



**Case
Study
No. 15**

*The
Environmental
Benefits Of
Bicycling
And Walking*

**National Bicycling
And Walking Study**

U.S. Department
of Transportation

**Federal Highway
Administration**

THE ENVIRONMENTAL BENEFITS OF
BICYCLING AND WALKING

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THE ENVIRONMENTAL BENEFITS OF BICYCLING AND WALKING IN THE UNITED STATES

1. Executive Summary

Note: The summary of key findings of the report begins on p. 3 and continues through p. 8.

Introduction

Bicycling and walking are the two major non-fuel-consuming, non-polluting forms of transportation in the United States. Millions of Americans ride bicycles and/or walk for a wide variety of purposes --- commuting to work, as part of their job, for personal business such as shopping and visiting, and for pleasure and recreation. For many of these citizens, bicycling and walking are an important --- and in some cases the prime --- means of transportation.

The personal and societal benefits of bicycling and walking are myriad, ranging from individual health and thrift to community-building and personal empowerment. The environmental benefits are numerous as well, particularly in relation to the prevailing major mode of transport in the U.S. - the private car. Bicycling and walking conserve roadway and residential space; avert the need to build, service, and dispose of autos; and spare users of public space the noise, speed, and intimidation that often characterize motor vehicle use, particularly in urban areas.

By far the greatest environmental benefit of bicycling and walking, however, is that they bypass the fossil fuel system to which the American economy has become addicted. Aside from the modest additional food intake which fuels the bicyclist's or walker's incremental expenditure of muscular energy (and the associated energy requirements to grow and deliver those rations, and to manufacture bicycles as well), bicycle-riding and walking do not contribute to the environmental damage inherent in extracting, transporting, processing, and burning petroleum or other fossil fuels.

Thus, to the extent that bicycling and walking displace trips that otherwise would have involved use of motor vehicles, they enable society to reduce consumption of fossil fuels and the associated pollution and other environmental damage. Bicycling and walking also provide a special benefit: people who bicycle and walk instead of drive are generally avoiding driving short distances

on a cold, extra-polluting engine.

Accordingly, our key findings of the environmental effects of bicycling and walking concern the amount of *fuel consumption and automotive pollution* that they avoid by displacing use of passenger vehicles. Other benefits of bicycling and walking are discussed briefly beginning at p. 33.

Methodology Summarized

Quantifying the fuel use and pollution avoided by bicycling and walking involved these steps:

- Estimating miles bicycled and walked in the United States;
- Estimating the "VMT tradeoff" for bicycling and walking --- the extent to which miles bicycled and walked substitute for miles that would have been driven in motor vehicles;
- Estimating per-mile emissions and fuel consumption of these avoided miles driven, for four air pollutants --- carbon dioxide (CO₂), which is the primary greenhouse gas responsible for global warming; and the three "criteria" pollutants that apply to motor vehicles --- carbon monoxide (CO), nitrogen oxides (NO_x) and volatile organic compounds (VOC's, previously referred to as hydrocarbons).¹

For the first two of these steps, we estimated "low" and "high" values to obtain reasonable lower and upper bounds of n-files bicycled and walked and vehicle miles avoided. The result was a low-high range for petroleum avoided, and emissions avoided. These estimates are based on current (1990-91) data and conditions for bicycling, walking and emissions.

For the third step, we took note of the disproportionately high rate of emissions from short automobile trips - which are precisely the kinds of trips that bicycling and walking most commonly displace.

¹ Passenger vehicle emissions of the remaining two criteria pollutants, particulate matter and lead, are extremely small relative to CO, NO_x, and VOC'S. Diesel-engine cars do emit particulates, but diesels account for only approximately one percent of the U.S. passenger vehicle fleet.

To place these emission and fuel savings in context, we compiled current U.S. petroleum usage and emissions for four concentric levels of consumption --- passenger vehicles only (autos, motorcycles, and light trucks); all motor vehicles (including heavy trucks); all transportation; and the entire U.S. economy. We then calculated the percentage of each of these levels that bicycling and walking avoid by substituting for motor vehicle operation.

A Scenario of Expanded Bicycling and Walking for the Year 2000

Bicycling and walking are far less common per capita in the United States than in most other industrial countries - the result of a self-reinforcing set of circumstances and policies that include externalization of many motor vehicle societal costs, social and political biases against public institutions such as transit, and dispersed settlement patterns. While these phenomena are deeply entrenched, recent developments including enactment of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), greater attention to health, fitness, and the environment, and improved technology (e.g., advent of more user-friendly" mountain bicycles) have kindled interest in expanding opportunities for bicycling and walking.

Accordingly, we postulated two scenarios in which U.S. bicycle and walking miles would undergo significant increases between now and 2000:

- a "low" or "flexible funding" scenario, in which bicycling increases from current levels by a factor of 3, and walking by a factor of 1.5;
- a "high" or "directed funding" scenario, in which bicycling increases by a factor of 5, and walking by a factor of 2.5.

Our report includes estimates of emissions and fuel avoided in the year 2000 under both scenarios, expressed in absolute terms and as percentages of emissions and fuel used in the overall economy, the transportation sector, and by motor vehicles.

Results - 1990-91 Actual Bicycling and Walking

Miles Traveled (See Tables 1 and 2)

- U.S. bicycle miles traveled range between 5.8 and 21.3 billion per year.

- U.S. miles walked range between 20.5 and 44.1 billion miles a year.
- Combined U.S. miles bicycled and walked range between 26.3 and 65.4 billion miles per year.

For comparison, U.S. passenger vehicles traveled an estimated 2,061 billion miles in 1991 (see Table 3). Thus, combined bicycling and walking miles are between 1.3% and 3.2% of motor vehicle miles traveled.

Auto Miles Displaced (See Tables I and 2)

Not every walking or bicycling trip displaces an auto (or light truck or motorcycle) trip. Indeed we estimate that only around a third (26%-37%) of walking miles displace an automobile mile, and that probably a little under half (38%-56%) of bicycling miles displace auto miles. The remainder of walking or bicycling trips would have been accomplished through car-pooling or transit, or would not have occurred at all.²

Accordingly, passenger vehicle miles displaced by bicycling and walking are considerably less than actual miles bicycled and walked. We estimate that:

- U.S. passenger vehicle usage displaced annually by bicycling ranges between 2.2 and 12.0 billion miles.
- Passenger vehicle miles displaced by walking range between 5.4 and 16.1 billion miles a year.
- Combined miles displaced by bicycling and walking range between 7.6 and 28.1 billion miles annually. This range is equivalent to 0.4%-1.4% of total passenger vehicle miles actually traveled in 1991 (see Table 3).

Emissions and Fuel Displaced (See Tables 4A and 5A)

Emissions and fuel displaced may be calculated in 120 different ways, reflect-

² These estimates of vehicle miles displaced are conservative and, perhaps, simplistic in that they ignore the tendency of bicycling and walking to reinforce economic and other trends encouraging dense (i.e., urban) settlement patterns; because most trips for work, personal business and pleasure in such communities can be satisfied by traveling shorter distances than in car-dominated areas, over the long term a mile walked or bicycled may well substitute for more than one mile driven. See discussion at p. 34ff.

ing: three levels of results (for bicycling alone, walking alone, and the two combined); two sets of estimates for vehicle miles displaced (low and high); four pollutants plus petroleum usage; and four sectors as a baseline for comparison (ranging from passenger vehicles alone, to the U.S. economy as a whole).

Tables 4A and 5A present the full set of results. Below, we have summarized our findings in terms of *bicycling and walking combined*, in comparison to passenger vehicle emissions and fuel use (as well as in absolute terms).

Bicycling and walking together displace annually:

- Petroleum: 420-1,590 million gallons of motor gasoline, or 0.4%-1.5% of fuel consumed by U.S. passenger vehicles (autos, light trucks, and motorcycles - see Table 4A). This figure reflects only gasoline that would have been consumed by motor vehicles displaced by bicycling and walking; it excludes energy required to manufacture, store, and service the vehicles or the fuel itself (e.g., refining energy; see also Footnote 18).
- CO₂: 4.2-15.5 million tons, or 0.4%-1.6% of passenger vehicle emissions (see Table 5A for this and other emission comparisons)'.
'
- CO: 370,000-1,355,000 tons, or 1.4%-5.0% of passenger vehicle emissions.
- NO_x: 10,100-37,500 tons, or 0.3%-1.2% of passenger vehicle emissions.
- VOC'S: 33,900-121,000 tons, or 0.7%-2.6% of passenger vehicle emissions.

Bicycling and walking save higher percentages of CO and VOC emissions than CO₂ and NO_x, in part because the short auto trips displaced by bicycling and walking are disproportionately emission-intensive for CO and VOC'S.

Results - Projected for Year 2000, under two different funding scenarios

Our "low" scenario assumes that many cities and states will use the "flexible funding" provisions of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) to increase investment in bicycling and walking infrastructure and promotion. Policy-led changes in land-use patterns are modest, however. **In the low case, bicycling increases from current levels by a factor of 3,**

and walking by a factor of 1.5.

The "high" scenario assumes that continuing environmental, quality-of-life, and transportation problems (e.g., congestion) lead the Federal Government to direct dedicated funding to States and cities to increase levels of bicycling and walking.

This "directed funding" path is also motivated by the need to satisfy the air Pollution reduction targets in the Clean Air Act Amendments of 1990, and also employs land-use planning and auto-disincentives such as fuel taxes and congestion pricing to reduce motor vehicle trips. **In the high case, bicycling increases by a factor of 5, and walking by a factor of 2.5.**

Projected Miles Traveled, Year 2000 (See Table 3)

- U.S. bicycle miles traveled in 2000 could range between 17.4 and 106.5 billion per year.
- U.S. miles walked in 2000 could range between 30.8 and 110.3 billion miles a year.
- Combined U.S. miles bicycled and walked in 2000 could range between 48.2 and 216.8 billion miles per year.

For comparison, U.S. motor vehicles traveled Could reasonably be expected to increase from 1991 levels by 1.5% per year to the year 2000, to approximately 2,357 billion annual miles.³ Combined bicycling and walking miles would range between 2.0% and 9.2% of motor vehicle miles traveled (see Table 3).

Projected Auto Miles Displaced, Year 2000 (See Table 3)

- U.S. auto (and light truck) usage displaced annually by bicycling could range between 6.6 and 60 billion miles in the year 2000.
- Auto miles displaced by walking could range between 8.1 and 40.3 billion miles a year in 2000.
- Combined annual miles displaced by bicycling and walking could range

³ Although passenger vehicle VMT would almost certainly differ between the "flexible funding" (low) scenario and "directed funding" (high) scenario, to simplify the analysis we have assumed the same growth in VMT to the year 2000 for both scenarios.

between 14.7 and 100.3 billion miles. This range would be equivalent to between 0.6%-4.3% of total auto (and light truck) miles expected to be traveled in 2000.

Projected Emissions and Fuel Displaced, Year 2000 (See Tables 4B and 5B)

Between 1990-91 and 2000, passenger vehicle per-mile emissions are projected to decrease significantly as new cars with increasingly improved pollution controls replace older vehicles. Based on EPA projections as interpreted by Konheim & Ketcham, we project an approximate halving of per-mile emissions of CO, NO_x, and VOC's (see Table 6B). We have also assumed that fuel requirements and, hence, CO₂ emissions per mile traveled would decline by 10%.

Still, although overall vehicle emissions are expected to be lower in the year 2000 due to mandated tailpipe controls and cleaner fuels, bicycle and walk trips will continue to displace short, relatively pollution-intensive auto trips.

With these assumptions, and the projected bicycling and walking miles stated above, we calculate that in the year 2000 bicycling and walking together could displace:

- Petroleum: 750-5,100 million gallons of motor gasoline per year, or 0.7%-4.5% of fuel projected to be consumed by U.S. passenger vehicles (autos, light trucks, and motorcycles).
- CO₂: 7.3-49.8 million tons, or 0.7%-4.8% of projected passenger vehicle emissions.
- CO: 310,000-2,110,000 tons, or 2.2%-15.1% of projected passenger vehicle emissions.
- NO_x: 8,700-59,300 tons, or 0.5%-3.6% of projected passenger vehicle emissions.
- VOC'S: 38,900-254,000 tons, or 1.1%-7.5% of projected passenger vehicle emissions.

These year-2000 calculations are highly significant, since they suggest that under an accelerated growth effort such as the "directed funding" scenario outlined here, bicycling and walking could displace as much as 4-15% of pro-

jected passenger vehicle emissions of CO, NOx, and VOC'S, and 5% of passenger vehicle emissions of carbon dioxide.

Although a cost comparison is beyond our scope, the relatively low-cost nature of many walking and particularly bicycling facilities Suggests that actions to expand human-powered transportation could reduce air pollution for less perunit cost than many other approaches (e.g., so-called "alternative fuels"). When the myriad other environmental and societal benefits of bicycling and walking are factored in as well, the case for expanding these modes becomes still more compelling.

2. Commentary: Reversing the Marginalization of Human-Powered Transport

Human-powered modes of transportation - chiefly walking and bicycling ---- are chronically underreported and under-studied in the United States. Unlike driving, which is painstakingly measured and analyzed, or even public transit such as rail, buses, and ferries, whose ridership is diligently recorded, walking and bicycling have been ignored by most energy experts, economists, statisticians and transport planners (not to mention policy makers).

From time to time, and increasingly in the past decade, efforts have been made to estimate the amount of bicycling and walking in the United States. While these attempts (which are reported further below) have sometimes been ingenious and even valuable, none has been comprehensive. Most measurements of U.S. bicycling and walking have been at a grassroots level, and these have lacked the funding support and official imprimatur needed for a definitive analysis.

To anyone who has thought seriously about foot- and pedal-powered transportation, this inequality between human-powered and fuel-driven transport should not be surprising. Human power doesn't use purchased fuels; therefore, it doesn't figure in energy accounting. Walking and bicycling largely fall outside the transaction economy of gasoline, tolls, and fareboxes that characterizes cars, buses, and trains; thus, human-powered transport hardly enters into the national income categories that make up the Gross Domestic Product (GDP). By training, mandate, and institutional tradition, most transport planners are so focused on cars, highways, and large-scale transit systems that they overlook bicyclists and walkers as practitioners of transportation.

This pervasive bias against human-powered transport has a parallel in energy analysis. Until recently, small-scale renewable energy was missing from the energy accounting system that tallies Btu's from oil, gas, coal, nuclear, and large hydro. Even today, there is no systematic accounting of energy contributed by sunlight. As solar designer-philosopher Steve Baer wrote in 1975:

If you take down your clothesline and buy an electric clothes dryer, the electric consumption of the nation rises slightly. If you go in the other direction and remove the electric clothes dryer and install a clothesline, the consumption of electricity drops slightly, but there is no credit given anywhere on the charts and graphs to solar energy which is now drying the clothes....

If you drive your car to the corner to buy a newspaper, the gasoline consumption appears. If you walk - using food energy --- the event has disappeared from sight, for the budget of solar energy consumed by people in food is seldom mentioned.⁴

Baer also described the "humiliation" that solar energy advocates experienced at being excluded from the "energy pies" that assigned "slices" to fossil, nuclear, and hydro but not to solar, which was too small to appear. "The demoralized reader," wrote Baer, "is then ripe to be persuaded of the necessity of nuclear power plants or offshore drilling. The accounting system shows that he has done absolutely nothing with solar energy. He lacks even a trace of a useful habit or activity that he could build on."⁵

Bicycling and walking, the major modes of renewable transportation, are perhaps in an analogous position to that of solar energy a decade or two ago. If an activity is ignored, so are its benefits. Conversely, if the benefits can be tallied, or at least estimated, then the activity itself may come to be esteemed. This may be of particular value to bicyclists and walkers, who frequently are not only demoralized but bodily threatened by motorists and motor-oriented planners who out of carelessness and/or brutishness would deny them use of road space.

Today, as the Automobile Century draws to a close, the far-flung damage from motor transport is finally drawing increasing attention (and opposition) ---- and none too soon. Bicyclists and walkers suffer damage from motor vehicles not only as citizens and taxpayers, but as victims of a transport system and motor Culture that subject them to constant danger and abuse. It is vital that the environmental benefits of bicycling and walking be appreciated not only by planners and public officials, but by the populace at large.

⁴ Steve Baer, *Sunspots*, Zomeworks Corporation, Albuquerque, NM, p. 115. Baer credits the "clothesline paradox" to Peter Van Dresser.

⁵ *Ibid.*, pp. 114-115.

3. Discussion of Findings Presented in the Tables

Tables 1 through 7 contain the key analytical work in this report. They present available data, supplemented where necessary with the authors' judgment, to estimate bicycling and walking miles, fuel savings, and emission displacement. Figures are presented in absolute terms and relative to significant national parameters (e.g., U.S. fuel requirements and emissions from passenger vehicles). Here we briefly discuss key assumptions, findings, and methodological issues for each table. The tables themselves are presented at the end of this section.

Table 1 - Estimated Bicycle Miles Traveled in the United States, 1991

This table estimates bicycle miles traveled for five categories of usage --- Commuting, Personal, Commercial, Recreation, and Children. This approach lends itself to estimating not only miles traveled, but also miles of passenger vehicle miles displaced. The wide (almost four-fold) range of estimates reflects differences among available data sources.

Key Findings

Annual bicycle miles traveled range between 5.8 and 21.3 billion miles per year. Assuming a U.S. population of 232 million people age 5 and over (out of a total of 250 million), this range is equivalent to between 25-92 miles bicycled per person per year, or roughly 1/2- 2 miles per person per week. Recreational bicycling accounts for almost half (45%) of total miles bicycled, followed almost equally by commuting (17%), personal business (15%) and children (15%), and finally commercial (8%).

The percentage of these bicycle miles that actually displace passenger vehicle miles is estimated at between 38% and 56%. This in turn implies a range of passenger vehicle travel of 2.2-12.0 billion miles per year displaced by bicycling. This is equivalent to roughly 10-50 miles of vehicle travel displaced by bicycling per person per year, or 0.2-1 mile per week. Divided among types of bicycling, recreational bicycling again accounts for 45% of vehicle travel displaced, followed by personal business (22%).

