Bicycling

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Glossary

automobile Any self-guided, motorized passenger vehicle used for land transport, usually with four wheels and an internal combustion engine.

bicycle Any pedal-driven, two-wheeled conveyance propelled by human power.

bike lane A linear portion of a roadway demarcated for the predominant or exclusive use of bicycles.

bike path A linear path or pathway physically separated from conventional motorized roadways for the predominant or exclusive use of bicycles.

efficiency For transport vehicles, ratio of distance traversed to energy consumed.

gear For bicycles, relationship between pedaling and movement, often expressed as distance traveled in one revolution of the pedals (metric gear ratio).

sprawl Land-use patterns characterized by low population density, high automobile density, extensive road network, and little or no opportunity to travel via transit, cycling, or walking.

traffic calming Any roadway design feature or environmental intervention intended to reduce speeds and volumes of vehicular traffic.

A bicycle is any pedal-driven, two-wheeled conveyance propelled by human power. Bicycles revolutionized transport during the 1800s, becoming the first mass-produced personal transportation device, only to be literally pushed aside by automobiles during the 20th century. Nevertheless, the bicycle remains the world's most numerous transport vehicle, outnumbering cars by a two-to-one margin. Bicycles are the predominant transport vehicle in China and are a staple of urban transit throughout Northern Europe. They are the most energy-efficient machine of any kind in widespread use and are three orders of magnitude less energy-consuming than automobiles per distance traversed. Moreover, bicycles conserve not just on a per-trip basis but also at the social level by encouraging the substitution of proximity for distance and adding to the efficiency advantage of dense urban settlements over sprawling, suburbanized land-use patterns. In addition, cycling provides the opportunity to obtain healthful physical activity in the course of daily life while enhancing personal autonomy vital to mental health. Accordingly, preserving and indeed expanding the bicycle's role in urban transport is increasingly viewed as a global priority for social cohesion, urban viability, oil conservation, and protection of the climate against greenhouse gases.

1. INTRODUCTION

The bicycle—any pedal-driven, two-wheeled conveyance propelled by human power—is the world's most numerous transport vehicle and the most energy-efficient machine in widespread use. The bicycle was also the first mass-produced personal transportation device and created the preconditions for the development of the automobile a century ago. It is ironic, then, that the automobile, wherever it has been widely adopted, has largely driven the bicycle from the roads, causing global energy use to skyrocket along with a multitude of other social ills.

Consider that to travel 1 km on flat terrain, a cyclist operating a sturdy "roadster" bicycle at 10 mph expends a mere 60,000 joules (14.5 kilocalories). To cover the same distance with a typical U.S. passenger car rated at 20 mpg requires 115 million joules or nearly 2000 times more energy.

To be sure, the car/bicycle energy ratio varies with the number of people carried (cars' "load factors" average more than 1, but so do bicycles' load factors in developing countries), with vehicle weight and efficiency (small cars use 33–50% less fuel than so-called light trucks, and similarly lightweight "10-speed" bicycles require less energy than do roadster bikes), and with energy losses in processing gasoline and obtaining food. Still, under most combinations of assumptions, bicycles can cover a given distance using one-thousandth of the fuel that automobiles use.

Moreover, as social theorist Ivan Illich observed, the distance one travels is a product of the dominant mode of transport. Bicycles go hand in hand with short distances and urban density, whereas cars' voracious need for space both demands and feeds suburban sprawl. In short, bicycles serve proximity, whereas cars create distance.

Partly as a result of this vicious circle, cars have come to account for nearly 30% of world petroleum consumption and to produce nearly 15% of emissions of carbon dioxide, the most prominent greenhouse gas. Thus, expanding the role of bicycles vis-à-vis automobiles seems to be an obvious prescription for a world riven by conflict over petroleum and facing ecological upheaval from climate change.

Yet despite concerted efforts by thousands of cycle advocates in scores of countries, cycling appears to be losing ground, or at best running in place, in most nations' transport mix. Bikes outnumber cars worldwide, but they are used for fewer "trips" overall and probably cover less than one-tenth as many person-miles as do autos. How can this quintessentially human scale and efficient machine flourish again during the 21st century?

