Environmental Benefits of Bicycling and Walking in the United States

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Bicycling and walking are underappreciated modes of mobility in the United States. In an attempt to reassert the benefits of these human-powered transportation modes, the fuel and emissions savings resulting from current levels of bicycling and walking have been estimated. On the basis of high estimates of miles traveled by bicycling and walking, these combined modes displace between 1.2 and 5.0 percent of passenger vehicle emissions of carbon monoxide, nitrogen oxides, and volatile organic compounds. Additionally, bicycling and walking displace as much as 1.6 percent of carbon dioxide emissions from passenger vehicles. The environmental benefits that can be realized from increased bicycling and walking in 2000 are also projected. If federal and state governments go a step beyond the flexible funding provisions of the Intermodal Surface Transportation Efficiency Act of 1991 to direct state and federal funding toward investments in bicycling and walking infrastructure, higher levels of bicycling and walking and thus greater environmental benefits will result by 2000. Bicycling and walking could displace 4 to 15 percent of projected passenger vehicle emissions of carbon monoxide, nitrogen oxides, and volatile organic compounds and 5 percent of passenger vehicle carbon dioxide.

Human-powered modes of transportation—chiefly walking and bicycling—are chronically underreported and understudied 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 transportation 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. These attempts (such as the National Personal Transportation Study conducted every 7 years by FHWA) have sometimes been ingenious and even valuable, but none has been comprehensive. Most measurements of U.S. bicycling and walking have been performed only on a local level, and many have been conducted by grass roots groups, without 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 does not use purchased fuels; therefore, it does not 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. By training, mandate, and institutional tradition, most transportation 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 transportation 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-scale hydropower. Even today, there is no systematic accounting of energy contributed by sunlight. As 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. (*1*)

Baer also described the "humiliation" that solar energy advocates experience at being excluded from the "energy pies" that assign 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" (*1*).

To work against the dominant paradigm that ignores the contributions of bicycling and walking to mobility, the authors have quantified the major environmental benefits of these transportation modes.

PUTTING BICYCLING AND WALKING INTO THE PIE: ESTIMATING THE ENVIRONMENTAL BENEFITS OF BICYCLING AND WALKING

Bicycling and walking are the two major forms of transportation that neither use fuel nor pollute in the United States. Millions of Americans ride bicycles 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

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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 thrift and individual health to community building and personal empowerment. The environmental benefits are numerous as well, particularly in relation to the prevailing major mode of transportation in the United States—the private car. Bicycling and walking conserve roadway and residential space; avert the need to build, service, and dispose of automobiles; 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 that fuels a 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), bike riding and walking are free of 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 the 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 generally are avoiding driving short distances on a cold, extra-polluting engine.

Accordingly, the key findings of the environmental effects of bicycling and walking concern the amount of fuel consumption and automotive pollution that they avoid by displacing the use of passenger vehicles. Other benefits of bicycling and walking are discussed briefly after this section.

Quantifying the fuel use and pollution avoided by bicycling and walking involved estimating

1. Miles bicycled and walked in the United States,
2. The trade-off of vehicle miles traveled (VMT) for bicycling and walking,
3. Per-mile emissions and fuel consumption of these miles that were not driven for four air pollutants.

Miles Bicycled and Walked

To estimate the miles bicycled and walked in the United States, the authors drew on a range of transportation studies from FHWA's National Personal Transportation Study of 1990 to studies of the modal split in Boulder, Colorado, carried out by a local transportation planning agency. Then the authors developed high and low estimates of annual bicycling and walking for different motivations (e.g., commercial bicycling, recreational walking). Combining bicycling and walking, it is estimated that human-powered miles traveled in the United States ranged between 26.3 and 65.4 billion mi during 1990–1991.

VMT Trade-Off

Estimating the VMT trade-off for bicycling and walking means finding the extent to which miles biked and walked substitute for miles that would have been driven in motor vehicles: the authors account for the fact that not every walking or bicycling trip displaces a motor vehicle trip. Indeed, it is estimated that only about a third (26 to 37 percent) of walking miles displace an automobile mile and that probably a little less than half (38 to 56 percent) of bicycling miles displace automobile miles. The rest of walking or bicycling trips would have been accomplished through carpooling or transit, or would not have occurred at all. Accordingly, passenger vehicle miles displaced by bicycling and walking are considerably fewer than actual miles bicycled and walked.

U.S. passenger vehicles traveled an estimated 2.061 trillion mi in 1991 (2). Thus, combined bicycling and walking miles are between 1.3 and 3.2 percent of VMT.