Table 2 --- Estimated Walking Miles Traveled in the United States, 1991

This table estimates miles walked for the same five categories of usage employed in Table 1 ----Commuting, Personal, Commercial, Recreation, and Chil-

dren. The twofold range of estimates is less than for bicycling miles, reflecting smaller differences among available data sources.

In estimating miles walked we have had to be sensitive to what Ramsay refers to as "the informal and incidental nature of much walking." Many journeys on foot cover only very short distances, notes Ramsay, and many of these are within buildings, or parking lots, or otherwise as part of brief transitions from one mode to another.⁶ In order to simplify the analysis, we have attempted to exclude indoor walking, very short walking trips, trips to and from transit vehicles, and other minor foot journeys made in conjunction with automobile use. These trips are not insignificant, however, and should be explored in a more comprehensive analysis.

Key Findings

Annual walking miles traveled range between 20.5 and 44.1 billion miles per year. Averaged across Americans age 5 and over, this is equivalent to a range of 88-190 miles walked per person per year, or roughly 2-4 miles per person per week. The low estimate in the range is almost four times the low estimate of bicycle miles, while the high estimate is about double the corresponding bicycle estimate. For comparison, estimated per capita walking in Great Britain is 5.4 miles,⁷ or about twice the midpoint of the range estimated here.

We estimate the percentage of U.S. walking miles that actually displace passenger vehicle miles at between 26% and 37%. This in turn implies a range of passenger vehicle travel of 2.2-12.0 billion miles per year displaced by walk-ing, equivalent to roughly 23-70 miles of vehicle travel displaced by walking per person per year, or a little Under 1/2 -1 1/2 miles per week.

Table 3 --- Bicycling and Walking Miles Relative to Passenger Vehicles

This table compares estimated miles bicycled and walked from Tables I and 2 to U.S. passenger miles traveled by motor vehicle (passenger cars, light trucks,

⁶ Anthony Ramsay, *A Systematic Approach to the Planning of Urban Networks for walking*, in Rodney Tolley, ed., *The Greening of Urban Transport*, Belhaven Press, London, 1990, p. 162.

⁷ *National Travel Survey 1985/1986 Report: Part 1*, (U.K.) Department of Transport, cited in Barbara Preston, *The Safety of Walking and Cycling in Different Countries*, in Tolley, *op. cit.*, p. 54.

and motorcycles). These comparisons are performed in several ways ---- separately and combined for bicycling and walking; on the basis of actual miles bicycled and walked and also vehicle miles displaced; and actual for current levels and projected for the year 2000.

Key Findings

Current bicycle miles traveled are equivalent to between 0.3%-1.0% of vehicle miles, and displace 0.1%-0.6% of vehicle miles. Miles walked are equivalent to between 1.0%-2.1% of vehicle miles, and displace 0.3%-0.8% of vehicle miles. Combined miles bicycled and walked are equivalent to between 1.3%-3.2% of vehicle miles, and displace 0.4%-1.4% of vehicle miles.

These percentages would increase significantly under either of the scenarios we have sketched for expanding bicycling and walking transportation pursuant to the 1991 ISTEA legislation, the 1990 Clean Air Act Amendments, and to the rising sentiment in favor of reduced dependence on automobiles and a wider range of transportation choices.

Under the "flexible funding" scenario, bicycling would increase by a factor of 3, to between 17 and 107 billion miles per year, and walking by a factor of 1.5 to between 31 and 110 billion miles per year. Under the "high" or "directed funding" scenario, bicycling increases by a factor of 5, and walking by a factor of 2.5. Finally, we assume that passenger vehicle VMT - our baseline for comparison, will increase by 1.5% per year between 1991 and 2000.

Taking into account the two scenarios, bicycling would range between 69-424 miles per capita per year, or roughly 1-8 miles per person per week; walking would range between 122-439 miles per capita per year, or 2¹/₂-11¹/₂ miles per person per week. On a VMT basis, human-powered travel would be equivalent to 0.7%-4.5% of U.S. passenger mile vehicles (cycling), 1.3%- 4.7% of passenger mile vehicles (walking), and 2.0% - 9.2% for bicycling and walking combined.

On a *displaced VMT* basis, bicycling would displace between 26-239 miles per capita per year, or a range of 1/2-5 miles per person per week; walking would displace between 32-160 miles per capita per year, or 1/2-3 miles per person per

week.⁸ Human-powered travel would displace 0.3%-2.6% of U.S. passenger mile vehicles (cycling), 0.3%-1.7% of passenger mile vehicles (walking), and 0.6%-4.3% for bicycling and walking combined.

Table 4A ---- Fuel Savings from Bicycling and Walking in the United States (1990-91 Time Frame)

This table calculates the gasoline fuel "saved" or displaced by bicycling and walking, and compares these savings with U.S. petroleum consumption. The comparison is made to four sectors or levels of the economy, each of which is a subset of the next - passenger vehicles only, all motor vehicles, all transportation, and the entire United States. The figure for the last level (entire U.S.) encompasses all energy use, expressed in gallons of petroleum equivalent; essentially all direct energy use in the other three sectors is actually expended as petroleum.

Gasoline Consumption displaced by bicycling and walking was calculated by estimating gallons required per mile traveled by passenger vehicles, and applying this ratio to vehicle miles displaced, as estimated in Tables 1 and 2. The gallon-per-mile figure was based on the U.S. average for passenger cars, modified in two ways. First, it was increased to reflect the higher fuel requirements of light trucks, which account for almost 25% of total passenger vehicle miles traveled; this adjustment, which was based on fuel consumption of cars, light trucks, and motorcycles, weighted by VMT, was approximately 7%. Second, the resulting average was increased by another 10% to reflect the higher fuel requirements of vehicles traveling in urban areas and on local and arterial roads, where the predominant amount of VMT displaced by bicycling and walking takes place.

Note that although we have reflected the tendency of bicycle and foot trips to displace public transit (this is a key factor in the less than 1-to-1 substitution of bicycle or walk miles for vehicle miles), we have excluded any fuel savings from such displacement. Rather, we assume that transit routes are designed and operated much the same as they would be if there was no bicycling or

⁸ To calculate per capita values of bicycling and walking in the year 2000, we used the Census Bureau's projection of 251.4 million Americans age 5 and over in 2000 ---- a 7.7% increase over 1990. *1990 Statistical Abstract of the United States*, Table 18.

walking. This assumption is both simplifying and conservative.⁹

Key Findings

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 U.S. economy.

Walking currently displaces between 300 and 910 million gallons of gasoline per year. This is equivalent to 0.3%-0.8% of fuel consumed by passenger vehicles, and 0.06%-0.17% of all energy used by the entire U.S. economy.

Bicycling and walking together currently displace between 420 and 1,590 million gallons of gasoline per year. This is equivalent to 0.4%-1.5% of fuel consumed by passenger vehicles, and 0.1%-0.3% of all energy used by the entire U.S. economy.

(See Table 4A for percentage comparisons to All Motor Vehicles and All Transportation.)

Table 4B --- Fuel Savings from Bicycling and Walking in the United States (Year 2000)

This table parallels Table 4A, using estimated bicycling and walking levels for the year 2000 (reflecting the "flexible funding" and "directed funding" scenarios), and comparing them to the increased baseline of passenger vehicle miles traveled delineated in Table 3. We assume a 10% improvement in motor vehicle fuel efficiency, which we apply not only to passenger vehicles but to all three of the larger "levels" of the economy shown in the table.

Key Findings

In the year 2000, bicycling could displace between 340 and 3,050 million gallons of gasoline per year. This would be equivalent to 0.3%-2.7% of fuel con-

⁹ Synergies among transit, bicycling, and walking almost certainly outweigh competition, primarily because the availability of several alternatives to automobiles helps the user avoid car ownership and/or usage, which in turn encourages use of non-automobile modes. Explicit policies to improve bicycle-transit links would reinforce this complementarity.

sumed by passenger vehicles, and 0.06%-0.5% of all energy used by the entire U.S. economy.

Also in the year 2000, walking could displace between 410 and 2,050 million gallons of gasoline per year. This would be equivalent to 0.4%-1.8% of fuel consumed by passenger vehicles, and 0.07%-0.4% of all energy used by the entire U.S. economy.

Finally, in the year 2000 bicycling and walking combined could displace between 750 and 5,100 million gallons of gasoline per year. This would be equivalent to 0.7%-4.5% of fuel consumed by passenger vehicles, and 0.1%-0.9% of all energy used by the entire U.S. economy.

Table 5A - Emission Savings from Bicycling and Walking in the United States (1990-91 Time Frame)

This table translates the VMT and associated petroleum consumption avoided by bicycling and walking into emission reductions. It does so by applying emission factors per passenger vehicle mile for the four key automotive air pollutants - carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOC's). The resulting emission displacement is compared to current nationwide emissions of these pollutants for the same four economic sectors or levels treated in Tables 4A and 4B ---- passenger vehicles only, all motor vehicles, all transportation, and the entire United States.

The emission factors themselves were developed through painstaking calculations shown in Tables 6A and 6B; indeed, they were able to be estimated somewhat more precisely than the underlying figures for miles bicycled and walked. The one emission factor derived in Table 5A is that for CO₂. It was calculated based on the carbon composition of gasoline and on the national average amount of gasoline required to propel a passenger vehicle one mile (with the adjustment for urban and local roads from Table 4). Another 10% was added to reflect CO₂ emissions from petroleum refining; this was the only explicit way in which the environmental impact of petroleum refining was captured in this report.

We have excluded emission savings from reduced operation of public transit vehicles due to bicycling and walking (see discussion under Table 4A).

Key Findings

To simplify presentation, emission savings are stated here for bicycling and walking together, and as a percentage of emissions from all U.S. passenger vehicles and by the entire U.S. economy. See Table 5A for a full presentation of emission savings separately by mode, and compared to all motor vehicle emissions and all transportation.

CO₂ --- Bicycling and walking together displace between 4.2 and 15.5 million tons of carbon dioxide per year - 0.4%-1.6% of all CO₂ emissions from U.S. passenger vehicles, and 0.1%-0.3% of entire United States emissions of CO₂.

CO --- Bicycling and walking together displace between 370,000 and 1,355,000 tons per year of carbon monoxide - 1.4%-5.0% of all CO emissions from U.S. passenger vehicles, and 0.6%-2.3% of entire U.S. emissions of CO.

NO_x --- Bicycling and walking together displace between 10,100 and 37,500 tons per year of nitrogen oxides - 0.3%-1.2% of all NO_x emissions from U.S. passenger vehicles, and 0.05%-0.2% of entire U.S. NO_x emissions.

VOC's --- Bicycling and walking together displace between 33,900 and 120,700 tons per year of volatile organic compounds 0.7%-2.6% of VOC emissions from U.S. passenger vehicles, and 0.2%-0.7% of entire U.S. VOC emissions.

Table 5B - Emission Savings from Bicycling and Walking in the United States (Year 2000)

This table parallels Table 5A, using projected emissions displaced by bicycling and walking for the year 2000. Although bicycling and walking would increase dramatically by 2000 under our "flexible funding" and "directed funding" scenarios, the emissions displaced would increase less than proportionately because improvements in emission controls are projected to reduce emissions per VMT. As Table 5B shows, from 1990 to 2000 per-mile emissions are assumed to decline by 56% for CO and NO_x and by 38% for VOC'S; the 10% reduction shown for CO₂ is for the assumed 10% improvement in fuel economy.

Of course, the same emission factor reductions that moderate the increase in emission savings from expanded bicycling and walking will also reduce the

projected baseline of nationwide emissions from all motor vehicles. Thus, by 2000 bicycling and walking would be displacing relatively large shares of total emissions, as the findings below indicate.

Key Findings

CO₂--- In 2000, bicycling and walking together Could displace between 7.3 and 49.8 million tons of carbon dioxide per year. This would be equivalent to 0.7%-4.8% of all year-2000 CO₂ emissions from U.S. passenger vehicles, and 0.1%-1.0% of entire year-2000 emissions of CO₂ for the entire United States.

CO - Bicycling and walking together could displace between 310,000 and 2.1 million tons per year of carbon monoxide - 2.2%-15.1% of projected CO emissions from U.S. passenger vehicles, and 1.0%-6.8% of entire U.S. emissions of CO projected for 2000.

NO_x - Bicycling and walking together could displace between 8,700 and 59,300 tons per year of nitrogen oxides. This would be equivalent to 0.5%3.6% of all NO_x emissions from U.S. passenger vehicles projected for the year 2000, and 0.1%-0.6% of entire U.S. NO_x emissions at that time.

VOC's - Bicycling and walking together could displace between 38,900 and 254,100 tons per year of VOC'S. This would be 1.1%-7.5% of VOC emissions from U.S. passenger vehicles in 2000, and 0.3%-1.9% of entire U.S. VOC emissions in 2000.

Table 6 - Emission Factors for Light-Duty Gasoline Vehicles

This table contains no findings for the report. Rather it presents the derivation of emission factors for the criteria pollutants for mobile transportation (CO, NO_x, VOC'S) that were applied to estimate emissions displaced by bicycling and walking in Table 5.

The emission factors were based on EPA's Mobile-4.1 emission factor model. Mobile-4.1 divides the continental U.S. into four different climate regions, to reflect combustion differences due to temperature. It also delineates different road conditions, to reflect combustion differences due to driving speeds. We weighted these factors to account for actual VMT on different road types and different regions; however, as described in Table 7, we adjusted the road types to give greater weight to local roads, because bicycling and walking dispropor-

tionately displace passenger miles on smaller roads.

Additionally, we took into account the shorter-than-average auto trips which would be displaced by bicycle and walk trips.¹⁰ Short vehicle trips are more emission-intensive than longer trips because vehicles emit carbon monoxide and volatile organic compounds at higher rates at the beginning of a trip, when the engine is cold. For instance, under typical speeds on a local urban street, engines running cold produce 4-5 times the CO and twice the VOC emissions per mile as engines running "hot."

At the end of a trip, engines continue to emit VOC's (via evaporation) after the engine has been turned off - a phenomenon known as "hot soak." Emission factors differ between auto trips displaced by walking and by bicycling for VOC'S, because the amount of VOC's emitted via hot soak is relatively independent of trip length. Because walk trips are shorter, they have higher, hot soak emissions per mile, and therefore higher emissions per mile than the longer bike trips.

Bicycling and walking are well positioned to eliminate the heightened emissions consequences of cold engines and hot soaks, *precisely because bicycle and walk trips can easily replace short, pollution-intensive auto trips.*

Emission factors for the year 2000 were also based on Mobile-4.1, incorporating EPA projections of per-mile emission rates based on assumed conditions for average travel speeds, thermal states, ambient temperature conditions, fuel used, emissions inspection, and other factors. The results represent the fleet average, accounting for displacement of older vehicles by new (and less-polluting) vehicles.

Although overall vehicle emissions will be lower in the year 2000 due to mandated tailpipe controls and reformulated gasoline, we assume that vehicles will still be stuck in the short-trip, pollution dis-economy trap caused by cold engines and hot soaks. In the year 2000, bicycle and walk trips will continue to deliver "high-power" emissions relief by displacing short auto trips.

¹⁰ We estimated that the average bicycle trip length which displaces an auto trip is 2.7 miles; the average "displacing" walk trip is 1.3 miles. (See note in Table 6.)

Table 7 - Annual U.S. Miles of Travel by Region and Roadway System

Like Table 6, this table presents no final results or findings, but is included because it develops input data to another table. Table 7 estimates U.S. passenger vehicle miles traveled by region and roadway type, in order to weight EPA's Mobile-4.1 emission factors and obtain national average factors for CO, NOx and VOC'S. These factors are then used to derive the emission factors shown in Table 6 which are used to calculate national emissions avoided by bicycling and walking in Table 5.

We made one major adjustment to the raw VMT data. Any displacement by bicycling and walking of vehicles currently traveling on interstates is likely to be de minimis. We therefore eliminated interstates' share of each region's VMT; we also tripled the percentage of VMT on local streets. We then prorated the resulting VMT percentages calculated for the two roadway types (arterial-collector and collector-local) so that they would sum to 100% in each region.

Table 1

**Estimated Bicycle Miles Traveled in the United States, 1991
and Passenger Vehicle Miles Displaced**

	HIGH ESTIMATES (regular type)	LOW ESTIMATES (Italic)						
	(A)	(B)	(C)	(D)	(E)	TOTAL		
1	Category of bicycle use	Commuting	Personal	Commercial	Recreation	Children	TOTAL	
2	Number of regular bicyclists	2,800,000	5,000,000	500,000	27,500,000	15,000,000		
			1,700,000	3,750,000	250,000	15,000,000	6,000,000	
3	Daily miles, per bicyclist	8	4	10	10	2		
			5	3	8	5	2	
4	Days per week of bicycle use	4	4	7	1	3		
			3	3	5	1	2	
5	Weeks per year of bicycle use	40	40	50	35	35		
			35	35	35	35	30	
6	Annual miles per bicyclist	1,280	640	3,500	350	210		
			483	336	1,400	175	120	
7	Millions of bicycle miles	3,584	3,200	1,750	9,625	3,150	21,300	
			821	1,260	350	2,625	720	
8	Share of total bicycle miles	17%	15%	8%	45%	15%	5,800	
			14%	22%	6%	45%	12%	
9	Auto trips displaced per bike trip	0.75	0.75	0.75	0.50	0.25	0.56	
			0.50	0.50	0.50	0.33	0.20	
10	Millions of auto miles displaced	2,688	2,400	1,313	4,813	788	12,000	
			411	630	175	875	144	
11	Share of total auto miles displaced	22%	20%	11%	40%	7%	2,200	
			19%	29%	8%	40%	7%	

NOTES AND SOURCES (numbers refer to rows, letters to columns)

1 .A is home-workplace journeys; B is non-work transportational cycling (e.g., errands, visits); C is on-the-job cycling including couriers, factories, facilities maintenance and food delivery; D includes touring, competition, vacation, etc.; E is persons age 16 and under.