2. BICYCLE DEVELOPMENT

The essential elements of the bicycle are two wheels in line connected by a chain drive mechanism, with a rider simultaneously balancing and pedaling. Some bicycle historians attribute the first sketch of such a device to Leonardo da Vinci or, as argued by author David Perry, to an assistant in Leonardo's studio. A drawing with two large eight-spoked wheels, two pedals, a chain drive, saddle supports, a frame, and a tiller bar appears in the *Codex Atlanticus*, a volume of Leonardo's drawings and notations dating from around 1493 and assembled during the 16th century. However, the drawing was not discovered until 1966, during a restoration, leaving its authenticity open to question.

European inventors produced a number of self-propelled, hand- or foot-powered conveyances over the subsequent several centuries, all employing four wheels for stability. A practical two-wheeled device was first produced by the German Karl von Drais in 1816 and was patented 2 years later. His 40-kg Laufmaschine ("running machine") was propelled not by a mechanical drive but rather by pushing the feet against the ground, like a hobby horse, yet was capable of 13- to 14-kph speeds on dry firm roads. Similar machines with foot-operated drive mechanisms, using treadle cranks, appeared in Scotland during the late 1830s. True bicycles—two-wheel vehicles with pedal cranks located on the hub of the drive wheel—finally emerged in 1863 in France and spread quickly throughout Europe and to the United States.

Because these "pedal velocipedes" lacked gearing, each turn of the pedals advanced them only a distance equal to the circumference of the front wheel. To achieve high speeds, designers resorted to enormous front-drive wheels, reaching diameters of 4 feet for ordinary use and up to 6 feet for racing models. Although ungainly and difficult to operate, these "high-wheelers" proliferated and led to important innovations such as tangent-spoked wheels to resist torque, tubular diamond-shaped frames to absorb stress, hand-operated "spoon" brakes that slowed the wheels by pushing against them, and hubs and axles with adjustable ball bearings.

The final two steps in the evolution of the modern bicycle came during the 1880s: gearing to allow the use of smaller, more manageable wheels and chain-and-sprocket drives that transferred the drive mechanism to the rear wheel. These advances led to the so-called safety bicycle, the now-familiar modern design in which the cyclist sits upright and pedals between two same-sized wheels—the front for steering and the rear for traction.

As noted by Perry, this modern machine revolutionized cycling and is widely considered the optimal design. Innovations making bicycles safer, easier to use, and more comfortable followed in quick succession; these included pneumatic tires, "free-wheels" allowing coasting, multispeed gearing, and lever-actuated caliper brakes operating on rims rather than on tires. The safety bike transformed bicycling from a sport for athletic young men to a transport vehicle for men, women, and children alike. By 1893, safety bicycles had replaced velocipedes, and by 1896, Americans owned more than 4 million bicycles—1 per 17 inhabitants.

The bicycle boom of the late 1800s swept through the industrialized world, and bicycle manufacture became a major industry in Europe and America. One census found 1200 makers of bicycles and parts, along with 83 bicycle shops, within a 1-mile radius in lower Manhattan. The pace of invention was so frenetic that during the mid-1890s the United States had two patent offices: one for bicycles and another for everything else. The lone urban traffic count in the United States to include bicycles, taken in Minneapolis, Minnesota, in 1906 after bicycling levels had peaked, found that bicycles accounted for more than one-fifth of downtown traffic—four times as much as did cars.

This "golden age of bicycling" proved to be short-lived. Following the classic pattern of corporate capitalism, a wave of mergers and buy-outs consolidated small shops run by enthusiasts and financed on the cheap into factories whose assembly-line efficiencies entailed high fixed costs. Overproduction followed, and then came market saturation, price wars, stock manipulations, and bankruptcies. Never universally popular, particularly in dense urban areas where swift and stealthy bicycles frightened pedestrians, the bicycle industry found its public image tarnished.

