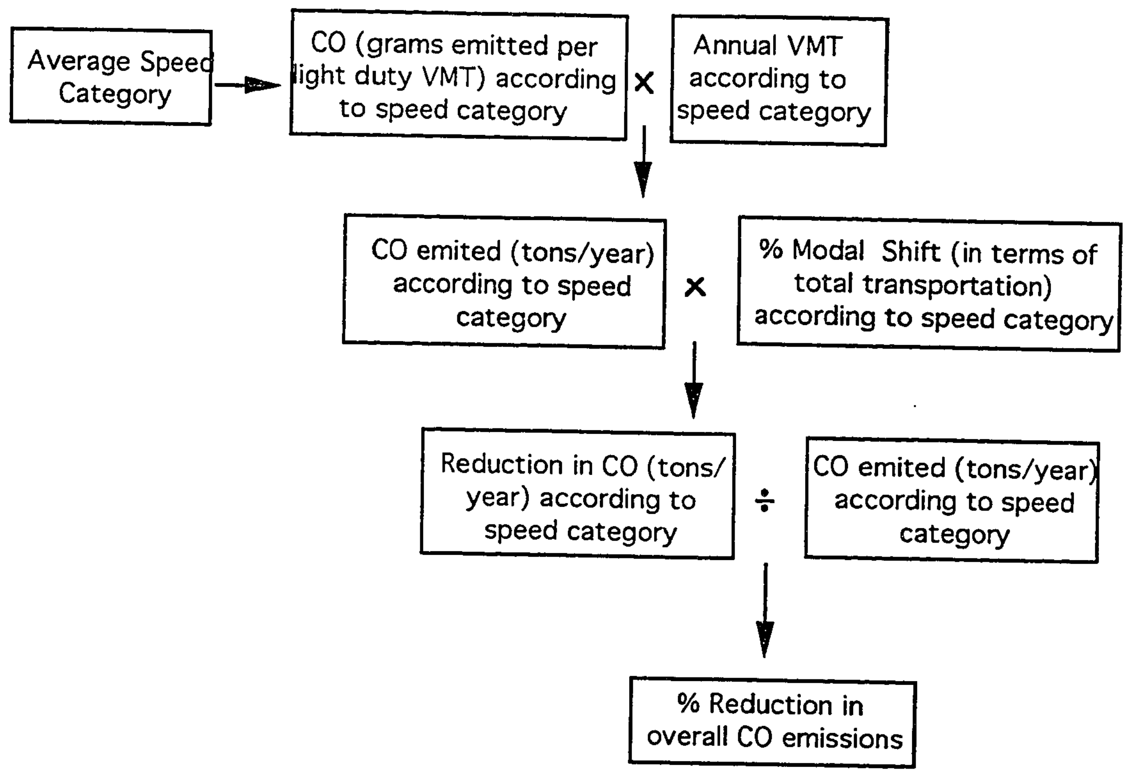

Figure 10 Flow Chart of Table 15:
Hypothetical Case Study of Net Reductions in Carbon Monoxide Emissions Due to a Shift to Bicycle Usage

CHAPTER VI

CONCLUSIONS

The purpose of this thesis was to determine whether funding bicycle facilities in order to improve air quality is a sound policy. To answer this question, this study examined how bicycle facilities affect bicycle ridership levels and how bicycle transportation affects air quality.

This study began by examining the types, amounts and effects of air pollution, particularly in the San Francisco Bay Area. The second chapter discussed several different criteria pollutants, including hydrocarbons, carbon monoxide, oxides of nitrogen, oxides of sulfur, particulate matter, and others. Since there is so much damage to human health and the environment from air pollution, and because state and federal standards are continually being exceeded, it was established that air pollution is indeed a significant problem, especially in Santa Clara County.

Chapter 3 looked at one way to help ease this problem: bicycle transportation. This chapter detailed the benefits and detriments of bicycle transportation, and also examined bicycle facilities such as bike lanes and paths, incentive and education programs, and bicycle project funding.

The next section of this study looked at how factors such as bicycle facilities affect the levels of bicycle ridership. This was determined using a variety of methods: bicycle counts, surveys, and site comparisons. The results indicated that constructing or improving bicycle facilities is one way to increase the level of ridership for a given area.