2.A High A is from "Bicycling Magazine's 2nd Annual Harris Poll on Bike Commuting," (1991). Low A is based on 1990 National Personal Transportation Study (NPTS) finding of 4 billion annual bicycle miles. KEA estimates 20% are commuting miles, implying 1.7 million commuters at above regularity.

2.B High B is a KEA estimate. Low B is based on the NPTS. KEA estimates that 30% of 4 billion annual bicycle miles are for personal business, implying 3.8 million cyclists at the above regularity.

2.C C are KEA estimates.

2.D High D is based on 1991 Harris Poll finding that 26 million adults rode 5 or more times for recreation in the last mild weather month, plus estimates of vacation and competitive riders from Bicycle Institute of America (BIA) "Bicycling Reference Book, 1992-1993 Edition." Low D is based on 50% of bicycle miles from the NPTS, plus vacation and competitive riders from the BIA.

2.E High E is based on BIA estimates (44 million children cyclists) and the finding from the 1982-1983 National Recreation Survey that 56.8 million children and adults age 12+ had bicycled in the last three months. 19

million children (age 7 - 17) rode bicycles 6 times or more in 1988 according to the 1990 Statistical Abstract of the U.S. Table 392. Children have not been counted in A and D which are based on the Harris Poll. Low E is a KEA estimate based on High E adjusted for the inclusion of children in the NPTS recreation riders.

3-5 and 9. Estimates by KEA.

Table 2

**Estimated Walking Miles Traveled in the United States, 1991
and Passenger Vehicle Miles Displaced**

HIGH ESTIMATES (regular type)		U.S. Population in 1990					250000000
LOW ESTIMATES (<i>Italic</i>)		Adult population in 1990	192000000				
	(A)	(B)	(C)	(D)	(E)		
1	Category of walking	Commuting	Personal	Commercial	Recreation	Children	T O T A L
2	Number of regular walkers	10,000,000	38,400,000	3,000,000	40,000,000	5,800,000	
			8,500,000	25,600,000	1,500,000	35,000,000	2,900,000
3	Daily miles, per walker	4.0	3.0	3.0	4.0	2.0	
			3.0	2.5	2.5	4.0	2.0
4	Days per week of walking	4.0	4.0	5.0	2.5	3.0	
			3.5	3.5	4.0	1.5	2.0
5	Weeks per year of walking	40	40	45	40	35	
			40	35	40	40	30
6	Annual miles per walker	640	480	675	400	210	
			420	306	400	233	120
7	Millions of walking miles	6,400	18,432	2,025	16,000	1,218	44,100
			3,570	7,840	600	8,148	348
8	Share of total walking miles	15%	42%	5%	36%	3%	20,500
			17%	38%	3%	40%	2%
9	Auto trips displaced per walk trip	0.50	0.50	0.33	0.17	0.25	0.37
			0.33	0.33	0.25	0.13	0.20
10	Millions of auto miles displaced	3,200	9,216	675	2,667	305	16,100
			1,190	2,613	150	1,358	70
11	Share of total auto miles displaced	20%	57%	4%	17%	2%	5,400
			22%	48%	3%	25%	1%

NOTES AND SOURCES (numbers refer to rows, letters to columns)

1. A is home-workplace journeys, including walking part of transit trips; B is non-work transportational walking (e.g., errands, visits); C is on-the-job walking, e.g., by postal workers, sales people, farm workers, police, and security workers; D includes exercise walking, hiking, running, or jogging and charitable walks (walk-a-thons); E is persons age 16 and under.
2. A High A is a KEA estimate extrapolating from 1990 Boulder CO Diary Study which found that residents averaged 250 miles walked annually. If the U.S. population over 17 walked at the same rate as Boulder adults, the U.S. as a whole would walk 48 billion miles each year. 15-20% of this figure is 8-9 billion miles, implying 13-14 million walkers at the above regularity. KEA reduced this estimate to 10 million walkers to acknowledge Boulders exceptional walking conditions. Low A is based on 1990 National Personal Transportation Study (NPTS) finding of 20 billion miles walked annually. KEA estimates 18% are commuting miles, implying 8.5 million commuters at above regularity.
2. B High B is a KEA estimate based on the Boulder Study. It assumes 20% of the adult population walked at this regularity for personal business. Low B is based on the NPTS. KEA estimates that roughly 40% of 20 billion miles walked annually are for personal business implying 25.6 million walkers.
2. C For High C KEA assumed that 1/3 of the 3 million agricultural workers walks regularly for their work. Three times this amount would account for other 'commercial' walkers. Low C is 1/2 High C.
2. D High D is based on Table 392, "Participation in Sports Activities, 1988," from 1990 Statistical Abstract, showing that 50 million adults walked for exercise, 16 million hiked, and 23 million ran or jogged in 1988. The 1982-1983 Nationwide Recreation Study found that 53% of respondents had walked for pleasure within the last year. Additionally, if 40% of walking miles are for recreational purposes, then the Boulder study implies 50 million recreational walkers at the above regularity. Low D is based on the NPTS: 40% of 20 billion miles walked implies 35 million recreational walkers.
2. E High E assumes that 10% of children walked at the above regularity. Low E is 5% of children. These estimates are consistent with "Participation in Sports Activities, 1988," showing that 5 million children ages 7 - 17 walked for exercise; 4 million hiked; and 6

million ran or logged in 1988.
3-5 and 9. Estimates by KEA

Table 3
U.S. Bicycling and Walking Miles
Relative to Passenger Vehicles

Scenario	Actual VMT	Passenger Vehicle VMT		Vehicle VMT Displaced
		Displaced ---(millions of miles) ---	% of Pass. Actual	
------(1990-91 Time Frame)-----				
Bicycle, High	21,300	2,000	1.03%	0.58%
Bicycle, Low	5,800	2,200	0.28%	0.11%
Walking, High	44,100	16,100	2.14%	0.78%
Walking, Low	20,500	5,400	0.99%	0.26%
Bic+Walk, High	65,400	28,100	3.17%	1.36%
Bic+Walk, Low	26,300	7,600	1.28%	0.37%

----- (Year-2000 Time Frame) -----				
Bicycle, High	106,500	60,000	4.52%	2.55%
Bicycle, Low	17,400	6,600	0.74%	0.28%
Walking, High	110,250	40,300	4.68%	1.71%
Walking, Low	30,750	8,100	1.30%	0.34%
Bic+Walk, High	216,750	100,300	9.20%	4.26%
Bic+Walk, Low	48,150	14,700	2.04%	0.62%

	----- Passenger Vehicle VMT (millions of miles) -----		
	1989	1991 (est)	2000 (est)
Automobiles	1,478,000	1,568,010	1,792,847
Motorcycles	10,370	11,002	12,579
Light Trucks	454,300	481,967	551,076
All Passenger Vehicles	1,942,670	2,061,000	2,357,000
Assumed annual growth, 1989 to 1991:		3.0%	
Assumed annual growth, 1991 to 2000:		1.5%	

Notes and Sources

Bicycling and Walking VMT are from Tables 1 and 2. Percentages are relative to 1991 and 2000 passenger vehicle VMT.

Passenger Vehicle VMT data for 1989 are from FHWA, Highway Statistics 1991, FHWA-PL-91-003, "Annual Vehicle Miles of Travel, 1990," p. 192. Growth assumptions to 1991 and 2000 are KEA assumptions.

Table 4A

Fuel Savings from Bicycling and Walking in the United States
(1990-91 Time Frame)

	Passenger Vehicles (Autos, Light Trucks, Motorcycles)	All Motor Vehicles (includes Heavy Trucks),	All Transport-	All U.S.
Nationwide Fuel Consumption, 1990 (in million gallons of petroleum or equivalent; see note):	107,700	131,600	170,900	534,100

Scenario	Actual VMT	Passenger Veh. VMT	Gasoline Displaced	Portion of U.S. Petroleum Displaced	Displaced	(by sector)	
		Displaced	(Million Gallons)				
Bicycle, High	21,300	12,000	680	0.63%	0.52%	0.40%	0.13%
Bicycle, Low	5,800	2,200	120	0.11%	0.09%	0.07%	0.02%
Walking, High	44,100	16,100	910	0.84%	0.69%	0.53%	0.17%
Walking, Low	20,500	5,400	300	0.28%	0.23%	0.18%	0.06%
Bic+Walk, High	65,400	28,100	1,590	1.48%	1.21%	0.93%	0.30%
Bic+Walk, Low	26,300	7,600	420	0.39%	0.32%	0.25%	0.08%

Fuel Consumption Factors

Average U.S. Passenger Car Miles per Gallon, 1990	20.92
MPG Ratio, Passenger Vehicle to Passenger Car	0.9314
Average U.S. Passenger Vehicle Miles per Gallon	19.48
MPG Adjustment, Urban/Rural & Interstate/Other	1.1
Average Miles per Gallon, Vehicles Displaced by Bic+Walk	17.71
Average Fuel Consumption per VMT Displaced	0.0565

Notes and Sources

Bicycling and Walking VMT and Passenger Vehicle VMT displaced are from Tables 1 and 2, and are approximated for 1991.

Nationwide fuel consumption: All Motor Vehicles is for 1990 and is from U.S. Dept. of Transportation, Federal Highway Administration, "Highway Statistics 1990," FHWA-PL-89-005, Table, Motor-Fuel Use (p. 5), Highway only (col. 9, which is the sum of cols. 1, highway private and commercial; 4, highway federal; and 5, highway state, county, and municipal). Autos & Light Trucks, All Transport, and All U.S., calculated by prorating All Motor Vehicles by ratios of CO₂ emissions in Table 5, this report. All U.S. counts all U.S. fossil fuel consumption in petroleum equivalent (gallons), excluding renewable, biomass and nuclear.

Average Passenger Car Fuel Consumption from U.S. Dept. of Energy, "Monthly Energy Review," DOE/EIA-0035(92/05), May 1992, Table 1.10. MPG ratio adjusts for motorcycles and light trucks, using relative MPG and VMT in FHWA, "Highway Statistics 1988," Table VM-1. MPG Adjustment is KEA estimate, reflecting lower MPG on urban and local roads (where cycling and walking are concentrated) than on rural and interstates.

Table 4B
Fuel Savings from Bicycling and Walking in the United States
 (Estimated for Year-2000 Time Frame)

Assumptions regarding Changes In Conditions from 1990-91 to 2000

Increase In Bicycling Miles (multiplicative)

High Scenario	5
Low Scenario	3

Increase In Walking Miles (multiplicative)

High Scenario	2.5
Low Scenario	1.5

Improvement In Motor Vehicle Fuel Efficiency: 10%
 (measured as reduction in gallons per mile)

Change In VMT and Other Economic Activity: 18%

	Passenger Vehicles (Autos, Light Trucks, <u>Motorcycles</u>)	All Motor Vehicles (includes Heavy <u>Trucks</u>),	All Trans- port-	<u>All U.S.</u>
Nationwide Fuel Consumption, 2000 (in million gallons of petroleum or equivalent; see note):	114,200	139,500	181,100	566,100

Scenario	Actual VMT	Passenger Veh. VMT Displaced ----- (millions of miles)	Gasoline Displaced (Million -----gallons)	Portion of U.S. Petroleum	Displaced	(by sector)	
Bicycle, High	106,500	60,000	3,050	2.67%	2.19%	1.68%	0.54%
Bicycle, Low	17,400	6,600	340	0.30%	0.24%	0.19%	0.06%
Walking, High	110,250	40,300	2,050	1.80%	1.47%	1.13%	0.36%
Walking, Low	30,750	8,100	410	0.36%	0.29%	0.23%	0.07%
Bic+Walk, High	216,750	100,300	5,100	4.47%	3.66%	2.82%	0.90%
Bic+Walk, Low	48,150	14,700	750	0.66%	0.54%	0.41%	0.13%

Notes and Sources

Improvement in motor vehicle efficiency is KEA estimate for 1990 to 2000. Change in VMT assumes growth of 3% for 1991 and 1.5%/yr thereafter.

Table 5A
Emission Savings from Bicycling and Walking in the United States
(1990-91 Time Frame)

Nationwide Emissions of Key Pollutants (metric tons; each sector is subset of -next sector)

		CO₂	CO	NO_x	VOC
Passenger Vehicles	Autos, Lt Trucks, M-cycles)	9.7E+08	2.7E+07	3.1E+06	4.7E+06
All Motor Vehicles	(includes heavy trucks)	1.2E+09	3.0E+07	5.6E+06	5.1E+06
All Transportation	(includes air, marine, etc.)	1.5E+09	3.8E+07	7.5E+06	6.4E+06
All United States	(encompasses all sectors)	4.8E+09	6.0E+07	2.0E+07	1.9E+07

Total Bicycling and Walking VMT, and Motor Vehicle Pollution Displaced

Mode, Scenario	VMT Actual	Vehicle VMT Displaced (in millions)	Pollution Displaced (metric tons)			
			CO₂	CO	NO_x	VOC
Bicycle, High	21,300	12,000	6,620,000	579,000	16,000	43,100
Bicycle, Low	5,800	2,200	1,210,000	106,000	2,900	7,900
Walking, High	44,100	16,100	8,880,000	777,000	21,500	77,600
Walking, Low	20,500	5,400	2,980,000	260,000	7,200	26,000
Bic+Walk, High	65,400	28,100	15,500,000	1,355,000	37,500	120,700
Bic+Walk, Low	26,300	7,600	4,200,000	370,000	10,100	33,900

Percentage of US. Emissions Avoided by Bicycling and Walking

Mode, Scenario		CO₂	CO	NO_x	VOC
<u>Vehicle Emissions Displaced</u>		<u>Portion of U.S. Passenger</u>			
Bicycle, High		0.68%	2.13%	0.51%	0.92%
Bicycle, Low		0.12%	0.39%	0.09%	0.17%
Walking, High	(Same Figures as Above)	0.92%	2.86%	0.69%	1.66%
Walking, Low		0.31%	0.96%	0.23%	0.56%
Bic+Walk, High		1.60%	4.98%	1.20%	2.58%
Bic+Walk, Low		0.43%	1.36%	0.32%	0.73%

Mode, Scenario		CO₂	CO	NO_x	VOC
<u>Emissions Displaced</u>		<u>Portion of U.S. Motor Vehicle</u>			
Bicycle, High		0.56%	1.91%	0.29%	0.84%
Bicycle, Low		0.10%	0.35%	0.05%	0.15%
Walking, High	(Same Figures as Above)	0.75%	2.57%	0.38%	1.51%
Walking, Low		0.25%	0.86%	0.13%	0.51%
Bic+Walk, High		1.31%	4.47%	0.67%	2.35%
Bic+Walk, Low		0.35%	1.22%	0.18%	0.66%

<u>Mode, Scenario</u> <u>Vehicle Emissions Displaced</u>	<u>CO₂</u>	<u>CO</u>	<u>NO_x</u>	<u>VOC</u> <u>Portion of U.S. Passenger</u>
Bicycle, High	0.43%	1.54%	0.21%	0.67%
Bicycle, Low	0.08%	0.28%	0.04%	0.12%
Walking, High (Same Figures as Above)	0.58%	2.07%	0.29%	1.21%
Walking, Low	0.19%	0.69%	0.10%	0.41%
Bic+Walk, High	1.01%	3.60%	0.50%	1.88%
Bic+Walk, Low	0.27%	0.98%	0.13%	0.53%

<u>Mode, Scenario</u> <u>Emission Emissions Displaced (all sectors)</u>				<u>Portion of Total U.S.</u>
Bicycle, High	0.14%	0.96%	0.08%	0.23%
Bicycle, Low	0.03%	0.18%	0.01%	0.04%
Walking, High (Same Figures as Above)	0.18%	1.29%	0.11%	0.41%
Walking, Low	0.06%	0.43%	0.04%	0.14%
Bic+Walk, High	0.32%	2.25%	0.19%	0.65%
Bic+Walk, Low	0.09%	0.62%	0.05%	0.18%
Emission Factors (Grams / Mile),	551	48.2	1.33	(Bicycling) 3.59 (Walking) 4.82

Notes and Sources

Bicycling and Walking VMT and Auto VMT displaced are from Tables 1 and 2, this report.

Transportation Emissions of CO, NO_x, and VOC are for 1990 and are from EPA, "National Air Pollutant Emission Estimates, 1940-1990," Nov. 1991, EPA-450/4-91-026, Tables B-3, B-4, B-5. All Sector Emissions (transportation and other sectors, e.g., industry) of CO, NO_x, and VOC are from EPA, "National Air Quality and Emissions Trends Report, 1990," Nov. 1991, EPA-450/4-91-023. All CO₂ emissions are from U.S. Office of Technology Assessment, "Changing by Degrees: Steps to Reduce Greenhouse Gases," Feb. 1991, Figure 5-1, converting C to CO₂ ratio of molecular weight to atomic weight of C (44/12).

Emission factors for CO, NO_x, and VOC are from U.S. EPA's official emissions factor model: MOBILE4.1. The emission factors were weighted in Tables 6 and 7, this report, to reflect region, roadway type, urban or rural setting, and average speed. CO₂ emission factor derived by KEA directly below.