Of course, reversals of fortune were standard fare in late-19th century capitalism, and many industries, particularly those employing advanced technology, bounced back. Unfortunately for the bicycle business, on the heels of the shakeout in bike manufacture came the automobile.

3. THE BICYCLE DURING THE AUTO AGE

The bicycle catalyzed development of the car. A number of technical advances essential to the fledgling automobile industry, from pneumatic tires and ball bearings to factory-scale production engineering and a functional network of paved urban roads, owe their emergence to bicycles. No less important, the bicycle's ethos of independent, self-guided travel helped to split open the railroad-based paradigm of travel as mass transport along a fixed linear track.

But once the car took hold, it imposed its own ideology, one antithetical to bicycles. For one thing, cars used the same roads as did bicycles (the very roads that were paved as a result of bicyclists' campaigning), and through incessant noise and fumes, superior speed, and sheer physical force, cars literally pushed bicyclists aside. What is more, as recounted by social historian Wolfgang Sachs, the engine-driven car proved to be a more alluring cultural commodity than did the self-propelled bicycle. Although the bicycle leveraged bodily energy and broadened the individual's arena of direct activity many times over, the substitution of mechanical power for muscular exertion conveyed a sense of joining the leisure class and became equated with progress.

Thus, the bicycle's "defect of physicality," as Sachs termed it, put it at a disadvantage compared with the new technologies of internal combustion, electric motor drive, and flying machines. Rather than defend their right to cycle, the masses aspired to abandon the bicycle in favor of the auto. And abandon it they did, as fast as rising affluence and the advent in 1908 of the mass-produced, affordable car, Henry Ford's Model T, permitted. Although reliable data are lacking, by the end of the 1920s, bicycles probably accounted for only 1 to 2% of U.S. urban travel, an order-of-magnitude decline in just a few decades.

A similar devolution occurred in Europe during the long boom after World War II, albeit less steeply and with important exceptions. However, even now, bicycles outnumber cars by a two-to-one margin around the world, primarily due to economics. Cars cost roughly 100 times as much to buy as do bicycles and require fuel as well as maintenance, putting them out of reach of a majority of the world's people.

4. THE BICYCLE AND HUMAN POWER

According to data compiled by Vance A. Tucker of Duke University, a walking human consumes approximately 0.75 calorie of energy per gram of body weight for each kilometer traveled. This is less than the rate for birds, insects, and most mammals but is more than that for horses and salmon. However, atop a bicycle, a human's energy consumption falls fivefold, to a rate of roughly 0.15 calorie per gram per kilometer. As S. S. Wilson noted, "Apart from increasing his unaided speed by a factor of three or four, the cyclist improves his efficiency rating to No. 1 among moving creatures and machines."

Wilson attributed the bicycle's high efficiency mainly to its effective use of human muscles.

TABLE I

Cyclist Performance Factors

Factor	Average	Sport	Pro
Resting heart rate (breaths/min)	70	50	30
Anaerobic threshold (breaths/min)	160	175	185
Maximum heart rate (breaths/min)	180	190	195
Blood volume (ml)	10	25	50
Lung capacity (L)	5	6.5	8
VO_2 maximum (O_2 uptake, ml/kg-minute)	40	60	85
Thrust (Foot-pounds)	15	30	55
Cadence (rpm)	70	90	100
Watts	50	200	500
Calories (kcal)	135	750	2,150
Speed (kph)	15	30	50

Whereas a walker expends energy raising and lowering the entire body as well as accelerating and decelerating the lower limbs, the cyclist's sitting posture relieves the leg muscles of their supporting function. Because the cyclist's feet rotate smoothly at a constant speed and the rest of the body is still, the only reciprocating parts of the cyclist's body are the knees and thighs. Even the acceleration and deceleration of the legs is optimized given that one leg is raised by the downward thrust of the other. Wind resistance, the main constraint on the racing cyclist (because it varies with the square of the cyclist's velocity relative to the wind), is less significant at ordinary utilitarian speeds.