Avoided Per-Mile Emissions and Fuel Consumption

The per-mile emissions and fuel consumption avoided by not driving were estimated for four air pollutants: carbon dioxide (CO_2), 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 (NOx), and volatile organic compounds (VOCs, or hydrocarbons). (Passenger vehicle emissions of the remaining two criteria pollutants, particulate matter and lead, are extremely small relative to CO, NOx, and VOCs. Diesel-engine cars do emit particulates, but diesels account for only about 1 percent of the U.S. passenger vehicle fleet.) For this step, the authors 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. Short vehicle trips are more emission-intensive than longer trips because vehicles emit CO and VOCs at higher rates at the beginning of a trip, when the engine is cold. Additionally, at the end of a trip, engines continue to emit VOCs (via evaporation) after the engine has been turned off, a phenomenon known as hot soak. These two factors lead to higher emissions per mile on short automobile trips than long ones.

Working with low and high estimates—lower and upper bounds of miles bicycled and walked and vehicle miles avoided—the authors developed a low-high range for petroleum and emissions avoided. These estimates are based on current (1990–1991) data for bicycling, walking, and emissions. The results appear in Table 1. Under the high estimate, bicycling and walking annually displace between 1.2 and 5.0 percent of passenger vehicle emissions of CO, NOx, VOCs, and CO_2.

To place this result in context, passenger vehicles account for 20 percent of U.S. energy consumption (this estimate excludes the energy required to manufacture, store, and service the vehicles or the fuel itself) and are responsible for 20 percent of total U.S. CO_2 emissions, 45 percent of CO emissions, 16 percent of NOx emissions, and 25 percent of VOC emissions.

SCENARIO OF EXPANDED BICYCLING AND WALKING FOR 2000

Bicycling and walking are far less common per capita in the United States than in most other industrial countries, the

TABLE 1 Environmental Benefits of Bicycling and Walking, 1990–1991

	Bicycling		Walking		Bicycling & Walking	
	High	Low	High	Low	High	Low
Bicycling/Walking Miles Traveled (millions)	21,300	5,800	44,100	20,500	65,400	26,300
Passenger Vehicle:						
Miles Displaced (millions)	12,000	2,200	16,100	5,400	28,100	7,600
% Miles Displaced	0.6%	0.1%	0.8%	0.3%	1.4%	0.4%
Petroleum Displaced (millions of gallons)	680	120	910	300	1,590	420
% Petroleum Displaced	0.6%	0.1%	0.8%	0.3%	1.5%	0.4%
Emissions Displaced (metric tons)						
CO_2	6,620,000	1,210,000	8,880,000	2,980,000	15,500,000	4,200,000
CO_2 %	0.7%	0.1%	0.9%	0.3%	1.6%	0.4%
CO	579,000	106,000	777,000	260,000	1,355,000	370,000
CO %	2.1%	0.4%	2.9%	1.0%	5.0%	1.4%
NOx	16,000	2,900	21,500	7,200	37,500	10,100
NOx %	0.5%	0.1%	0.7%	0.2%	1.2%	0.3%
VOC	43,100	7,900	77,600	26,000	120,700	33,900
VOC %	0.9%	0.2%	1.7%	0.6%	2.6%	0.7%

result of a self-reinforcing set of circumstances and policies that includes externalization of many motor vehicle societal costs, social and political biases against public institutions such as transit, and dispersed settlement patterns. Although 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., the advent of more user-friendly bicycles such as mountain bikes) have kindled interest in expanding opportunities for bicycling and walking.

Accordingly, the authors postulated two scenarios in which U.S. bicycle and walking miles would undergo significant increases between now and 2000. The "low" scenario assumes that many cities and states will use the flexible funding provisions of 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) will 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 automobile 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. Estimates of the reduced passenger vehicle VMT, fuel consumption, and emissions resulting from these year 2000 scenarios are given in Table 2.

The authors assume that U.S. VMT for motor vehicles could reasonably be expected to increase from 1991 levels by 1.5 percent per year to 2000, to approximately 2.357 trillion mi/year. [Although passenger vehicle VMT would almost certainly differ between the "flexible funding" (low) and "directed funding" (high) scenarios, to simplify the analysis the authors have assumed the same growth in VMT to the year 2000 for both scenarios.] Combined bicycling and walking miles would then range between 2.0 and 9.2 percent of motor vehicle VMT.