CO₂emission factor derived as follows

Density of gasoline (grams/gallon):	2796
Molecular weight of gasoline (C ₇ , H ₁₃)	97
Weight CO ₂ per molecule of gasoline	308
CO ₂ emissions (grams/gallon)	8,878
Passenger vehicle fuel (gallons/mile) (see Table 4)	0.0565
CO ₂ emissions, direct (grams/mile)	501
Estimated refinery loss factor	10%
CO₂ emissions, total (grams/mile)	551

Table 5B

Emission Savings from Bicycling and Walking in the United States
(Estimated for Year-2000 Time Frame)

Assumptions regarding-Changes in Conditions from 1990-91 to 2000

Increase In Bicycling Miles (multiplicative)

High Scenario	5
Low Scenario	3

Increase In Walking Miles (multiplicative)

High Scenario	2.5
Low Scenario	1.5

Change In VMT (percent Incrs, 1990 to 2000) 18%

Emission Factors for the Year 2000 (grams/mile)

	CO₂	CO	NO_x	VOC
	496	21.1	0.59	(Bicycling) 2.22
				(Walking) 3.00

Percentage Reduction from 1990:10% (Walking) 56% 56% 38% 38%

Nationwide Emissions of Key Pollutants

subset of -next sector)

(metric tons; each sector is

		CO₂	CO	NO_x	VOC
Passenger Vehicles	Autos, Lt Trucks, M-cycles)	1.0E+09	1.4E+07	1.6E+06	3.4E+06
All Motor Vehicles	(includes Heavy Trucks)	1.3E+09	1.6E+07	2.9E+06	3.7E+06
All Transportation	(includes air, marine, etc.)	1.6E+09	1.9E+07	3.9E+06	4.7E+06
All United States	(encompasses all sectors)	5.1 E+09	3.1E+07	1.0E+07	1.4E+07

Total Year-2000 Bicycling and Walking_VMT,,_pnd Motor Vehicle Pollution Displaced

	VMT	Vehicle VMT	Pollution Displaced			
	Actual	Displaced	(metric tons)			
Mode, Senarlo	(in millions)		CO₂	CO	NO_x	VOC
Bicycle, High	106,500	60,000	29,800,000	1,260,000	35,500	133,200
Bicycle, Low	17,400	6,600	3,300,000	140,000	3,900	14,600
Walking, High	110,250	40,300	20,000,000	850,000	23,800	120,900
Walking, Low	30,750	8,100	4,000,000	170,000	4,800	24,300

Blc+Walk, High	216,750	100,300	49,800,000	2,110,000	59,300	254,100
Bic+Walk, Low	48,150	14,700	7,300,000	310,000	8,700	38,900

Percentages of Year-2000 U.S. Emissions Avoided by Bicycling and Walking

<u>Mode, Scenario</u> <u>Vehicle Emissions Displaced</u>	<u>CO₂</u>	<u>CO</u>	<u>NO_x</u>	<u>VOC</u> <u>Portion of U.S. Passenger</u>
Bicycle, High	2.90%	9.00%	2.18%	3.91%
Bicycle, Low	0.32%	1.00%	0.24%	0.43%
Walking, High (Same Figures as Above)	1.94%	6.07%	1.46%	3.55%
Walking, Low	0.39%	1.21%	0.29%	0.71%
Blc+Walk, High	4.84%	15.08%	3.63%	7.46%
Blc+Walk, Low	0.71%	2.22%	0.53%	1.14%
<u>Mode, Scenario</u> <u>Emissions Displaced</u>				<u>Portion of U.S. Motor Vehicle</u>
Bicycle, High	2.37%	8.08%	1.21%	3.56%
Bicycle, Low	0.26%	0.90%	0.13%	0.39%
Walking, High (Same Figures as Above)	1.59%	5.45%	0.81%	3.23%
Walking, Low	0.32%	1.09%	0.16%	0.65%
Bic+Walk, High	3.96%	13.54%	2.03%	6.79%
Bic+Walk, Low	0.58%	1.99%	0.30%	1.04%
<u>Mode, Scenario</u> <u>Transportation Emissions Displaced</u>				<u>Portion of U.S.</u>
Bicycle, High	1.83%	6.51%	.91%	2.85%
Bicycle, Low	0.20%	0.72%	0.10%	0.31%
Walking, High (Same Figures as Above)	1.23%	4.39%	0.61%	2.59%
Walking, Low	0.25%	0.88%	0.12%	0.52%
Blc+Walk, High	3.05%	10.90%	1.52%	5.44%
Blc+Walk, Low	0.45%	1.60%	0.22%	0.83%
<u>Mode, Scenario</u> <u>Emissions Displaced (all sectors)</u>				<u>Portion of Total U.S.</u>
Bicycle, High	0.58%	4.07%	0.35%	0.98%
Bicycle, Low	0.06%	0.45%	0.04%	0.11%
Walking, High (Same Figures as Above)	0.39%	2.75%	0.23%	0.89%
Walking, Low	0.08%	0.55%	0.05%	0.18%
Blc+Walk, High	0.98%	6.82%	0.58%	1.87%
Bic+Walk, Low	0.14%	1.00%	0.09%	0.29%

Notes and Sources

Bicycling and Walking VMT and Auto VMT displaced are from Tables 1 and 2, this report. For increase in bicycling and walking in the year 2000, see text.

Transportation emissions of CO, NO_x, and VOC in year 2000 are based on 1990 emissions, decreased by ratio

of 2000 to 1990 emission factors and increased by projected increase in VMT (3% for 1991, 1.50%/yr thereafter) . CO₂ emissions are multiplied by increase in VMT, but decreased by 10% to reflect assumed increase in fuel efficiency.

Emission factors for CO, NO_x, and VOC are from U.S. EPA, MOBILE4.1, per notes to 1990-91 part of this table. CO₂ emission factor is decreased 10% from 1990-91 emission factor.

Table 6

**EMISSION FACTORS FOR LIGHT-DUTY GASOLINE VEHICLES
GRAMS/MILE**

Factors Indicate emissions displaced per mile of automobile travel displaced by bicycling and walking.
WEIGHTED BY URBAN/RURAL, ROAD TYPE

	1990		2000		1990	2000	
	Urban	Rural	Urban	Rural			
CARBON MONOXIDE - BICYCLING AND WALKING							
NORTHEAST							
Arterial/Collector	40.3	31.2	15.4	9.70	53.4	23.2	
Collector/Local	78.0	43.9	38.0	17.6			
NORTHWEST							
Arterial/Collector	42.5	32.9	16.1	10.2	54.9	23.4	
Collector/Local	82.5	46.4	39.8	18.4			
SOUTHEAST							
Arterial/Collector	29.8	23.2	11.8	7.50	38.0	17.1	
Collector/Local	57.2	32.4	29.3	13.5			
SOUTHWEST							
Arterial/Collector	33.8	26.3	13.2	8.40	42.7	18.8	
Collector/Local	65.3	36.8	32.8	15.1			
							CO EMISSION FACTOR WEIGHTED BY VMT PER REGION
							1990 2000
							<u>48.2</u> <u>21.1</u>
NITROGEN OXIDES - BICYCLING AND WALKING							
NORTHEAST							
Arterial/Collector	1.34	1.35	0.53	0.46	1.38	0.60	
Collector/Local	1.45	1.34	0.74	0.53			
NORTHWEST							
Arterial/Collector	1.28	1.28	0.53	0.46	1.32	0.59	
Collector/Local	1.40	1.28	0.74	0.53			
SOUTHEAST							
ArteriaUCollector	1.23	1.23	0.53	0.46	1.27	0.59	
Collector/Local	1.35	1.23	0.75	0.53			
SOUTHWEST							
Arterial/Collector	1.25	1.25	0.53	0.46	1.29	0.58	
Collector/Local	1.37	1.25	0.74	0.53			
							NO _x EMISSION FACTOR WEIGHTED BY VMT PER REGION
							1990 2000
							<u>1.33</u> <u>0.59</u>

					WEIGHTED BY URBAN/RURAL, ROAD TYPE		
	1990		2000		1990	2000	
	Urban	Rural	Urban	Rural			
VOLATILE ORGANIC COMPOUNDS - BICYCLING							
NORTHEAST							
Arterial/Collector	3.05	2.70	1.80	1.50	3.50	2.08	
Collector/Local	4.35	3.20	2.65	1.90			
NORTHWEST							
Arterial/Collector	3.15	2.80	1.90	1.70	3.55	2.20	
Collector/Local	4.45	3.30	2.85	2.00			
SOUTHEAST							
Arterial/Collector	3.35	3.00	2.10	1.90	3.74	2.43	
Collector/Local	4.65	3.50	3.15	2.20			
SOUTHWEST							
Arterial/Collector	3.30	3.00	2.10	1.80	3.67	2.36	
Collector/Local	4.60	3.40	3.05	2.20			
							VOC EMISSION FACTOR WEIGHTED BY VMT PER REGION
							1990 2000
							3.59 2.22

VOLATILE ORGANIC COMPOUNDS - WALKING

NORTHEAST							
Arterial/Collector	4.15	3.80	2.40	2.20	4.60	2.74	
Collector/Local	5.45	4.30	3.35	2.50			
NORTHWEST							
Arterial/Collector	4.45	4.10	2.70	2.50	4.83	3.00	
Collector/Local	5.70	4.60	3.65	2.80			
SOUTHEAST							
Arterial/Collector	4.75	4.40	3.10	2.80	5.14	3.37	
Collector/Local	6.05	4.90	4.05	3.20			
SOUTHWEST							
Arterial/Collector	4.70	4.40	3.00	2.80	5.05	3.29	
Collector/Local	5.95	4.80	4.00	3.10			
							VOC EMISSION FACTOR WEIGHTED BY VMT PER REGION
							1990 2000
							4.82 3.00

Notes and Sources

From Konheim & Ketcham, Brooklyn, N.Y., derived from the U.S. EPA's official emission factor model: MOBILE4.1. Emission factors for the year 2000 incorporate MOBILE4.1 projections of per-mile emission rates based on assumed conditions for average travel speeds, thermal states, ambient temperature conditions, fuel used, emissions inspection, and other factors. See text for explanation of greater VOC emissions associated with "displacing" walk trips.

Average length of a bicycle trip displacing an auto trip at 2.7 miles/trip; average length of a walk trip displacing an auto trip at 1.3 miles/trip, derived from Table 1. Assumptions: Commuting, Recreation and Childrens' daily miles divided into 2 (two) trips a day each; Personal, 3 (three) trips/day; and Commercial, 5 (five) trips/day. High and low estimates of auto miles displaced were averaged,

"Urban" is the average of the emission factors for cities and suburbs.

Weights for Road Type, Urban/Rural, and Regional VMT from Table 7, this report.

Table-7
ANNUAL U.S. MILES OF TRAVEL BY REGION AND ROADWAY TYPE, 1989

	Passenger Vehicles Only						VMT in Region					
	Cities	Rural	All	Cities	Rural	All	Cities	Rural	All	Cities	Rural	Adjusted
	Vehicle Miles			% of All VMT in Region			Region% of U.S			Adjusted		
NORTHEAST												
Arterial/Collector	2.5E+11	1.5E+11	4.0E+11	43%	27%	70%	48%	51%	49%	26.3%	17.1%	
Collector/Local	1.2E+11	5.8E+10	1.8E+11	20%	10%	30%	56%	51%	54%	37.1%	19.4%	1
SUBTOTAL	3.7E+11	2.1E+11	5.8E+11	63%	37%	100%	51%	51%	51%	[Total = 100%]		
NORTHWEST												
Arterial/Collector	4.3E+10	3.1E+10	7.4E+10	40%	29%	70%	8%	10%	9%	25.1	18.6%	
Collector/Local	1.9E+10	1.3E+10	3.2E+10	18%	12%	30%	9%	11%	10%	33.2	23.0%	
SUBTOTAL	6.2E+10	4.4E+10	1.1E+11	58%	42%	100%	9%	11%	9%	[Total = 100%]		
SOUTHEAST												
Arterial/Collector	1.0E+11	7.5E+10	1.8E+11	41%	30%	71%	20%	25%	22%	25.5%	19.5%	
Collector/Local	4.3E+10	2.9E+10	7.2E+10	17%	12%	29%	21%	25%	22%	32.6%	22.4%	1
SUBTOTAL	1.4E+11	1.0E+11	2.5E+11	58%	42%	100%	20%	25%	22%	[Total =100%]		
SOUTHWEST												
Arterial/Collector	1.2E+11	4.3E+10	1.6E+11	58%	21%	79%	24%	14%	20%	42.0%	13.9%	
Collector/Local	2.9E+10	1.4E+10	4.3E+10	14%	7%	21%	14%	12%	13%	30.5%	13.6%	
SUBTOTAL	1.5E+11	5.7E+10	2.1E+11	73%	27%	100%	21%	14%	18%	[Total =100%]		
ENTIRE U.S.												
Total Art/Collector	5.1E+11	3.0E+11	8.2E+11	45%	27%	72%	100%	100%	100%			
Total Collector/Local	2.1E+11	1.1E+11	3.2E+11	18%	10%	28%	100%	100%	100%			
TOTAL	7.2E+11	4.2E+11	1.1E+12	63%	37%	100%						

Notes and Source:

Passenger vehicles includes autos, light-duty trucks, and motorcycles.
 Vehicle miles data from Konheim & Ketcham, derived from data provided by FHWA, 1991.

SEA adjustment for roadway type eliminated interstate and tripled the weight of local streets to reflect the greater number of auto miles displaced by bicycling and walking miles from local streets. The weights were then adjusted proportionally to sum to

.00% in each region.

4. Other Environmental Benefits from Bicycling and Walking Not Quantified Here

This report has focused almost exclusively on the fuel savings and emission reductions arising from bicycling's and walking's displacement of motor vehicle use. Of all of the environmental benefits from human-powered transportation, these are the most obvious, most easily quantified, and probably the most significant. However, bicycling and walking generate a wide array of other important benefits to the environment and to society at large. We list and briefly describe these here.

Cycling and Walking Environmental Benefits, in addition to Fuel Savings and Emission Reductions

Road Space/Congestion --- Bicycling and, especially, walking require far less physical road (or sidewalk) space per traveler than automobiles. This is due to differences in both "vehicle" size and speed. (While in theory the size of a traffic stream able to pass a given point should be proportional to speed, safe braking distance is proportional to the speed squared, suggesting that, in practice, the size of the stream is inversely proportional to its speed.)

Thus, human-powered travelers avoid most of the exorbitant need for roadways exerted by motor vehicles, along with associated environmental damage including loss of open space, conversion of farm land, expropriation of valuable urban property, elimination of water and flood drainage, and the various direct impacts from creating, installing, and maintaining pavement surfaces. Similarly, bicycling and walking add little or nothing to congestion ---- an important point as vehicle use increasingly exceeds roadway capacity, causing chronic congestion.¹¹ Annual U.S. motor vehicle congestion costs have been estimated at \$100 billion or more,¹² suggesting that national VMT and associated

¹¹ Rodney Tolley has written, "One person walking or cycling has no effect on the opportunity surface of others, or on the choices that others can make. In short, using your feet allows you to move without interfering with anyone else's freedom. The contrast with car use, where no one can save time without forcing others to lose it, is marked." Tolley, *A Hard Road: The Problems of Walking and Cycling in British Cities*, in Tolley, ed., *The Greening of Urban Transport*, op. cit., p. 13.

¹² The World Resources Institute cites GAO and other estimates of \$100 billion or higher, while Ketcham and Komanoff estimate \$168 billion (1990 dollars). See Footnote 87 for full citations.

congestion displaced by bicycling and walking constitute a significant environmental and economic benefit.

Land Use ("Sprawl") - Perhaps the most insidious of the various "self-reinforcing" aspects of motor vehicles is that their "use causes facilities and services to become more widespread often to the point where they are beyond the range of [cyclists and walkers]."¹³ Or, as Ivan Illich put it, "motorized vehicles create new distances which they alone can shrink. They create them for all, but they can shrink them for only a few."¹⁴ Moreover, as motor vehicles have expanded into a Cycling norm, cities have either been badly compromised through auto-centered remodeling that undermines urban density, or have been bypassed altogether through suburban and exurban residential and commercial development. In this way, motor vehicles have been both catalyst and creature of dispersed, resource-intensive non-urban settlement.

Cycling and walking help counter this dynamic. Although in the popular mind countryside may be more conducive to bicycling and walking, these modes are actually more common in urban areas, where distances are shorter, which favors bicycle and foot travel over motor travel. The converse of this is that bicycling and walking buttress the economic and social vitality of cities; precisely because, in conjunction with public transport, they enable travel to occur without motor vehicles, bicycling and walking in effect make possible the density that defines urban life and commerce. Although quantification of this phenomenon is beyond our scope, the "glue" that bicycling and walking supply to cities is an important antidote to environmentally and socially destructive sprawl.

Roadway Accidents ---- Between 45,000 and 50,000 people die in U.S. roadway accidents each year, including roughly 7,000 pedestrians and 1,000 bicyclists. Based on the estimates of U.S. miles walked, bicycled, and driven in this report, per-mile fatalities as well as injuries appear to be considerably higher for walking and bicycling. While such a comparison might suggest that substitution of bicycling and walking for motor vehicle use would increase road accidents, such a conclusion is probably fallacious, for several reasons.

¹³ Rodney Tolley, *A Hard Road*, op. cit., pp. 13-14.

¹⁴ Ivan Illich, *Energy and Equity*, Calders and Boyars, London, 1974, quoted in Tolley, op. cit.

First, the majority of bicyclist deaths, and virtually all pedestrian deaths, occur in collisions with motor vehicle; thus, increases in bicycling and walking and decreases in vehicle use tend to improve safety of "prior" bicyclists and walkers.¹⁵

Second, as mentioned above, bicycling and walking help reinforce dense settlement patterns in which trips for work, personal business and pleasure can be confined to shorter distances; thus, over the long term a mile walked or bicycled can substitute for more than one mile driven ---- in effect, reducing accident rates per trip or per person', if not per mile. Third, improved bicycling and walking facilities facilitate safety as well as greater mobility for bicyclists and pedestrians.

Fourth, increases in bicycling and walking also tend to give rise to political demand to reduce motor vehicle speed and frequency; thus, growth in pedal and foot traffic can result in declining per-mile casualties, following a period of accommodation.

Road accidents exact enormous costs to American society and the economy through loss of life, lost productivity at work and home, cost and time of rehabilitation, and victim and family pain and suffering. The Urban Institute has estimated these costs at roughly \$363 billion per year (1990 dollars).¹⁶ A careful, "whole-systems" analysis of the effect of bicycling and walking on road accidents would contribute importantly to understanding of the total environmental benefits of bicycling and walking.