According to Perry, during a 1-h ride, an average person on a touring bike covering 15 km burns approximately 135 calories for an average power output of 50 W; over the same hour, a professional racing cyclist covers 50 km, burning 2150 calories and producing approximately 500 W (0.67 horsepower) (Table I).

"It is because every part of the design must be related to the human frame," wrote Wilson, "that the entire bicycle must always be on a human scale." He concluded, "Since the bicycle makes little demand on material or energy resources, contributes little to pollution, makes a positive contribution to health, and causes little death or injury, it can be regarded as the most benevolent of machines."

5. BICYCLE VARIETY

There is an enormous variety of bicycle types, reflecting human ingenuity, technical evolution, and a broad range of design criteria such as comfort, roadworthiness, speed, durability, and economy. As noted by Perry, a 22-pound road bicycle contains some 1275 parts in two dozen functional systems (e.g., wheels, chains, derailleurs, crank sets). Bicycle components require an unusual mix of lightness and durability, rigidity, and flexibility to provide a range of functions such as steering, braking, balancing, and climbing over a variety of terrains in various weather conditions. Moreover, in much of the world, bicycles must withstand the stress of carrying several passengers or cargoes weighing several hundred kilograms.

Most bikes fit into one of five broad categories:

- *Safety bicycles*. These bikes are the standard design established during the late 19th century and still employed throughout Asia and Africa. They have wide upright handlebars, medium-width tires, heavy construction for stability and durability, and up to three internal hub gears.
- *Racing or touring (10-speed or road) bicycles*. These bikes have the lightweight aerodynamic design initially developed for racing during the early 20th century and widely used today for sport. They have narrow "dropped" handlebars and skinny tires and achieve 10 gears through a double front chain ring and a 5-speed rear derailleur.
- *Mountain bikes*. These bikes are a recent (circa 1980) design, adding lightweight racing and touring components to the classic upright posture safety bicycle, with wide knobby tires for off-road use and a triple chain ring for steep inclines. A "hybrid" variant with slimmer tires is widely used in industrial countries for urban commuting.
- *Human-powered vehicles (or HPVs)*. HPVs are an entire class of machines combining aspects of bicycles, tricycles, and even cars developed by engineers and enthusiasts to "push the envelope" of nonmotorized transportation. They include recumbent bicycles in which riders recline against a backrest and the pedals are placed far forward. Using streamlined "fairing" to minimize wind resistance, HPVs have achieved 60-min speeds of 82 kph versus a maximum of 56 kph for standard racing bikes.
- *Utility cycles*. These bikes, with dedicated compartments and/or trailers for carrying large and heavy loads, are common in Asia and also are used in industrial nations in settings ranging from factory floors to urban food delivery. Pedicabs conveying passengers in separate compartments are widely used in China, Bangladesh, and parts of Africa, although authorities in Indonesia and elsewhere

have confiscated millions in forced motorization campaigns.

6. BICYCLES AROUND THE WORLD

Along with 1.2 billion bicycles, the world's 6.1 billion people possess 600 million motorized passenger vehicles (cars and light trucks), making for roughly 1 bike per 5 persons and 1 automobile per 10 persons. However, only a handful of countries actually show this precise two-to-one ratio because most of the world's motor vehicles are in the industrial nations, whereas most bicycles are in the developing world.

Although precise data are not available, it is likely that the average car is driven approximately 10,000 miles per year, whereas the average bicycle probably logs fewer than 500 miles per year. Based on these rough figures, the world's bicycles collectively travel less than one-tenth as many miles as do cars, although their share of trips is somewhat larger.

Three countries or regions are of particular interest: China, the world's most populous nation and still a bicycling stronghold, in spite of policies designed to encourage car use; the United States, the *ne plus ultra* of automobile use; and Northern Europe, where public policy restraining automobile use has brought about a bicycle renaissance amid affluence (Table II).