Chapter 5 of this study then examined how bicycle transportation affects air quality in Santa Clara County. This chapter addressed the following issues:

1) what the increase in motor vehicle caused air pollution and total air pollution in Santa Clara County would be if bicycle commuter miles were motor vehicle miles; and 2) how an increase or decrease in the level of bicycle ridership would affect air quality in Santa Clara County. The results of the data showed that if bicycle commuter miles were motor vehicle miles, motor vehicle-caused air pollution would increase by 1.25%, and total air pollution would increase by .49%. The data also showed that if bicycle ridership levels climbed to 6% (a figure that is currently nearly achieved in the city of Palo Alto), total air pollution in Santa Clara County would decrease by 1.47%. Furthermore, these figures represent a conservative estimate of the impact Santa Clara County bicyclists have on the County's air quality; the actual impact bicyclists have on the County's air quality is probably much greater.

Currently, bicycle transportation displaces at least 7.34 tons of air pollutants per day in Santa Clara County and could displace even more if bicycle ridership levels were to increase. One way of making the levels of bicycle ridership increase is through improved bicycle facilities.

RECOMMENDATIONS

This study has shown that one strategy to improve the air quality in Santa Clara County is by increasing the level of bicycle ridership through improved bicycle facilities. Improving the air quality for Santa Clara County and the Bay Area is the overriding goal of the Bay Area Air Quality Management District. Planning and developing an efficient transportation system for Santa Clara County and the Bay Area - which includes bicycle transportation - is the main goal of transportation agencies, such as Caltrans and MTC. The goal of the city and county agencies in Santa Clara County is to meet the needs of the public, which includes both helping to improve air quality and transportation systems. In order to meet these goals, certain steps must be taken.

The first step is recognizing the important role that bicycles play (or could play) in the county's transportation system. Currently, bicycle transportation is not viewed, for the most part, by the public or officials as a viable, efficient transportation mode. This is evident by the relative lack of bicycle transportation facilities in many parts of Santa Clara County. While some areas in the county, such as Palo Alto, have very good facilities for bicyclists, most of the county is geared toward the dominant mode of transportation, the automobile, which is one of the reasons why the air quality in Santa Clara County is as poor as it is.

The next step is to implement programs to encourage bicycle transportation. The U.S. Department of Transportation Federal Highway Administration's report, Case Study No.3: What need to be done to promote bicycling and walking?, lists the following general strategies for promoting bicycle transportation:[63]

1) Provide the option of bicycle transportation. That is, provide bicycle paths and lanes, allow bicycle access to all destinations, provide secure bicycle parking, etc.

2) Make the option attractive: provide incentives to use bicycle transportation, disincentives to use automobiles, educate the public, etc.

3) Recognize the option. As previously mentioned, bicycle transportation must be recognized as being an integral part of a transportation system. Bicycle

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[63] U.S. Department of Transportation Federal Highway Administration, Case Study No. 3: What needs to be done to promote bicycling and walking? (Washington D.C.: GPO, 1992), 50.

transportation coordinators and advisory committees must be appointed to assist with planning and securing funds for projects. Long and short term bicycle transportation plans must be formed.

Certain steps also need to be taken which are specific to Santa Clara County. The county's Transportation Agency has put out a draft of their Santa Clara County Bicycle Plan, which has not yet been approved by the Santa Clara County Board of Supervisors. The draft Bicycle Plan includes policy recommendations for the county and cities within the county on bicycle route systems, mapping, bicycles and transit, education programs, bicycle route design and maintenance, and several other aspects of bicycle transportation (see Table 15).[64] If these measures are taken, this study has shown that it is very likely that bicycle ridership will increase, thereby reducing the amount of air pollutants emitted in Santa Clara County, and improving total air quality.

In the last two decades, great steps have been taken to improve Santa Clara County's air quality, with much success. However, air quality levels still remain a problem in Santa Clara County, and much more can be done. Improved bicycle facilities and increased bicycle transportation can make Santa Clara County a better and more healthy place to live.

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[64] Santa Clara County Transportation Agency, Planning and Capital Development Division, Planning and Programming, Santa Clara County Bicycle Plan Draft (San Jose, Ca., January 1994), 30.