Noise ---- Roadway traffic generates noise through a variety of mechanical and physical processes, including tires moving over pavement, engine exhaust, operation of engines and related equipment, friction of brake shoes on drums or discs, operation of air brakes, and transmission and drive train friction ---- not to mention discretionary equipment operated by drivers (e.g., horns and alarms). Noise from motor traffic erodes not only urban civility but also human health and economic well-being.

Although much vehicle noise is from heavy trucks, which are little if at all displaced by bicycling and walking, a considerable part is generated by passen-

¹⁵ See Tolley, *op. cit.*, for evidence that increased vehicle use is associated with increases in pedestrian casualties, particularly in areas where children still congregate, play and travel on roadways.

¹⁶ Urban Institute, *The Cost of Highway Crashes*, prepared for the Federal Highway Administration, Contract DTFH61-85-C-00107, June 1991. Costs adjusted from 1988 dollars to 1990 dollars by KEA, using GDP deflator.

ger vehicles. Ketcham and Komanoff estimate annual U.S. health and productivity costs from motor vehicle noise at approximately \$22 billion (1990 dollars), based on a 1981 study for the Federal Highway Administration that inferred a per-decibel estimate of the economic impact of highway noise from property value differences between homes located near and far from urban interstates.¹⁷ In contrast, walking and bicycling generate little if any noise.

Other Costs of Motor Vehicles, which translate as Environmental Benefits of Bicycling and Walking --- Listed Briefly

- Drilling, shipping, and storing oil causes widespread environmental pollution, ranging from huge oil spills such as the Exxon Valdez in Alaska's Prince Edward Sound, to far greater amounts of oil and gasoline routinely leaked and poured into sewers and seeping into groundwater. Petroleum consumption by bicycling and walking is *de minimis* (i.e., extremely small amounts of lubricants applied to bicycle parts and in bicycle manufacture).
- Car and truck air-conditioning units account for about a quarter of chlorofluorocarbon (CFC) use in the United States. These manmade chemicals are considered responsible for an estimated 14% of the greenhouse effect, ranking third behind CO₂ (responsible for about 50%) and methane (18%).¹⁸ CFCs also are destroying the stratospheric ozone layer, thereby exposing life on earth from humans to vital microorganisms to excess levels of deadly ultraviolet radiation. In contrast, bicyclists and walkers do not employ artificial air-conditioning.
- Stormwater runoff of salts applied to de-ice highways harms the environment, as do lead and toxic organics from auto emissions, brake lining wear, etc. The portion of this allocable to bicycling and walking is quite small ---- in proportion to their use of road and sidewalk space (and, indeed, municipalities are far less aggressive at removing snow from sidewalks than from roadways).
- Approximately 10 million car and truck chassis and 250 million

¹⁷ See Footnote 87.

¹⁸ U.S. EPA, "The Greenhouse Effect: How It Can Change Our Lives," *EPA Journal*, Vol. 15, No. 1, Jan/Feb 1989.

tires are dumped into the environment each year, with little recycling. Analogous impacts from bicycling and walking are largely worn-out bicycles and parts (some of which are recycled internationally by Bikes Not Bombs and other mobility-development projects) and footwear.

- Motor vehicles contribute to destruction of public property such as parkland, sidewalks, and other facilities through crashes and routine driving and parking in off-road areas. Damage to public and natural areas by hikers and "mountain" bikers, although a concern to nature and wilderness lovers, is of a lower order of magnitude.
- Manufacturing, transporting, and storage of motor vehicles also harms the environment. At least one source estimated the energy requirements of vehicle manufacture at roughly 20% of total lifecycle energy.¹⁹ Analogous impacts from bicycle manufacture are probably proportional to relative "vehicle" weight, i.e., roughly two orders of magnitude less.

Refining and storing petroleum products pollutes air, land, and water. We have excluded such impacts, except for adding 10% to tailpipe emissions to estimate the emission factor for carbon dioxide (CO₂).

¹⁹ A 1984 calculation by Toyota that 20% of energy use devoted to the auto was consumed in materials and vehicle manufacture was cited in Greenpeace International, *Environmental Impact of the Car*, London, 1991, p. 43.

5. Estimating Current Levels of Bicycling and Walking in the United States

Estimating bicycling and walking's contribution to mobility in the United States is a complex task. Little hard data have been compiled and the few available sources do not employ uniform methods to estimate the amount of bicycling and walking. The paucity of data is, in part, a result of transportation planners' focus on highway planning to accommodate ever-increasing automobile use. Within this planning framework, there has been no perceived need for information about non-motorized transportation.

The Federal Government conducts two periodic national surveys of personal transportation choices - the *U.S. Census of Journeys to Work* and the *National Personal Transportation Study*. A number of municipalities and regional associations from Seattle (WA) to Gainesville (FL) also conduct transportation surveys. But many of these Surveys suffer from the same shortcoming which plagues transportation planning as a whole: the failure to perceive bicycling or walking as legitimate modes of transport which require planning and infrastructure.²⁰ Thus, walking and bicycling trips often remain obscured in transportation surveys, buried in a mode choice known as "other."²¹ *Only researchers who design surveys to seek out walking and bicycling find levels approaching actual usage.*

Accordingly, we have made it our mission to derive a comprehensive estimate of bicycling and walking by evaluating existing sources of information and augmenting them with our own knowledge of reliance on these modes. This section of our report introduces existing estimates of bicycling and walking, identifies the strengths and weakness of each, and then explains our estimates.

²⁰ A classic example of this "planning myopia" is the New York Metropolitan Transportation Council's study *Hub-Bound Travel 1990*. This report claimed to survey "all public and private transportation modes." (p. 1) Yet while including ferries, which transport only 45,000 people on a daily basis, the report excluded bicycling and walking, which are the primary mode used by approximately 75,000 and 1 million New Yorkers per day, respectively. (Several million more New Yorkers walk in conjunction with their use of public transit.)

²¹ Although the "Early Results" of the 1990 *National Personal Transportation Study*, provided data for bicycling and walking trips, the "Summary of Travel Trends" issued six months later lumped bicycling and walking into the "other" category, thus obscuring these modes.

Several different methods are used to estimate levels of bicycling and walking. Principal among them are:

- transportation diary studies
- traffic counts
- surveys of journeys to work
- recreational surveys, and
- bicycling advocates' estimates.

Examples of each are detailed below. Rather than surveying every estimate, we illustrate the methods used to examine bicycling and walking with a view toward putting our chosen method in context.

A. DIARY STUDIES

Diary studies attempt to survey trip and trip taker characteristics for every trip on a fixed day or period of time. This is the most comprehensive survey of travel, intended to survey all trip purposes and all trip modes. Diary studies can also provide information on the characteristics of trip segments, such as where a bicycle is used to get to a transit stop.

Studies that are conducted in mild weather months or that ask about complementary travel modes are likely to reveal higher levels of bicycling and walking. However, transportation diary studies focused exclusively on trip-based transport may undercount recreational walking and bicycling. As a final caveat, because diary studies require expenditure of time and effort by the respondent, trip-making of "busy" people may be underrepresented in the results.

1990 Diary Study of Modal Split in Boulder Valley

In 1990, the City of Boulder undertook a comprehensive survey of its residents' transportation choices. Participants in the study recorded their travel for one day during the week of Sept. 16-22, 1990. 1,332 mail-back surveys were completed and returned. Surveyors then conducted a non-respondents study and adjusted the results to reflect the fact that the sample non-respondents group took fewer (but longer) trips than the respondents group and were less likely to use non-automobile modes.

The survey found that 19% of trips in Boulder are taken by foot and 9% by bicycle. These relatively high rates are partly attributable to the presence of a

large university population (University of Colorado), Boulder's land-use patterns (mixed residential and commercial) and a culture and infrastructure supportive of non-motorized transportation. However, surveyors were also careful to create a survey instrument which could fully reveal walking and bicycling as transportation mode choices.

The surveyors defined modal split as "a method of dividing travel into all available modes."²² They note that this definition avoids pro-automobile biases inherent in surveys that count only trips to work, that divide trips between public and private transportation, or that lump bicycling and walking into an "other" category which could include anything from airplane to school bus. Additionally, the Boulder survey defined a trip as "anything longer than a city block." This definition helps counter respondents' potential bias to regard a strip" as a correlated phenomenon.

Many Surveys of transportation choices request information only about trips to or from work or school. The Boulder study showed that the majority of trips are made between home and a place other than work or school, such as shops or friends' homes.²³ Additionally, more walking trips are taken for non-work purposes; walking share for all trip purposes was 19.5%, compared to only 10.5% for the work commute. Bicycling's share of the work/school modal split, 9.3%, was slightly higher than its share of all trips, 8.8%.²⁴ The mean length for a bicycle trip was 2.1 miles; a walking trip, 0.7 miles; and all trips, 4 miles. The average trip took 15 minutes; trip duration was Virtually the same for every mode except transit buses, for which trips averaged twice as long.

The Boulder Study provides extensive information about Boulder residents' travel. It is the most thorough travel study we have seen and an excellent source of comparison to national and community-based travel data. The City is repeating the survey in the fall of 1992 and every two years thereafter.

1990 National Personal Transportation Study

The National Personal Transportation Study (NPTS) is conducted every seven

²² City of Boulder, *1990 Diary Study of Modal Split in Boulder Valley*, p. 4.

²³ *Ibid.*, p. 14.

²⁴ *Ibid.*, p. 16.

years by the Federal Highway Administration. In the most recent study, over the course of 1990, the study collected information by telephone interview from 22,000 households in the U.S. about all trips taken by the respondent and household members age 5 or older. Questions were asked about the respondent's travel on a selected day and long-distance travel during the prior two week period.

According to the *NPTS*, in 1990 7.7% of all trips were made by foot, and 0.7% by bicycle. The percentage of *miles* traveled was 0.5% by foot; 0.1% by bicycle.

The NPTS is a relatively comprehensive survey for several reasons:

- it seeks information about all trips regardless of purpose,
- it surveys people over the course of an entire year,
- it includes children,
- it provides information about miles traveled, and
- it is balanced for urban, suburban and rural travel respondents.

Nevertheless, we believe that the *NPTS* most likely underestimates the actual levels of bicycling and walking because:

- The Survey explicitly sought out infrequent motorized trips greater than 75 miles, but not infrequent bicycling and walking trips.
- The survey form presents recreational travel as "pleasure driving" and as other trips with specific social or recreation purposes other than the trip itself. This presentation works to undercount recreational bicycling and walking, in two ways - because "pleasure driving" is not pleasure bicycling or walking, and because bicycle or walking trips with no purpose other than the bicycling or walking itself would not fit into this definition of trip-based transportation. Since, by our estimates, recreational trips are the largest and second largest categories of bicycling and walking, respectively (see Tables 1 and 2), this bias is particularly significant.
- The *NPTS* would not adequately measure uses of bicycles that are not

specifically transportation (such as competition).

- Important commercial bicycle uses are most likely underrepresented due to the small NPT samples.
- A note in the "Early Results" of the Study indicates that children's walking and bicycling, may be undercounted by parents.
- Walking trips linked to transit trips are most likely undercounted.

There are enormous differences between the *NPTS* and the 1990 Boulder Diary Study in estimated bicycling walking miles. The Boulder Study shows 21 times as many bicycle miles per person and three times as many walking miles per person as are documented in the *NPTS*. To be sure, part of the difference is real, the result of Boulder's land use, demographics, and support for bicycling. However, subtle differences in survey methodology may indicate a bicycling and walking under-count on the part of the *NPTS*.

In Boulder, surveyors found that respondents often would not remember walking trips or consider such trips "transportation" unless prompted to do so. The Boulder survey specifically, asked respondents if they had counted all bicycling and walking trips. Additionally, a trip was defined for Boulder respondents as anything longer than a city block. *NPTS* respondents conditioned to think of a trip as something done in a car might have ignored some of their shorter walking trips. Emphasizing this point, a Boulder surveyor related the story of a potential survey respondent who called the survey headquarters to say that she didn't think she should participate because she didn't own a car.²⁵ A leading West German transportation surveyor reports similarly that "many interviewees did not mention their short journey especially those made within a Multi-stage trip."²⁶

Accordingly, we have based our "low" estimate of Current walking and bicycling levels on the *NPTS*, with several adjustments for the above limitations.

²⁵ Telecom with Michelle, Miller, Department of Research and Evaluation, May 28, 1992.

²⁶ Rolf Monheim, *Policy Issues in Promoting the Green Modes*, in Tolley, ed., *Tile Greening of Urban Transport*, Belhaven Press, London, 1990, p. 136.

Chicago Area Transportation Study: Household Travel Survey 1989

Another local diary study is the *1989 Household Travel Survey* examining transportation patterns of residents of Chicago and surrounding counties. Volume One of this multi-volume study examines the Chicago Central Business District (CBD). Notably, City of Chicago respondents made 37% of trips by walking, vs. only 3% for suburban McHenry County. (The survey results do not indicate bicycling trips.) Mean distance of all trips in the Chicago CBD was 4 miles; 8 miles for McHenry County.

B. TRAFFIC OR CORDON COUNTS

Traffic counts or cordon counts (a count of the number of bicycles that enter a marked area of a right of way) help planners find the most heavily traveled bicycle routes in a city. This information is useful for municipalities and regions already committed to planning bicycle facilities. However bicycle counts which do not estimate bicycles as a share of all traffic, or which show rises and declines in bicycle traffic in isolation from increases or decreases in the general traffic volumes, are less valuable.

San Diego Association of Governments: Bicycle Counts at Selected Intersections in San Diego County, 1990

This report does not estimate the total number of bicyclists in San Diego or bicyclists' share of the modal split. However, it does show bicycle traffic volumes at major intersections. The report authors note "This information is used by local government agencies in planning for and providing a regional network of safe bicycle routes and facilities that will encourage people to use the bicycle as an alternative means of commuting." (p. 3) Counters found an average of 22 bicyclists per hour, per avenue.

Transportation Alternatives: Bicycle Counts on Midtown Avenues, 1988-1992

In 1988, 1989, 1990, and 1992, volunteers from Transportation Alternatives, a New York City advocacy group, counted vehicles during midday on weekdays on New York City's busiest avenues, in mid-Manhattan. For the four years, bicycle flow per avenue ranged between 125 and 173 bicycles per hour, with

bicycles ranging from 7.2-9.6% of all vehicles.²⁷ Even on rainy days bicycles averaged 6% of midtown avenue traffic. These results call into question "official" New York City Department of Transportation (NYC DOT) estimates that bicycles are only 1-2% of traffic in New York City's business district.²⁸

In addition, a 1991 report entitled *Assessing the Percentage of Bicyclists in the Traffic of Manhattan's Central Business District*, by Transportation Alternatives member Mary Frances Dunham, indicates that human factors also mar the NYC DOT's bicycle count surveys. Standing alongside DOT counters and simultaneously recording her own count, Dunham consistently counted more bicycles than did the DOT counters. She attributed the discrepancies to several factors:

- The DOT counters were tired by long counting days
- The DOT counters did not position themselves properly to see all bicycles
- The DOT counters did not count all traffic modes
- In general, the DOT counters did not have an investment in counting as many bicycles as actually existed.

These results demonstrate that to achieve accurate transportation survey results, a commitment on the part of the surveyor to bicycling (or walking) as a transportation mode may be imperative.

C. SURVEYS OF JOURNEYS TO WORK

Surveys of mode choice for the work trip are useful for planners concerned with employee trip reduction schemes such as those mandated by the 1990 Clean Air Act Amendments. Because work is a frequent and predictable trip generator, planners may prefer to survey home-work trip characteristics and focus on modifying employee trip-making choices. However, as noted above, the Boulder Diary Study and the *National Personal Transportation Study* found that such trips are a minority of total trips.

²⁷ *Bicycles Near 10% of Midtown Avenue Traffic*, July 20, 1990 press release, Transportation Alternatives. For 1992 survey, see *City Cyclist*, July/August 1992, p. 10, or contact T.A. at 92 St. Marks Place, New York, NY 10009.

²⁸ NYC DOT's bicycle surveys count only bicycle traffic crossing 60th St. from uptown Manhattan or entering Manhattan via the Brooklyn Bridge. Transportation Alternatives' include circulating intra-CBD bicycle traffic.

1960-1980 Census of Journeys to Work ----- U.S.A. and Selected Cities

The Federal Highway Administration's *National Bicycling and Walking Study Interim Report* and Newman and Kenworthy's *Cities and Automobile Dependence: An International Sourcebook* (1989) report on travel mode choice for the work commute as surveyed in the U.S. Census.

The Interim Report highlights cities such as Bloomington (IN), Chico (CA), and Gainesville (FL) as cities that the 1980 Census found had large walking and bicycling commuter populations. The map on page 5 of the report shows cities that, according to the Census, had greater than 15% of commuters travelling to work by foot or bicycle.

Australian transportation planners Peter Newman and Jeffrey Kenworthy present the combined number of bicycling and walking commuters for 10 Standard Metropolitan Statistical Areas (the city plus surrounding related areas) and the cities proper - Boston, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Phoenix, San Francisco, and Washington, DC. These data are from the 1960, 1970, and 1980 Census. In 1980, bicycling and walking commuters made up an average share of 5.3% in the SMSAs, and 8.4% for the cities alone. Only three cities, Boston, New York, and Washington DC, experienced a growth in the share of bicycling and walking commuters 1960-1980.