4.1 China

Large-scale bicycle manufacture and use have been a centerpiece of Chinese industrialization and urbanization since shortly after the 1949 revolution. By the 1980s, production for both domestic use and export had reached 40 million bikes per year, outnumbering total world car output. Today, China's 1.3 billion people own a half-billion bicycles, 40% of the world's total, and the bicycle is the mainstay of urban transportation throughout the country. Not just individuals but also whole families and much cargo are conveyed on bicycles, bike manufacture and servicing are staples of China's economy, and mass urban cycling is an indelible part of China's image in the world. Traffic controllers in the largest cities have counted up to 50,000 cyclists per hour passing through busy intersections; in comparison, a four-lane roadway has a maximum throughput of 9000 motor vehicles per hour.

This is now changing, perhaps irreversibly, as China invests heavily in both automobiles and mechanized public transport. Although domestic auto sales in 2002 numbered just 800,000 versus bicycle sales of 15 to 20 million, the auto sector is growing rapidly at 10 to 15% per year. "Bicycle boulevards" in Beijing and other major cities have been given over to cars, with bikes excluded from 54 major roads in Shanghai alone. The safety and dignity enjoyed by generations of Chinese are beginning to crumble under the onslaught of motorization.

Although the number of bicycles in China is still growing, sales have dropped by one-third since the early 1990s. With cyclists increasingly forced onto buses and subways, the bicycle's share of trips in Beijing and Shanghai has fallen precipitously to 40% and 20%, respectively, from more than 50% a decade or so ago. Indeed, the incipient conversion of the world's premier bicycle nation into a car-cum-transit society is eerily reminiscent of America a century ago.

TABLE II

Bicycles and Automobiles in Selected Countries and Regions (circa 2000)

Country or region	Bicycles	Autos	Bicycle/auto ratio	Bicycles per 1000	Autos per 1000
China	500,000,000	18,000,000	28	392	14
India	60,000,000	10,000,000	6	59	10
Japan	60,000,000	40,000,000	1.5	472	315
Germany	60,000,000	40,000,000	1.5	732	488
The Netherlands	12,000,000	6,000,000	2	750	375
United States	120,000,000	180,000,000	0.7	421	632
Argentina	5,000,000	5,000,000	1	135	135
Africa	40,000,000	20,000,000	2	50	25
World totals	1,200,000,000	600,000,000	2	198	99

The difference is that China's population is an order of magnitude larger than that of the United States in 1900, making the fate of cycling in China a matter of global moment. Profligate burning of fossil fuels is recognized to threaten humanity through global climate change, and a simple calculation demonstrates that if China were to match the U.S. per capita rate of auto use, world carbon dioxide emissions would rise by one-quarter, a catastrophic defeat in the effort to limit greenhouse gases.

6.2 United States

Like no other society in history, the United States is dominated spatially, economically, and psychologically by automobiles. Registered autos outnumber bikes by a two-to-one ratio, but more important, more than 90% of individuals' transportation trips are by car. A mere one-hundredth as many, or 0.9%, are by bicycle, and a majority of these are for recreational riding rather than for "utilitarian" transport. Some reasons follow:

- *Car culture*. Under America's cultural triumvirate of mobility, physical inactivity, and speed, the car has been enshrined as the norm and cycling is consigned to the margins. In turn, the perception of cycling as eccentric or even deviant contributes to an unfavorable climate for cycling that tends to be reinforcing.
- *Sprawling land use*. A majority of Americans live in suburbs, increasingly in the outermost metropolitan fringe whose streets and roads are suitable only for motorized vehicles. Cities are more conducive to cycling, with smaller distances to cover and congestion that limits motor vehicle speeds, but they too are engineered around autos, and few have marshaled the fiscal and political resources to ensure safety, much less amenity, for cyclists.
- *Subsidized driving*. Low gasoline taxes, few road tolls, and zoning codes requiring abundant free parking are a standing invitation to make all journeys by car, even short trips that could be walked or cycled.
- *Poor cycling infrastructure*. Spurred by federal legislation letting states and localities apply transportation funds to "alternative" modes, the United States has invested $2 billion in bicycle facilities since the early 1990s. Nevertheless, provision of on-street bike lanes, separated bike paths, cycle parking, and transit links has been haphazard at best and is often actively resisted.
- *Cycling danger*. A bike ride in the United States is three times more likely to result in death than is a trip in a car, with approximately 800 cyclists killed and 500,000 injured annually. Not surprisingly, the prospect of accident and injury is a powerful impediment to bicycling in the United States. Moreover, cycling's actual risks are compounded by cultural attitudes that attribute cycle accidents to the supposedly intrinsic perils of bicycles, unlike motorist casualties, which are rarely considered to imply that driving as such is dangerous.