Between 1990–1991 and 2000, passenger vehicle per-mile emissions are projected to decrease significantly as new cars with increasingly improved pollution controls replace older vehicles and new, cleaner fuels come into use. The authors project an approximate halving of per-mile emissions of CO, NOx, and VOCs on the basis of projections from the Environmental Protection Agency. Fuel requirements—hence, CO_2

TABLE 2 Environmental Benefits of Bicycling and Walking, 2000

	Bicycling		Walking		Bicycling & Walking	
	High	Low	High	Low	High	Low
Bicycling/Walking Miles Traveled (millions)	106,500	14,500	132,300	30,750	238,800	45,250
Passenger Vehicle:						
Miles Displaced (millions)	60,000	6,600	40,300	8,100	100,300	14,700
% Miles Displaced	2.5%	0.3%	1.7%	0.3%	4.3%	0.6%
Petroleum Displaced (millions of gallons)	3,050	340	2,050	410	5,100	750
% Petroleum Displaced	2.7%	0.3%	1.8%	0.4%	4.5%	0.7%
Emissions Displaced (metric tons)						
CO_2	29,800,000	3,300,000	20,000,000	4,000,000	49,800,000	7,300,000
CO_2 %	2.9%	0.3%	1.9%	0.4%	4.8%	0.7%
CO	1,260,000	140,000	850,000	170,000	2,110,000	310,000
CO %	9.0%	1.0%	6.1%	1.2%	15.1%	2.2%
NOx	35,500	3,900	23,800	4,800	59,300	8,700
NOx %	2.2%	0.2%	1.5%	0.3%	3.6%	0.5%
VOC	133,200	14,600	120,900	24,300	254,100	38,900
VOC %	3.9%	0.4%	3.6%	0.7%	7.5%	1.1%

emissions per mile traveled—have also been assumed to decline by 10 percent.

Although overall vehicle emissions will be lower in 2000, the authors 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 automobile trips.

The environmental benefits of bicycling and walking estimated in the 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 15 percent of projected passenger vehicle emissions of CO, NOx, and VOCs and 5 percent of passenger vehicle CO_2.

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

Other Environmental Benefits of Bicycling and Walking

The focus, thus far, is almost exclusively on the fuel savings and emission reductions arising from the displacement of motor vehicle use by bicycling and walking. 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.

Road Space and 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. (Although 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. Annual U.S. motor vehicle congestion costs have been estimated at $100 billion or more (*3*,*4*), suggesting that national VMT and associated congestion displaced by bicycling and walking constitute a significant environmental and economic benefit.

Land Use

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]" (*5*). Or, as 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" (*6*). Moreover, as motor vehicles have expanded into a cultural norm, cities have been either badly compromised through automobile-centered remodeling that undermines urban density or 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, nonurban settlement.

Bicycling 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. On the basis of 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. Such a comparison might suggest that the substitution of bicycling and walking for motor vehicle use would increase road accidents, but this conclusion is probably fallacious, for several reasons.

First, most bicyclist deaths and almost all pedestrian deaths occur in collisions with motor vehicles; thus, increases in bicycling and walking and decreases in vehicle use tend to improve safety of "prior" bicyclists and walkers. Second, as mentioned, 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 a mile driven—in effect, reducing accident rates per trip or per person, if not per mile. Third, improved bicycling and walking conditions facilitate safety as well as greater mobility for bicyclists and pedestrians by ameliorating traffic signaling and road condition problems that currently cause accidents involving bicyclists only or 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, after 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/year (1990 dollars) (7). A careful, whole-systems analysis of the effect of bicycling and walking on road accidents would contribute profoundly to the 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 passenger vehicles. Ketcham and Komanoff estimate annual U.S. health and productivity costs from motor vehicle noise at approximately $22 billion (1990 dollars), on the basis of a 1981 study for the FHWA 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 (*3*,*4*). In contrast, walking and bicycling generate little, if any, noise.

Other Costs of Motor Vehicle Use

Drilling, shipping, and storing oil cause 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).

Car and truck air conditioning units account for about a quarter of chlorofluorocarbon (CFC) use in the United States. These man-made chemicals are considered responsible for an estimated 14 percent of the greenhouse effect, ranking third behind CO_2 (responsible for about 50 percent) and methane (18 percent) (*8*). 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 use artificial air conditioning.

Storm water runoff of salts applied to deice highways harms the environment, as do lead and toxic organics from automobile emissions, brake lining wear, and the like. The portion of this due 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 tires are dumped into the environment each year, with little recycling. Analogous impacts from bicycling and walking are merely 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 storing vehicles also harm the environment. At least one source estimated the energy requirements of vehicle manufacture at roughly 20 percent of total life-cycle energy (*9*). 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. The authors have excluded such impacts from the quantified estimates, except for adding 10 percent to tailpipe emissions in estimating the emission factor for CO_2.

CONCLUSION

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 often are not only demoralized but bodily threatened by motorists and motor-oriented planners who, out of carelessness or brutishness, would deny them use of road space.

Today, as the Automobile Century draws to a close, the far-flung damage from motor transportation 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 transportation 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.

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