Boston has consistently outranked other large cities; walkers and bicyclists were 9.80% of the commuting population in 1980. However, while the *city of Boston* boasted the greatest increase in the share of bicycling and walking commuters 1960-1980 (19%), the Boston SMSAs bicycling and walking share declined by 20%. The decline in walkers and bicyclists in all SMSAs has far exceeded the rate of decline in the cities proper, suggesting that "suburban sprawl" reduces walking and bicycling.²⁹

1990 Census --- U.S.A. and New York

Recently released figures show 1990 Census data for Journeys to Work in the United States. According to the Census, in 1990 bicycles were the primary

²⁹ Sprawl discourages walking and bicycling in many ways, but most fundamentally by creating land uses that are inhospitable to non-automobile modes. Linked aspects of this include proliferation of cars, crowding of roads, expanded distances, low human density, and high automobile density.

mode choice of 0.4% of commuters, while walking's share was 4%. During 1980-1990, bicycling's share of journeys to work declined by 16%, and walking by 30%. Carpooling's share of commuters declined even more, by 32%, in 1980-1990, while the modal share of commuters driving to work alone rose 14%.

1990 Census data for New York State and New York City show that 7% of New York State commuters walked to work and 0.3% bicycled to work. In New York City, 11% walked and 0.3% bicycled to work. This represents a 6% decline in the share of commuters using bicycling or walking in New York City during 1980-1990.

The Census of Journeys to Work has important shortcomings regarding walking and bicycling:

- The Survey is conducted in the last week in March. This may not be a representative walking and bicycling period in much of the country, because of unfavorable weather.
- High school, college, and university commutes are excluded.
- Only primary travel modes are solicited. Thus, a New Yorker who takes the subway to work three times a week and bicycles twice would list "subway" as her travel mode. Similarly, a commuter who walks to a residential bus stop (and from the downtown bus stop to an office) would list "bus" as his mode.
- Only Journeys to Work are counted. The Boulder study and indeed every study we have reviewed reveals that work-related trips are a minority of total trips, and that walking's share of non-work trips exceeds its share of commuter trips.
- The census does not show miles traveled.
- The census excludes the walking or bicycling commutes of children under age 16. A higher proportion of children bicycle and walk because they cannot drive (as well as other, related cultural factors).

Finally, as noted, the 1990 Census of Journeys to Work found that 0.3% of commuter trips in New York City are made by bicycle; this implies that there

are approximately 12,000 bicycle commuters in New York City. At the same time, however, Transportation Alternatives (T.A.) has estimated that 75,000 New Yorkers ride bicycles for non-recreational purposes on a typical day. Assuming that one-third of these bicyclists are commuters, the T.A. estimate translates into 24,000 commuters, or twice the estimate from the Census.

D. SURVEYS OF RECREATIONAL CHOICES

The Federal Highway Administration's Interim Report on Bicycling and Walking takes note of the *1982-1983 Nationwide Recreation Survey*. This study, conducted over a complete year, asked respondents if they had bicycled or walked for pleasure in the prior three months. 28% of respondents indicated that they had bicycled, and 53% had walked for pleasure, according to this study.

The *1990 Statistical Abstract of the United States*, Table 392, "Participation in Sports Activities by Selected Characteristics, 1988," reports that a significant portion of adults and children bicycle and walk as a form of recreation. For this survey, National Sporting Goods Association contacted 10,000 households to ask about their primary recreational choices. 25% of those surveyed had bicycled 6 times or more in the prior year. Almost 50% of children ages 7 - 17 had bicycled. 29% of those surveyed reported having walked for exercise 6 times or more in the prior year.

E. OTHER IMPORTANT SURVEYS

Bicycle Transportation for Energy Conservation, U.S. Department of Transportation, 1980

This document was developed to meet requirements of the National Energy, Conservation Policy Act of 1978. The report estimated the current level of bicycling by supplementing the 1975 Travel-to-Work Supplement to the Annual Housing Survey with information about other trip purposes from regional bicycle use studies. Recreation and "Neighborhood" generated the greatest number of bicycle trips - 46% of all bicycle trips. Work trips were 5% of the total; school, 15%; personal business, 17%; and social, 17%. Recreation trips were the longest, averaging 2.5 miles in length. The report estimated a total of 18.8 million bicycle daily (weekday only) trips for all trip purposes', covering 33.8 million miles per day. Bicyclists rode 8.8 billion miles in 1975, according to

the Department of Transportation.³⁰

1990 and 1991 Harris Polls

In late 1990 and again in 1991, Harris Polls on bicycle use were conducted for *Bicycling Magazine*. The poll takers interviewed by telephone 1,250 adults across the country. The 1990 results were reported in *Bicycling Magazine's* special report, *A Trend on the Move: Commuting by Bicycle ---- An Overview of the Future of Bicycling as Transportation*. The results of the 1991 poll are in the form of press releases by *Bicycling Magazine*.

The polls focused on both regular and occasional bicycle use and asked respondents what incentives would induce them to become bicycle commuters. Some highlights from the 1991 survey follow:

- 46% said that they had ridden a bicycle in the past year, up from 42% the prior year.
- 84% of those who had ridden in the past year had ridden in the last mild weather month (the survey was conducted in December).
- 82% of those who had ridden in the last mild weather month said they rode for recreation; 7%, to commute to work.
- 40% of work commuters rode to work by bicycle 12 or more days a month.

The 1991 poll showed modest increases over the prior year's bicycle use. Among bicyclists, i.e., those who had ridden a bicycle in the past year, the level of bicycle commuting remained constant at 7%, while the percentage of those riding for recreation rose from 76% in 1990 to 82% in 1991.

These percentages indicate that the bicycle plays a significant role in the lives of millions of individuals the U.S. Assuming that the survey is representative of the adult population of the U.S. as a whole:

- 82 million adults rode a bicycle in 1991, and

³⁰ Based on 260 weekdays.

- 3 million commuted to work by bicycle.

Bicycle Institute of America

The Bicycle Institute of America's (BIA) *Bicycling Reference Book's* "Facts and Figures About Bikes and Bicycling" estimates that 52 million adults age 16 or older and 44 million children bicycled in 1991. 27.5 million bicycled regularly (averaging once a week); 4 million of regular bicyclists were bicycle commuters. According to the BIA, these figures were derived from a variety of sources including consumer surveys conducted in the mid-1980s and bicycle ownership data from bicycle manufacturers, rather than from systematic surveys of bicyclists or the populace as a whole.

Transportation Alternatives - Ethyl Corp Response

Based on Bicycle Institute of America estimates of bicycling levels in 1989, Transportation Alternatives (T.A.) determined the number of regular bicyclists for different bicycling categories such as commuting, recreation, and commercial (on-the-job) use. T.A. then estimated how many miles each of these bicyclists cover in a day, how many days each bicyclist rides and, ultimately, how many bicycle-miles are generated in a year. Information in this form allowed for easy calculation of fuel and pollution savings from current levels of bicycling. This method also counted multiple bicycle trips by single bicyclist. We have adopted this methodology for estimating the current levels of bicycling and adapted it to estimate walking levels.

ESTIMATED BICYCLE MILES TRAVELED IN THE UNITED STATES, 1990-1991

Table 1 provides KEA's estimate of the current level of bicycling in the United States and the amount of passenger vehicle miles displaced by bicycling. The table provides a high and low estimate for each bicycling category (commuting, recreation, etc.) . By dividing bicycling into categories of use we are able to more accurately estimate both the number of miles generated by each bicycling use and the amount of passenger vehicle miles which are displaced by that bicycling use.

For instance, a bicycle courier goes farther on his or her bicycle, and uses his or her bicycle more weeks of the year than an average bicyclist who rides her bicycle to the post office. Additionally, a typical adult bicycle commuter dis-

places more motorized vehicle use than does a child pedalling around the neighborhood. This methodology allows us to account for these differences. Our estimates of the component inputs - number of bicyclists, days per week, etc. --- rely on survey data wherever possible. However, in those cases where no survey data exist, we rely on our experience to inform our estimates.

Our "high" estimates of regular commuting (2.8 million) and recreational (27.5 million) bicyclists are based on the most recent survey of bicycling in the United States - *Bicycling Magazine's* Harris Poll conducted in December 1991. The high estimate of recreational riders also draws on the Bicycle Institute of America's "Facts and Figures About Bikes and Bicycling" from their 1992-1993 *Bicycling Reference Book*, containing information about bicycle vacationers and competitive bicyclists.

Our "low" estimates of commuters, "personal business" riders, and recreational riders are based on the *National Personal Transportation Survey*. By multiplying the average number of miles bicycled by the survey respondents by the U.S. population over age 5, we determined the total number of bicycle miles traveled in the U.S. in 1990. We then estimated the number of bicyclists for each category of bicycle use implied by the NPTS-based estimate of 4 billion total bicycle miles traveled.

We augmented these estimates with estimates of commercial and children's bicycling - categories not adequately surveyed by the *NPTS*. We relied on *BIA*, *Nationwide Recreation Survey* and figures presented in the *Statistical Abstract* table of sports participation to estimate children's bicycling. KEA's estimate of the number of commercial bicyclists relies on our judgment of bicycling's use in mail and package delivery, factories, building and grounds maintenance, and other for-pay situations. Similarly, KEA's estimates of daily miles per bicyclist and days per week and weeks per year of bicycle use are based on our general familiarity with bicycling in New York City and other U.S. cities, drawn from years of reading the literature and networking with bicycle advocates and transportation officials.

To summarize KEA estimates that in the U.S. circa 1990-1991:

- Between 1.7 and 2.8 million people were using bicycles to commute to work on a regular basis.
- Bicycles were used by between 3.8 and 5.0 million people to carry out

personal business such as shopping, visits to doctors, trips to the post office, etc.

- Commercial bicycle riders numbered between 250,000 and 500,000.
- Between 15.0 and 27.5 million people rode bicycles for recreation.
- From 6 to 15 million children were regular bicycle riders.
- Bicyclists generated between 5.8 and 21.3 billion miles per year for these trip purposes circa 1990-1991.

ESTIMATED WALKING MILES TRAVELED IN THE UNITED STATES, 1990-1991

Walking is something that most people do every day. According to Tolley, 97 percent of the population of Great Britain is "able to go out on foot,"³¹ and the ambulatory percentage in America is probably not much different. Less than a century ago, a majority of people relied heavily on their feet to get them places. In recent decades, however, both the practice and prestige of walking have been steadily marginalized. Indeed, as Ramsay notes, "In many districts of American cities, due to the very high rates of car ownership, anyone walking is suspected of being delinquent."³² But despite the cultural shift into automobiles, KEA estimates that between 20.5 and 44.1 billion miles were walked per year in the U.S. circa 1990-1991.

Our walking model adopts the same trip purposes as our bicycling model. The "high" estimates presented in the table derive from a number of sources. As with our bicycling model, we based our low estimates on the 1990 *National Personal Transportation Study* wherever possible.

Our high estimate of commuters who walk to work --- 10 million, or 5% of the adult U.S. population - is based on the 1990 Boulder, Colorado diary study. We also extrapolated a high estimate for "personal business" walkers from the Boulder study. We have adjusted -our high estimates downward to reflect the

³¹ Rodney Tolley, *A Hard Road*, op. cit., p. 15.

³² Anthony Ramsay, *A Systematic Approach to the Planning of Urban Networks for Walking*, in Tolley, op. cit., p. 169.

fact that Boulder presents exceptional walking conditions.

The number of people who walk because their work requires it, e.g. farm workers, postal workers, salespeople, etc., is estimated at 1.5 to 3 million. The high estimate includes one-third of agricultural workers (3 million) and also assumes that the total number of workers walking for their job is three times that for the farm sector. Our low estimate is half of the high estimate.

As in the case of bicycling, recreation motivates the largest group of walkers. Our high estimate is based on the *1990 Statistical Abstract*, Table 392, "Participation in Sports Activities, 1988," the National Recreation Survey and findings of the *Boulder Diary, Study*. Our low estimate is based on the *NPTS*.

Children's walking is shown in the *Statistical Abstract*. We derived both our high estimate (10% of children) and our low estimate (5%) from this source.

In summary, KEA estimates that in the U.S., 1990-1991:

- Between 8.5 and 10.0 million people walked to work regularly.
- Walking was a mode choice of between 25.6 and 38.4 million people engaged in personal business.
- Between 1.5 and 3.0 million people walked for commercial purposes,
- Recreational walkers numbered between 35 and 40 million.
- Between 2.9 and 5.8 million children walked regularly.
- Walkers traveled between 20.5 and 44.1 billion miles per year in the U.S circa 1990-1991.

Displaced Auto Miles

KEA's next step was to determine the percentage of auto trips displaced per bicycling or walking trip. Bicycling and walking trips do not displace an equal number of auto trips. This is because:

- 1) some trips would not have been made *except* by foot or bicycle (for instance, some recreation trips);

2) some walked or bicycled trips would be made by other non-passenger vehicle modes such as transit or foot; and

3) the bicyclist or walker might have shared a ride with a motorist.

We estimate that bicycle trips would have been taken in lieu of between 38% and 56% of auto trips, and that car trips would have been taken in a quarter to a third of the cases where walking trips were made. (The component assumptions leading to these percentages are shown in Table 1.) Thus, we estimate that bicycles displaced between 2.2 and 12.0 billion passenger vehicle miles annually, and walkers displaced between 5.4 and 16.1 billion auto miles, circa 1990-1991.

6. Year-2000 Scenarios

Introduction

To indicate the potential for expanded environmental benefits from bicycling and walking in the United States, this section poses two scenarios under which the modal share of bicycle and foot trips in the country's modal split expands several times over, and estimates the fuel and emission savings from each.

Most analyses of the growth potential for bicycle and foot transportation focus on governmental promotion and encouragement, particularly through infra- structural development and land-use policy. As an FHWA study said a decade ago:

The infrastructure for automobile travel includes not only the street and highway system, but also safe levels of lighting, ubiquitous parking facilities, and a proliferation of signs, signals and controls aimed at ensuring a safer driving environment ... it is perhaps this type of commitment to a mode that is needed to insure its acceptability and success.¹³

A small number of American communities have reasonably comprehensive infrastructures for bicycling and walking. Many have a partial infrastructure, with some components - bicycle paths, parking facilities, etc. ---- that are linked only haphazardly or not at all. Below, we present our scenarios together with brief descriptions of such infrastructures and evidence that their provision does indeed increase bicycling and walking, particularly when it is planned and developed comprehensively.

Bicycle riding appears to have increased in the U.S. in the 1980s, spurred in part by new bicycle designs which offered consumers safer and more comfortable machines. For example, the Bicycle Institute of America's "Facts and Figures About Bikes and Bicycling" estimates that the number of "adults riding regularly" more than doubled from 1985 to 1990, from 12 million to 27.5 million. However, other sources suggest that the increase in bicycling was far smaller and may not even have kept pace with nationwide growth in vehicle

³³ Ferroll Robinson, *Feasibility of Demand Incentives for Non-motorized Travel*, Barton-Aschman Associates, for FHWA. National Technical Information Service, Washington, DC, 1981, p. 138.

miles traveled (VMT).³⁴ Nor does the national average bicycling level come close to that of municipalities, regions, or countries with elaborate infrastructure provision for bicycling.

Walking trips may well have decreased in the United States over the past 10-15 years, in response to the linked phenomena of increased vehicle ownership and the ongoing deconcentration of residences and workplaces. The level of foot trips taken will depend on land-use patterns even more than on infrastructure. In any event, both of our scenarios are explicitly based on governmental policy and action, since both infrastructure and land-use are largely determined by government.

Scenarios Summarized

Low Scenario --- Flexible Funding

Our "low" scenario is a "flexible funding" case, driven by the Clean Air Act Amendments of 1990 and particularly the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Pursuant to this legislation, many cities and states elect to apply some of the funds not assigned directly to highway or transit modes to invest in bicycling and walking infrastructure and promotion. Policy-led changes in land-use patterns are modest, however, as is active discouragement of motor vehicle use through pricing or other disincentives. **In the low case, bicycling increases by a factor of 3, and walking by a factor of 1.5.**

High Scenario --- Directed Funding

The "high" scenario is a "directed funding" case. It builds on the emission and congestion savings and other benefits to cities and states which have used a period of flexible funding to energetically promote bicycling and walking. In this scenario, broad recognition of these savings leads the Federal Government to explicitly require States and cities to increase levels of bicycling and walk-

³⁴ VMT figures reported by the Motor Vehicle Manufacturers' Association imply compound annual average growth rates for all motor vehicles of 3.0% for 1980-85 and 3.9% for 1985-90. *Facts and Figures, 1991*, MVMA, Ann Arbor, MI, p. 192. In contrast, the *National Personal Transportation Study* reports a sharp decrease in bicycle miles traveled, from 3.89 billion in 1983 to 2.32 billion in 1990. While we believe that this finding flies in the face of anecdotal evidence and other indicators, it does suggest that bicycling may not have kept pace with driving in the 1980s,

ing and to provide dedicated funding for that purpose.

This directed funding path is further influenced by continuing environmental, quality-of-life, and transportation problems such as rising congestion-VMT pressure on cities and suburbs, chronic failure of states to meet federal clean air standards, and international efforts to stabilize carbon dioxide (CO₂) emissions at 1990 levels. Land-use planning to reduce motor vehicle trips, and explicit auto disincentives such as fuel taxes and congestion pricing also become prominent. **Under such a scenario, bicycling increases from current levels by a factor of 5, and walking by a factor of 2.5.**

Under these scenarios, annual U.S. bicycling miles traveled in 2000 would be equivalent to between 0.7% and 5.3% of passenger vehicle *miles*. Bicycling now constitutes 25%, 18%, and 11% of nationwide *trips* in highly industrialized Denmark, Netherlands, and the former West Germany, respectively.³⁵ Halving these countries' trip share figures to convert to mileage shares (direct mileage data were not available) would imply that bicycles account for 5-12% of passenger miles. Thus, for the most part, the range posited for the U.S. for 2000 would still be well below the Current share for Denmark, Netherlands, and West Germany.

Similarly, increasing walking by a factor of 1.5-2.5 would give it a 1.5%-6.5% share of U.S. person miles. Although direct comparisons to other countries' modal shares were not available, this level appears achievable assuming the land-use changes, public transit improvements and automobile disincentives that would accompany federal funding of bicycling and walking, particularly in the "directed" scenario.