These inhibiting factors are mutually reinforcing. Particularly with America's pressure group politics, the lack of broad participation in cycling severely limits support for policies to expand it. The lack of a consistent visible presence of cyclists on the road exacerbates the inclination of drivers to see cyclists as interlopers and to treat them with active hostility. "Feedback loops" such as these keep cycling levels low.

6.3 Northern Europe

There is one region in which bicycling coexists with affluence and automobiles. Despite high rates of car ownership, more than a half-dozen nations of Northern Europe make at least 10% of urban trips by bike, surpassing the U.S. mode share at least 10-fold.

The highest bike share, and the steadiest, is in The Netherlands, with 26% of urban trips in 1978 and 27% in 1995. Cycling's modal share rose sharply in Germany during the same period, from 7 to 12%—still less than half the Dutch level but impressive given Germany's rapid growth in auto ownership and use. Also notable is cycling's high share of trips made by seniors: 9% in Germany and 24% in The Netherlands.

Robust bicycling levels in Northern Europe are not accidental but rather the outcome of deliberate policies undertaken since the 1970s to reduce oil dependence and to help cities avoid the damages of pervasive automobile use. Not only are road tolls, taxes, and fees many times higher than those in the United States, but generously funded public transit systems reduce the need for cars, increasing the tendency to make short utilitarian trips by bicycle. Particularly in Germany, Denmark, and The Netherlands, comprehensive cycle route systems link "traffic-calmed" neighborhoods in which cycling alongside cars is safe and pleasant.

Indeed, the same kind of feedback loops that suppress cycling in the United States strongly nurture it in Northern Europe. Both density and bicycling are encouraged by policies ranging from provision of transit and cycle infrastructures to "social pricing" of driving; and Northern European states refrain from subsidizing sprawl development. Not only do a majority of Europeans live in cities as a result, but population densities in urban areas are triple those in the United States; correspondingly, average trip distances are only half as great, a further inducement to cycle.

7. BICYCLIST SAFETY AND DANGER

The bicycle's marvelous economy and efficiency have negative corollaries. First, unlike three- or four-wheeled conveyances, bikes are not self-balancing. Continuous motion is required to keep them upright, and they can tip and crash due to road defects, mechanical failure, or operator error. Second, crash mitigation measures such as seat belts, air bags, and crumple zones that have become standard in automobiles are not feasible for bicycles; only helmets offer a modicum of protection, and perhaps less than is commonly believed.

The exposed position of cyclists on the road makes them vulnerable to motor vehicles. Surpassing bicycles several-fold in velocity and at least 100-fold in mass, automobiles have approximately 1000 times more kinetic energy to transfer to a bicycle in a collision than is the case vice versa. Not surprisingly, although most of the total injury-accidents to bicyclists occur in falls or other bike-only crashes, severe injuries and fatalities are due mostly to being hit by cars. Approximately 90% of bicycle fatalities (95% for child cyclists) in the United States have motorist involvement, and the percentages elsewhere are probably as high.

Ironically, bicycles pose little danger for other road users and far less than do automobiles. In the United States, fewer than 5 pedestrians die each year from collisions with bikes, whereas 5000 are killed by motor vehicles. Motor vehicle users exact an enormous toll on themselves as well as on each other. Worldwide, total road deaths are estimated at 1 million people each year, with millions more becoming disabled in accidents. Based on "disability-adjusted life years," a statistic incorporating permanent injuries and the relative youth of victims, road deaths were ranked by the World Health Organization as the world's ninth-leading health scourge in 1990 and were predicted to rank third by 2020.