Table 15
Santa Clara County Bicycle Plan (Draft)
Policies and Recommendations*

Bicycle Route System

Policy 1: A countywide bicycle route system should be developed which is continuous across city boundaries and provides inter-county connections.

Policy 2: Priorities for developing bicycle facilities should be based upon providing a safe, user friendly, and convenient system.

Policy 3: Encourage the use of bicycles as an alternative to automobiles.

•Bicycles and Land Use

Policy 4: The County and cities should integrate provisions for bicycle use into land use planning.

Bicycle Route Design and Maintenance

Policy 5: The County and cities should design and construct a safe bikeway system.

Policy 6: When constructing or improving roadways, the County and cities should ensure adequate land sharing width.

Policy 7: When constructing, improving, or maintaining roadways open to bicyclists, the County and cities should ensure adequate surface quality.

Policy 8: When constructing, improving, or maintaining roadways, the County and cities should eliminate road hazards and ensure safety.

Policy 9: The County and cities should adopt or continue policies that allow bicyclists to use traffic signals safely.

Policy 10: The County and cities should develop a countywide, uniform bicycle route signage and/or numbering system.

Policy 11: The County and cities should consider bicycle access when constructing or improving any road crossing a barrier such as railroad tracks, freeways, expressways, rivers, or creeks.

Policy 12: The County and cities should pursue opportunities to develop special bicycle barrier crossing and shortcuts as part of a countywide bicycle route system.

Policy 13: Bicycles should be accommodated whenever a new travel corridor is provided.

Mapping

Policy 14: The County and cities should develop maps that classify streets according to their suitability for bicycling.

Supporting Facilities

Policy 15: The agencies involved should include bicycle facilities when new employment, commercial, or residential sites are developed.

Policy 16: The County should continue to provide secure bicycle parking at park-and-ride lots.

Bicycles and Transit

Policy 17: Provide safe and convenient access to bus stops and rail stations.

Education Program Policies

Policy 18: The County and cities should develop educational and enforcement programs.

Funding Sources

Policy 19: The County and cities should coordinate with MTC and Caltrans to maximize available funding.

Plan Implementation and Update

Policy 20: The Santa Clara County Bicycle Plan should be updated regularly to remain current.

Policy 21: The County and cities should employ full-time bicycle coordinators to implement the bicycle plans.

* From Santa Clara County Bicycle Plan (Draft). Prepared by Santa Clara County Transportation Agency, Planning and Capital Development Division, Planning and Programming. January 1994. Because of space constraints, this table includes the policies, but not the specific recommendations for each policy.

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GLOSSARY

Carbon Monoxide (CO):
A toxic gas produced by the incomplete combustion of carbon-containing substances. Motor vehicles are a major source of this gas.

Hydrocarbons (HC):
Any one of a multitude of compounds containing carbon and hydrogen, Hydrocarbons are found especially in fossil fuels.

Nitrogen Oxides (NOx):
Gases, mainly nitric oxide and nitrogen dioxide, mostly formed from atmospheric oxygen and nitrogen under high pressures and temperatures, such as in combustion engines.

Particulate Matter (PM):
This term refers to small particle matter, either solid or liquid. Particulate matter includes dust, dirt, smoke, mist, pollen, fumes, sprays, and metallic and mineral particles.

PM10:
A sub-category of particulate matter, PM10 refers to very fine, invisible particles, either solid or liquid, with an aerodynamic diameter equal to or less than 10 micrometers.

Reactive Organic Compounds (ROG):
A sub-category of TOGs, reactive organic gases react quickly to form photochemical smog or ozone.

Sulfur Oxides (SOx):
These gases, mainly sulfur dioxide and sulfur trioxide, are mostly formed from the combustion of sulfur-containing fossil fuels, such as coal and oil.

Total Organic Gases (TOG):
Gases that are made up of all hydrocarbons (hydrogen and carbon), including reactive organic gases (ROGs) and relatively inert gases.

Volatile Organic Compounds (VOC):
Similar to ROGs, volatile organic compounds are organic compounds that rapidly react at atmospheric temperatures.

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(2) State of California Air Resources Board, Technical Support Division, Emissions Inventory 1989. August 1991.