Potential for Increasing Bicycling and Walking Trips

Apart from infrastructure and policy considerations, "background" conditions such as bicycle ownership rates, trip distances, individual ability and climate suggest that there is ample potential for increasing U.S. bicycle and foot transportation.

³⁵ **Netherlands:** "Netherlands Adopts National Bicycle Policy," *Public Innovation Abroad*. International Center/Academy for State and Local Governments, March 1992. **Denmark and West Germany:** Fergusson and Rowell, *Bikes Not Fumes: The Emission and Health Benefits of a Modal Shift from Motor Vehicles to Cycling*. Cyclists' Touring Club, Godalming, England, 1991.

Bicycling

Between 40% and 50% of Americans are "bicyclists." According to recent Harris Polls, 82 million Americans age 18 and over bicycled in 1991, or 48% of the roughly 170 million in that age group.³⁶ The Bicycle Institute of America estimates that 96 million Americans (or 41% of a total of 232 million persons age 5+) are bicyclists, with 27.5 million riding at least once a week.³⁷

As is well known, the lion's share of U.S. personal transportation trips are by private car - at least 75%, according to the *National Personal Transportation Study*.³⁸ However, many of these trips are short-distance. A 1981 study of five representative U.S. cities and towns - which ranged over large cities and suburbs - --- found that 63% of auto trips for personal business and shopping were under 2 miles, while 84% were under 4 miles and 92% were under 6 miles. For commuting trips, 29% of journeys by car were less than 2 miles, 48% were under 4 miles and 61% were less than 6 miles.³⁹ More recent NPTS data suggest some increase in trip length,⁴⁰ but clearly a sizable percentage of VMT is in short-distance trips, particularly for personal trips.

There is no ironclad definition of maximum (or minimum) feasible bicycle trip length. *NPTS* data yield the calculation that the average bicycle trip in the U.S. in 1990 was 1.3 miles.⁴¹ Yet regular bicyclists generally ride farther. The

³⁶ *Bicycling Magazine*, "A Trend on the Move: Commuting by Bicycle --- An Overview of the Future of Cycling as Transportation," Rodale Press, Emmaus, PA, 1991.

³⁷ *Bicycling Reference Book, 1992-1993*. Bicycle Institute of America, Washington, DC, 1992, p. 39.

³⁸ FHWA, *Early Results: National Personal Transportation Study 1990*, Aug. 1991, Table 5, reports 75.1% of trips by passenger car, excluding pickup trucks but including vans.

³⁹ Robinson, *op. cit.* p. 36. The cities and towns studied were Austin, TX; Columbus, IN; Denver, CO; Huntington Beach, CA; and Philadelphia, PA.

⁴⁰ Average motor vehicle trip length in 1990 was 9 miles, according to *NPTS* --- longer for commuting, shorter for shopping. See *NPTS*, *op. cit.*, pp. 21-32. *NPTS* does not break down trip length data by percentage of trips less than certain distances.

⁴¹ According to the *NPTS*, in 1990 bicycles were the mode choice for 1.8 billion trips, or 0.7% of 253 billion total trips, and accounted for 2.3 billion miles traveled, or 0.1% of the 2.32 trillion total. Dividing bicycle miles by trips, average bicycle trip length

average bicycle trip lengths in Ottawa-Carleton, Ontario are 3.3 miles for commuting, 3.0 miles for shopping, and 4.2 miles for social trips.⁴² Goldsmith's analysis for the FHWA cites other surveys and estimates pegging mean U.S. bicycle commutes at 2.1, 4.7, and 5-6 Miles.⁴³

A survey of potential bicycle commuters in New York City found that 45% of respondents within a 5-mile radius would bicycle to work given specific infrastructure improvements (see below), while 54% of those in the 5-10 mile range would bicycle to work given the same improvements.⁴⁴ An analysis by U.S. DOT using U.S. census journey-to-work data from 1975 set the likely limit of bicycle commutes at 6 miles,⁴⁵ yet this may understate the true limit today in light of technical advances improving bicycling speeds and comfort.

In short, both data and experience strongly suggest that (i) a considerable percent of trip share and even mileage share is accounted for by short (say, 1-4 mile) journeys, and (ii) from a technical standpoint, there are few if any barriers to bicycling expanding to take on many more practical trips, especially those in the 1-4 mile range, but also some up to 6 and 10 miles long. With sufficient commitment by government, a 5-fold increase in bicycling miles does not appear beyond reach.

As one further check, a 1980 U.S. DOT study of potential bicycle commuting disqualified 40% of those living within 6 miles of work as bicycle commuters

was 1.3 miles.

⁴² *Ottawa-Carleton Cyclist Profile Survey*, Cumming Cockburn Ltd. (for Regional Municipality of Ottawa-Carleton), Ottawa, Ontario, May 1992.

⁴³ Stuart Goldsmith, *Reasons Why Bicycling and Walking Are Not Being Used More Extensively as Travel Modes*. FHWA, Washington, DC, 1992, 6-7.

⁴⁴ *Improving Manhattan Traffic and Air Quality Conditions: Effectiveness of Bicycle Programs*, New York City Dept. of Transportation, 1990. Finding reanalyzed and reported in "Commuters to DoT: We're Ready When You Are," *City Cyclist*, Jan./Feb. 1991, Transportation Alternatives, New York, NY. For further information, see letter from Transportation Alternatives to Gerard Soffian, Assistant Commissioner, NYC DOT, Nov. 29, 1990.

⁴⁵ *Bicycle Transportation for Energy Conservation*, U.S. DoT, Washington, DC, 1980.

on the basis of physical limitations,⁴⁶ and 50% of the remainder because of weather conditions, leaving 30% available to bicycle to work.⁴⁷ By comparison, our high estimate of current bicycle commuters, 2.8 million, is equivalent to only 2.3% of the labor force. A 5-fold increase in this rate to 12%, as envisioned in our high-growth scenario to 2000, would still be less than half of the potential participation envisioned in the DOT study. A comparable exercise for non-work trips would probably yield similar results.

Walking

Trip distance is an even more powerful determinant of the choice to walk. Goldsmith identified 2 miles as the upper limit for most walking trips,⁴⁸ and *NPTS* 1990 data indicate that the average U.S. walking trip is 0.6 miles in length.⁴⁹ According to the 1981 five-city study cited earlier, 29% of all journeys by car were under 2 miles, as were 63% of auto trips for personal business and shopping.⁵⁰ To the extent that the communities studied are representative of the country, and allowing for increases in trip length since 1981, a large number, if not a large percentage, of auto trips --- especially those for personal business - appear to take place within walking distance.

Goldsmith also found a mild correlation between the percentage of commuting

⁴⁶ Age may be overemphasized as an intrinsic constraint on ability to bicycle. In Nanjin, a typical large city in China, 36.5% of persons age 50-59 and 20.7% of persons age 60+ use bicycles as their primary mode of transportation (walking percentages are .42.9% and 61.3%, respectively). See Toshikazu Shimazaki and Yang Dongyuan, *Bicycle Usage in Urban China*, Preprint, Transportation Research Board, Washington DC, Jan. 1992, p. 4 and Table 2. Anecdotal evidence also suggests high levels of bicycling by older persons in Northern Europe.

⁴⁷ *Ibid.*, pp. 28-29.

⁴⁸ Goldsmith, *op. cit.* See p. 12 for survey responses from Seattle and Ontario on the length of a "walkable" trip. See also p. 55.

⁴⁹ According to the *NPTS*, in 1990 walking was the mode choice for 19.5 billion trips, or 7.7% of 253 billion total trips, and accounted for 11.6 billion miles traveled, or 0.5% of the 2.32 billion total. Dividing miles walked by trips, average walking trip length was 0.6 miles.

⁵⁰ Robinson, *op. cit.* p. 3.

populations traveling less than 2 miles and the level of foot trips to work.⁵¹ As expected, large, dense cities with public transit provision, along with university towns, experience the greater percentages of walking trips. In New York City, 8-11 % of all trips to work are primarily walking trips, and 7 % in Seattle.⁵² A 1989-90 Chicago-area study found that 36.5% of trips by residents of the Central Business District were by foot, and 10% of all Chicago residents surveyed walked to work. Still, 51% of total CBD trips were under 1 mile, and 75% were under 2 miles, suggesting that some increase in inner-city walking trips is possible so far as distance is concerned.⁵³

Perhaps surprisingly, data for the Chicago suburbs from the same period show that a large number of trips there are short as well. In Lake and McHenry Counties, 36%-40% of trips were less than 2 miles, and 18%-21% less than 1 mile. However, far fewer such trips are walked there than in the CBD --- 22% in Lake County and 14% in McHenry for trips under 1 mile,⁵⁴ implying that a great many suburban trips could be transferred to walking.

Still, surveys of impediments to walking have found trip distance cited far more than weather or physical difficulty,⁵⁵ suggesting that physical limitations and weather should not prevent walking from increasing by a factor of 2.5, as presented in our "high" scenario.

Year-2000 Scenarios for Increasing Bicycling and Walking Trips

Barriers to increased bicycle and foot transportation include lack of infrastructure facilitating travel by these modes, as well as the real or perceived danger and "crowding out" effect that heavy automobile traffic imposes on individuals attempting to bicycle or walk. Evidence presented below shows that appropriate infrastructure can significantly raise levels of bicycling and walking, especially when designed and built as a transportation *system*, as is the auto-truck-

⁵¹ Goldsmith, op. cit., pp. 55-56.

⁵² Ibid., p. 55, for New York City 8% and Seattle 7%. According to data from the 1990 Census, 10.9% of New York City commuters walk to work.

⁵³ Ibid., p. 56.

⁵⁴ Ibid.

⁵⁵ Ibid., p. 27.

highway-parking complex, rather than as a disconnected series of "facilities."

Additionally, since most trips that could be accomplished by non-motorized transport are relatively short, land-use patterns will affect the incidence of bicycling and walking. An important effect of increasing compact, mixed-use development and land use would be to make bicycle and foot trips more interesting and pleasant --- a subjective factor found to be important in many studies - and perhaps to foster a greater sense of community and public life, the absence of which may incline people to the isolation afforded by automobiles. Nonetheless, compact land use will facilitate increased bicycling and walking by reducing trip distances. Compact land use may also be necessary to raise pedestrian travel to the levels posited in our "high" case (a 2.5 factor increase over current levels).

Scenario I ----- Flexible Government Funding Available for Improving Bicycling and Walking Environments

The funding framework fashioned by the Federal Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has opened the door to rapid, government-supported proliferation of bicycle and foot transportation. The act marks a major shift in thinking at the Federal level, giving cities and States an opportunity to develop innovative, environmentally sustainable strategies which can select and match transport modes to appropriate travel needs. Of \$155 billion in Federal funds to be spent for transportation projects over the six-year period 1992-1997, at least \$31.5 billion, and potentially as much as \$80 billion, will be spent on transit and other non-highway programs, including bicycle and pedestrian projects. Specific allocations will be made by each state, subject to Federal guidelines that largely favor bridge and roadway maintenance over new construction and that put non-highway projects on a more equal footing with highways.

For most of the decade and perhaps longer, this "flexible" funding approach permanently replaces the older Federal approach which more specifically designated funding allotments for highways and public transit - and which largely ignored bicycle and pedestrian transport. Assuming that funds are spent effectively and that bicycling and walking demand are at least somewhat supplydriven, it seems reasonable that bicycling and walking trips will undergo significant increases in those cities and States that take advantage of ISTEA's bicycling and walking provisions.

Bicycling

Most of the major sections of the ISTEA legislation explicitly urge States and localities to fund bicycling projects and programs. Moreover, each State is directed to appoint a bicycle program coordinator and develop a long-range plan for bicycle transportation within the state. Metropolitan Planning Organizations are charged with developing biennial transportation improvement plans, which also must include a bicycling component.

Within such a "flexible" funding and planning context, cities and States that have already adopted some measure of bicycle planning are well positioned to further boost bicycle transport. Several dozen American jurisdictions have acted to institutionalize bicycle planning and infrastructure systems to varying degrees. Important steps already taken include establishing and expanding professional bicycle planning and promotion staff, and adopting master plans and high-visibility programs to elevate bicycling's status. Outstanding examples include Davis, Palo Alto, and Pasadena, CA; Boulder, CO; Madison, WI; Seattle, WA; Chicago, IL; as well as the State of New Jersey. Levels of bicycle program staff, bikeways, and bicycle parking facilities in these cities are far higher than the U.S. average.⁵⁶

Already, availability of ISTEA funding for bicycling appears to be leading other cities to boost their planning for bicycle transportation. Portland (OR) recently announced a modal-split goal for bicycling to reach 5% of commuter trips by the year 2000.⁵⁷ Portland's Alternative Transportation Program has already produced an area bicycle map, installed bicycle parking lockers, enacted a bicycle parking ordinance, and begun implementing a network of bicycle routes and lines.

Chicago's new modal split goal may be even more ambitious than Portland's

⁵⁶ Davis:Goldsmith, *op. cit.*, p. 47. Palo Alto: "Where Bicycle Is King," *The New York Times*, June 22, 1990. **Pasadena:** *The Plan to Make Pasadena Bicycle-Friendly*, Mayor's Bicycle Task Force, City of Pasadena, 1991. **Boulder:** *Go Boulder #12*, Jan./Feb. 1992, City of Boulder, Alternative Transportation Center. **Madison:** *Pro-Bike News*, Bicycle Federation of America, Vol. 12, No. 2, Feb. 1992. **Seattle:** "The 10 Best Cities for Cycling," *Bicycling*, April 1990. **Chicago:** See footnote 57. **New Jersey:** *City Cyclist*, Sept./Oct. 1992, p.2, Transportation Alternatives, New York, NY.

⁵⁷ *Pro-Bike News*, Vol. II, No. 7, July 1991, Bicycle Federation of America.

--- to convert 10% of car trips under 5 miles to bicycle trips by 2000.⁵⁸ The city's new *Bicycle 2000* plan seeks to build a 300-mile bicycle route network, adopt a bicycle parking ordinance and provide city-owned bicycle parking, develop commercial, governmental, and police use of bicycles, and expand bicyclist and driver education on bicycle transportation and safety.

A few State transportation agencies have also developed effective bicycling programs that can only grow and thrive in the flexible funding environment. Oregon is a leader with several full-time staff and a section of the state's unified transportation plan devoted to bicycling. The plan considers means to accommodate bicycles on transit vehicles, specifies weatherproof bicycle parking hardware for commuter destinations, and identifies streets for bicycle lane installation and rural roads for shoulder widening.⁵⁹

Experience demonstrates that funded, staffed bicycle programs able to provide bicycle transport infrastructure will boost levels of bicycling. This experience is supported by a host of studies and surveys that have found suppressed demand for bicycling in areas which lack such infrastructure.

The physical elements of bicycle transportation systems consist primarily of bicycle routes and bicycle parking facilities. These may take on a variety of forms, depending on local conditions and strategies. Bicycle parking in the suburbs or for urban shoppers may consist of outdoor racks for employees or customers; bicycle parking for commuters in high-theft urban areas may need to be inside buildings. A safe bicycle route between rural towns may be a wide shoulder on a State road, while in a dense inner city, it may be a curb lane painted a different color and grade-separated to distinguish it from both sidewalk and motor vehicle roadway. Other considerations include quality of road surfaces, workplace changing facilities, official promotion of bicycling as a desirable method of transportation, bicyclist and car driver safety education, bicycle links to mass transit service, and bicycle access to parks and other recreational areas.

Cities renowned for bicycling in both Europe and North America all have extensive networks of on-street bicycle lanes and supporting facilities like bicycle parking. Bicycle commuting and other utilitarian bicycling in Copenha-

⁵⁸ *Bicycle 2000*, City of Chicago, Mayor's Bicycle Advisory Council, 1992.

⁵⁹ *Pro-Bike News*, Vol. 12, No. 2, Feb. 1992, Bicycle Federation of America.

gen grew from 17% to 25% of all journeys in the five years following replacement of many inner-city parking lanes with curbside bicycle lanes.⁶⁰ Delft and Groningen in the Netherlands are famous for their extensive bikeway systems, complete with overpasses, tunnels, off-ramps, bicycle traffic signals, and parking installations. At least 40% of trips in Delft are made by bicycle; 50% of intra-city journeys in Groningen are bicycle trips, as are 20% of commutes from outside the City.⁶¹ A steady increase in the transport budget devoted to bicycle systems in Erlangen, Germany, helped effect an increase in bicycle trips from 14% to 30% over a 12-year period. Ambitious policies in the large Austrian city of Graz produced a doubling of bicycle trips from 6% to 12% in just three years.⁶²

Similarly, where parts of the environment have been planned to accommodate bicycling in the United States, use of bicycles increases. Davis (CA) has long provided facilities and programs for bicyclists, including an extensive bicycle lane system. Although the high bicycling level --- 25% of Davis commuting is by bicycle --- is sometimes attributed to the large university population, half of Davis bicyclists are non-Student working citizen.⁶³ Eugene (OR) and Palo Alto (CA), other university towns, have both seen significant increases in bicycling following active official encouragement and facility construction. 1980 Census figures for Eugene and Palo Alto showed over 8% and 10% of trips, respectively, made by bicycle.⁶⁴

The level of utilitarian bicycling correlates with existence of bikeways in non-university towns as well. Goldsmith compared major cities with differing ratios of bicycle lane miles per arterial roadway miles, and found that percent-

⁶⁰ *Copenhagen and Cyclists*, Copenhagen City Engineers Department, Copenhagen, 1989, p. 2. Cited in Rowell and Fergusson, *op. cit.*, p. 10.

⁶¹ **Delft**: "The Delft Cycle Plan," Dirk ten Grotenhuis, Delft Planning Office. *Proceedings*, Velo City '87 (Groningen), Netherlands Centre for Research and Contract Standardization in Civil and Traffic Engineering, p. 231. Groningen: "Cycling Policy in the City of Groningen," W. Huyink, Traffic Dept. of Groningen. *Proceedings*, Velo City '87, p. 220.

⁶² *Alternative Transportation Network*, Sept. 1990, Vol. 1, #2, Littleton, CO.

⁶³ Goldsmith, *op. cit.*, p. 47.

⁶⁴ *Urban and Suburban Transportation*, Campaign for New Transportation Priorities, Washington, DC, no date, probably 1992, p. 12.

ages of bicycle commuters were 3 times as great in cities with substantial bicycle lanes.⁶⁵ Indeed, nowhere in industrialized countries does one find significant levels of bicycling without dedicated facilities, although Goldsmith allows that the relationship between bicycling and bicycle lanes is both cause and effect.

Dedicated street space for bicycles - bicycle lanes - plays a big role in the infrastructure schemes described above. Indeed, according to Goldsmith, most surveys of bicyclists cite concerns over traffic safety as the single greatest deterrent to bicycling for everyday transportation.⁶⁶ These concerns may be well founded, at least according to a Canadian paper which reported a 50% increase in bicycle-motor vehicle accidents in Winnipeg from 1976 to 1989; the same paper observed a high degree of sidewalk bicycling, attributed to bicyclists' perceived dangers from roadway motor vehicle traffic.⁶⁷

Nonetheless, lack of dedicated street space is not the only impediment to increased bicycling. Bicycle theft, for example, runs into the tens of thousands annually in New York City,⁶⁸ and other East and West Coast cities report similar, if somewhat less extreme, problems.⁶⁹ While provision of bicycle lanes in such cities would certainly increase ridership, a coordinated policy providing both street space and secure parking would almost certainly produce bigger increases. Goldsmith also notes that use of bike-and-ride bicycle parking facilities depends greatly on adequate bicycling feeder routes.⁷⁰

Indeed, surveys of would-be bicycle commuters indicate that multiple, linked

⁶⁵ Goldsmith, op. cit., p. 40 and p. 57.

⁶⁶ Ibid., p. 7.

⁶⁷ Robert Thom and Alan Clayton, "Low-Cost Opportunities for Making Cities Bicycle Friendly Based on a Case Study Analysis of Cyclist Behavior and Accidents." *Transportation Research Board Preprint*, Washington, DC, January 1992.

⁶⁸ *Bicycle Blueprint: Making Bicycling a Mainstream Transportation Option in New York City* (forthcoming), Chapter 3. Transportation Alternatives.

⁶⁹ This suggests that Goldsmith, op. cit., may have underestimated bicycle theft and inadequate bicycle parking as a deterrent to bicycle commuting and other utilitarian bicycling in U.S. cities.

⁷⁰ Goldsmith, op. cit., p. 51.

improvements to the bicycling environment will need to be made in order to coax more bicyclists into everyday bicycle use. Respondents to *Bicycling Magazine's* Harris Poll ranked bicycle parking and workplace changing facilities close to safe bicycle lanes in importance as an incentive to taking up bicycle commuting.⁷¹ A New York City survey found that an overwhelming majority of would-be bicycle commuters would only consider riding a bicycle to work if these improvements were offered as a package.⁷² At the same time, these and other surveys do indicate that such a combination of improvements would indeed result in substantial increases in transportation bicycling.

Walking

As was just discussed for bicycling, improving infrastructure can increase the incidence of walking. However, the cost and ease of driving and spatial deconcentration (sprawl) determine the extent of pedestrian transportation to a greater degree than the presence of walking infrastructure.

The most significant aspect of the pedestrian environment is the sidewalk ---- considerations include not only sidewalk width but pavement quality, snow removal frequency, curb cuts, and even freedom from bicyclists and skaters. These issues are particularly important to the elderly, pregnant women, and people with children and/or packages.

Other hardware and software issues important to walking are:

- pedestrian-controlled traffic signals
- traffic-signal timing
- street lighting
- "street furniture" such as benches to make a street or district more hospitable
- foot access over major obstacles such as rivers and limited-access highways
- waterfront redevelopment
- pedestrian-only streets and
- "greenways" ---- car-free urban and suburban linear parks-trails linking key residential, recreational, and commercial destinations.

⁷¹ *Bicycling Magazine*, 1991 Harris Poll Press Release, May 18, 1992.

⁷² NYC Dept. of Transportation, op. cit.

Thus, devoting increased resources to pedestrian improvements will affect some increase in walking, even when situated within the traditional configuration of relatively narrow footways along the margins of motor vehicle routes, e.g., in sidewalk-free suburbs. Walking will also increase, in crowded cities from expanding sidewalks that cannot accommodate peak pedestrian flows.⁷³ Such improvements can be made under many of the same sections and provisions in the ISTEA legislation that allow for bicycle facilities.

ISTEA also contains language encouraging compact, pedestrian-friendly land use and development. Similarly, meeting the new Clean Air Act timetables for reducing air pollution, particularly regional ozone, will almost certainly require reversing long-term trends of urban and suburban sprawl. This is vitally important to prospects for pedestrian transportation, since big increases in walking trips will come only from more far-reaching policies ---- reducing motor traffic, increasing street space dedicated to or prioritized for pedestrians, zoning changes favoring more compact land use, and increased provision of public transit.

Indeed, many respondents to Robinson's 1981 survey for FHWA were unreceptive to scenarios positing "traditional" pedestrian improvements such as pathways, better sidewalks, lighting, and traffic signals - many of the elements listed above.⁷⁴ Conversely, there is much evidence of increased pedestrian travel from policies initiating traffic-calming measures, providing public transit or implementing land-use strategies favoring dense, mixed-use development.

Much of this evidence also singled out the unpleasant and unattractive environment caused by the presence of heavy motor traffic as a deterrent to increased walking, and the removal of this deterrent through planning as a major boon to pedestrian travel. Though it is not known just how much the domination of the streetscape by cars actually inhibits walking, surveys of pedestrians have identified it as a negative factor within the pedestrian environment.⁷⁵ Several Ger-

⁷³ For example, case studies of typical midtown Manhattan blocks showed that 78% of travelers were on foot and were confined to such small spaces that walking in the roadway adjacent to traffic was commonplace. See Regional Plan Association, *The Region's Agenda*, "Manhattan Walkers Need More Space," Vol. 19, No. 6, 1990.

⁷⁴ Robinson, *op. cit.*, pp. 60-61, p. 81.

⁷⁵ Goldsmith, *op. cit.*, p. 28. Also "No Sales Job Needed Here: Ontarians Want to Walk But Are Prevented by Anti-Pedestrian Policies," Wendy Hawthorne, Proceedings, 11th International Pedestrian Conference, *op. cit.*, p. 228. and Clarke and Hoinville, "Traffic

man studies have found pedestrians willing to walk up to four times as far on pedestrianized streets as along sidewalks of streets dominated by motor traffic.⁷⁶ Other studies show up to 114% increases in non-motorized use of traffic-calmed streets, as well as positive behavioral shifts toward pedestrians by motorists in such areas.⁷⁷

Clearly, pedestrian streets and traffic-calmed areas are more easily supported by higher-density, mixed-use areas, as are greater numbers of walking trips in more traditional urban street-sidewalk layouts. Higher densities also support public transit, which has an important symbiotic relationship with walking. "Nodal development strategies" "transit-oriented developments (TOD's)," and "urban villages," which mix a range of services within walking distances of residences and in close proximity to existing or new transit services, are spreading as planning techniques for increasing settlement and commercial development densities.

Density- and transit-encouraging development policies that have been in use in cities and provinces across Europe for decades are beginning to spread to North America. In the U.S., such developments may require changes in exclusionary zoning codes, lifting floor-to-area-ratio (FAR) restrictions to allow buildings with more floors, and limiting frontage of commercial spaces to discourage on-street parking. Vancouver (BC), Portland (OR), and San Francisco have well-known "urban village"-type developments,⁷⁸ and other regions are critically examining sprawl development problems from city- and even state-wide perspectives. Sacramento (CA) is attempting to forge consensus around a plan for city-wide mixed-use consolidation based around its new light rail system, which would alter existing subdivision practices and ensure higher levels of

Disturbance and Amenity Values," *Social Community and Planning Research (U.K.)*, 1978, cited in "The Role of Walking and Cycling in Public Policy," Mayer Hillman. *Consumer Policy Review (U.K.)*, April 1992.

⁷⁶ "Taming the Traveling Flea Circus of Mobility," Gerhard Meighorner and Ron Wiedenhoft. Proceedings, 11th International Pedestrian Conference (1990), Boulder, CO, 1991, p. 325.

⁷⁷ Jeffrey Kenworthy and Peter Newman, *Towards a More Sustainable Canberra: An Assessment of Canberra's Transport, Energy and Land Use*. Institute for Science and Technology Policy, Murdoch University, Perth, 1991, pp. 108-109.

⁷⁸ Newman and Kenworthy, op. cit., pp. 133-135.

walking by infilling a variety of housing types and services.⁷⁹ New Jersey recently enacted a land-use plan to restrict development in rural areas and encourage it around existing commuter rail facilities.⁸⁰

Density correlates closely with foot transportation. Based on their studies of 32 cities around the world, Newman and Kenworthy state firmly that density is the key determinant of automobile dependence:

Density largely determines the degree to which a city is dependent on the automobile and how much petrol it uses. Density and particularly the siting of high density areas, can make or break public transport systems ... Density also largely dictates whether it is possible to walk or ride a bicycle for a significant number of trips. As metropolitan areas and regions with cities, approach about 30 persons per hectare [7,000 to 8,000 persons per square mile], multiplicative changes occur towards more mixed land uses and shorter travel distances which significantly reduce dependence on the automobile.⁸¹

In the U.S., both compiled data and opinion surveys have found correlations between urban density and the level of walking.⁸² Robinson's 1981 survey for FHWA found that the "compact land-use" scenario elicited the biggest increase in respondents' willingness to walk under the posed condition, and the steepest decline in claimed levels of car use.⁸³ Lower-density areas clearly have longer average trips, though as we have seen above, many short trips continue to take place in the suburbs.

In addition to lack of sidewalks and other facilities, the low level of interpersonal contact and lack of community experienced in sprawled settlements may also suppress walking. A feedback effect from this absence may be less desire or demand for public interaction, hence less inclination to the public

⁷⁹ Ibid., p. 129.

⁸⁰ *Auto-Free Press*, July-Aug 1992. Transportation Alternatives, New York, NY.

⁸¹ Newman and Kenworthy, op. cit., p. 120. Also Newman and Kenworthy, *Cities and Automobile Dependence: An International Sourcebook*, Gower Technical, Brookfield, VT, 1989. Chapter 3, "Main Findings."

⁸² Goldsmith, op. cit., p. 58.

⁸³ Robinson, op. cit., pp. 51, 55.

experience of walking and greater inclination to the isolation afforded by motor vehicles. Very low levels of walking are ultimately incorporated into the built environment in the form of commercial strip development and sidewalk-free residence-only areas.⁸⁴

The relationship between public transit and the level of walking is unclear from existing data sources, in part because of lack of clarity about what constitutes a walking trip. Focus on "walking-only" trips probably obscures the significance of the pedestrian-Public transit relationship in high-density areas. Yet this relationship is strong and multifaceted, including the need for a viable pedestrian infrastructure to properly serve transit facilities,⁸⁵ as well as transit's ability to relieve the necessity of car ownership and to support dense development. That is, transit not only generates walking trips to and from stations; by facilitating non-auto-dependent urban densities and lifestyles, it also provides general support for a pedestrian environment.

Thus, improving the pedestrian environment in large U.S. cities already beleaguered by auto-gridlocked streets will depend heavily on stabilizing funding sources for mass transit systems. At the same time, many smaller U.S. cities, including San Diego, Buffalo, Portland (OR), Pittsburgh, Sacramento, St. Louis, and Baltimore, have expanded their transit systems by installing new light rail transit (LRT). This is important not just from a transportation standpoint, but from a land-use development one as well, as there is general agreement that LRT is more effective than bus systems at inducing dense, mixed development.

Limitations of the Flexible Scenario

The obvious reason for assigning the "low" case to the flexible funding scenario is that not all localities and states will respond to the potential for developing bicycling and pedestrian systems. In many areas, social and bureaucratic inertia may stay the course toward sprawl development and increased VMT,

⁸⁴ See "Designing Pedestrian-Friendly Commercial Streets," Richard Untermann. Proceedings, 11th International Pedestrian Conference, op. cit., p. 19.

⁸⁵ "Transit Agency as Pedestrian Advocate," Joel Woodhull. *Proceedings*, 12th International Pedestrian Conference, Boulder, CO, 1992, pp. 41-50.

⁸⁶ Newman and Kenworthy, *Toward a More Sustainable Canberra*, op. cit., pp. 81-90. Also *Auto-Free Press*, May-June 1992.

with consequent withering or crowding out of bicycling and walking.

Even where bicycling, walking, dense development, and transit are funded and encouraged, political pressure will be intense to maintain highway funding and drive-up automobile access to most destinations. In places, this pressure could compromise development of optimum bicycling and walking infrastructure systems. The European examples of high bicycling and walking levels cited above have emerged from a context of significant government-supported auto-restraint policies. Under the flexible scenario, however, transportation agencies in the U.S. may continue accommodating automobiles - stopping short of far-reaching pedestrianization and traffic calming - even as they begin to create more bicycling and walking facilities.

Nevertheless, we believe that the new transport funding framework, together with rapidly proliferating local government- and citizen-led initiatives for bicycle and pedestrian improvements and apparent citizen interest in greater transportation choice, should be capable of producing a tripling in bicycling and a 1.5 factor increase in walking. Cities that have positioned themselves to expand already considerable investment in bicycling may register even more impressive increases. Moreover, increased transit spending should mesh with rising local and state efforts to come to grips with -sprawl and congestion, aiding both bicycling and walking.

Scenario 2 - Directed Government Funding for Improving Bicycling and Walking Environments

The "high" case (a 5-fold increase from present levels of bicycling and a 2.5 factor increase for walking) posits a more explicit national commitment to non-motorized transportation than under the flexible scenario. Federal transportation funding would allocate specific monies for bicycling and pedestrian programs and infrastructure with the intent of boosting these modes nationwide to meet ambitious goals for modal share. Such an approach to transportation funding would be akin to that by the Dutch federal government, which has appropriated high levels of funding for bicycle facilities since the mid-1970s, and has adopted national policies renewing and deepening its commitment to bicycling, walking, and urban traffic restraint on several occasions since.

The other side of governmental commitment of this order would be an effort to stabilize national VMT to address the profound economic and environmental dislocations caused by traffic congestion. Such efforts would dovetail with

bicycling and walking strategies insofar as they involved increasing motorist user fees (in the form of congestion pricing and gas and weight-distance taxes), increased reliance on public transit, and encouragement of trip-reducing land use.⁸⁷ To the extent that dependence of pedestrian improvements on such measures is recognized, a strategy to increase walking, or perhaps the "walkability" of American communities, would be linked to transit and land-use policies. Such measures would of course also benefit bicycling.

Dedicated funding for non-motorized transportation in the U.S. would hardly be a novel idea. Since the early 1970s, Oregon has set aside 1% of its state transportation budget for bicycle programs and facility development.⁸⁸ A similar bill is now before the Massachusetts State legislature, while a gas tax proposal before the California legislature would yield \$20 million annually for bicycle and pedestrian projects. The "3% Solution" bill introduced in Congress in 1991 by Rep. Joseph Kennedy would have earmarked 3% of Federal transportation funds for foot and bicycle modes.

As noted earlier, the Netherlands achieved a 25% national modal split for bicycling through a nearly 20-year period of federal funding for bicycling infrastructure. Though bicycle use had traditionally been high in the Netherlands, bicycling diminished in the 1960s as car use proliferated. In 1975, after the first "oil shock," the Dutch Ministry of Transport and Public Works introduced the Bicycle Tracks Grant Act to ensure bicycling's viability by funding construction of rural and urban bicycle facilities on existing roads and streets; (*new roads and developments included bicycle facilities as part of the capital budget*).

The Bicycle Tracks Grant Act also heightened the awareness of local and provincial governments, acting as "turnkey" legislation spurring local authorities to

⁸⁷ The national economic and environmental costs of motor vehicle use are examined in James J. MacKenzie, et al., *The Going Rate: What It Really Costs to Drive*, World Resources Institute, June 1992, and B. Ketcham and C. Komanoff, *Win-Win Transportation: A No-Losers Approach to Financing Transport in New York City and the Region*, Transportation Alternatives, 1993 (forthcoming). The latter report also presents a strategy for internalizing the fiscal and societal costs of cars and trucks through user fees, and applying the revenues to finance non-vehicular transport.

⁸⁸ *State of Oregon Bicycle Master Plan*. Oregon Department of Transportation. Salem, OR, 1988, p. 7.

begin planning for bicycling at the local level.⁸⁹ Successor legislation maintained federal assistance to bicycling after expiration of the Act in 1985, and the commitment was renewed again recently with the adoption of specific transport modal split goals for bicycling and public transit. National policy in the Netherlands now aims to boost bicycling's share by another 30% over current levels by 2010, and public transit trips by 15%. 10% of capital outlays for roads in the Netherlands are now bicycle-related.⁹⁰

Similarly, a 3% or greater budgetary commitment by the U.S. Federal Government would spur local development of bicycling and walking facilities in previously neglected areas. ISTEA's provision for a bicycle-pedestrian coordinator and long-range bicycle plan at the State level is a start, but committed funding remains vital. Without it, even ISTEA may still relegate walking and bicycling to peripheral options with only vague requirements for planning treatment by states and MPO'S.

With firm Federal support, however, improvements could be carried out along the lines described in the previous section, though perhaps with more focus on driving disincentives and transit improvements linked to high-density, pedestrian-oriented development. Such policies would not only enjoy a concrete mandate; they would also operate in the heightened social context of having been elevated to national goals. As such, they would likely be embraced, rather than tolerated, by local and state public officials and planners.

⁹⁰ "The Effects of State-Subsidizing of Bicycle Facilities," A. Wilmink. *Proceedings, Velo City '87*, op. cit., pp. 209-212.

⁹¹ *Public Innovation Abroad*, op. cit.

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