7.1 Worldwide Differences

Bicycle safety policies differ widely around the world, as illustrated in the regions profiled earlier. China and other developing countries are too poor to invest in bicycle safety programs, but until recently they were also too poor for the cars that make such programs necessary. Historically, cyclists in China and other Asian nations have been able to rely on their sheer numbers to maintain their rights-of-way. In the United States, bicycle safety measures focus on changing cyclist behavior, primarily increasing helmet use (especially by children) and training cyclists to emulate motor vehicles through "effective cycling" programs. Little effort is made to address the nature and volume of motor vehicle traffic or the behavior of drivers toward cyclists.

In contrast, bicycle safety in Europe is promoted holistically as part of policies to encourage widespread cycling and universal road safety. Germany and The Netherlands promote both through provision of elaborate and well-maintained cycling infrastructures, urban design oriented to cycling and walking rather than to motor traffic, disincentives for and restrictions on car use, and enforcement of traffic regulations that protect pedestrians and cyclists.

The European safety model appears to be validated by low fatality rates. Despite stable or rising cycling levels from 1975 to 1998, cycle fatalities fell 60% in Germany and The Netherlands. The U.S. decline was less than half as great (25%) and may have been largely an artifact of reduced bicycling by children. Currently, bicycle fatalities per kilometer cycled are two to three times lower in Germany and The Netherlands than in the United States, and pedestrian fatalities per kilometer walked are three to six times less. Perhaps most tellingly, although Germany and The Netherlands have higher per-kilometer fatality rates for auto users than does the United States, their overall per capita rates of road deaths are lower—by one-third in Germany and by one-half in The Netherlands—in large part because cars are used less in both countries.

7.2 Cycle Helmets

Helmets have become an intensely polarized subject in bicycling during recent years. Many observers trace the origins of the debate to a 1989 epidemiological study in Seattle, Washington, associating helmet use with an 85% reduction in brain and head injuries. The authors subsequently employed better statistical methods and scaled back their results considerably, to a mere 10% reduction in severe injuries when body and not just head trauma is taken into account. But the initially reported connection between helmet use and injury reduction sparked campaigns in the United States and Australia to compel helmet use by child cyclists (later extended to skateboards, roller skates, and scooters) and to promote helmet wearing by adult cyclists.

Whether these campaigns have been useful or not is difficult to say. Child cycling fatalities have decreased in the United States, but that may be because fewer children now cycle. Adult fatalities have risen, possibly due to growth in the more dangerous kinds of motor traffic such as sport utility vehicles and drivers' use of mobile phones. Nevertheless, although links between helmet promotion and cycling injury prevention are inconclusive, the "helmet paradigm" is firmly established in U.S. policy.

In Europe, where injury prevention is subordinated to the larger goal of health promotion and where social responsibility is emphasized alongside individual accountability, helmets are considered irrelevant or even counterproductive to health. The influential British social scientist Mayer Hillman contends that cardiovascular and other physiological and psychological gains from cycling far outweigh the rider's crash risk, even in unsatisfactory present-day road environments. Therefore, Hillman's paradigm of cycle encouragement holds that cycling is so beneficial to individuals and society that no interferences should be tolerated, not even the inconvenience and unattractiveness of a helmet or the subliminal message that helmets may send about the dangers of cycling.

7.3 Safety in Numbers

Anecdotal evidence has long suggested that the per-cyclist rate of bicycle–motor vehicle crashes declines as the amount of cycling on a road or in a region increases. This "safety in numbers" effect is thought to occur because as cyclists grow more numerous and come to be an expected part of the road environment, motorists become more mindful of their presence and more respectful of their rights. The implication is that adding more cyclists to the road makes it less likely that a motorist will strike an individual cyclist and cause serious injury. Conversely, removing cyclists from the traffic stream raises the risk to those who continue to cycle.

This safety in numbers effect offers a plausible explanation for the fact that per-kilometer cycling fatality rates in Germany and The Netherlands are four times less than that in the United States, even though cycling percentages are more than 10 to 20 times higher in these European countries. Now, time-series estimates of this effect, although preliminary and site specific, are pointing intriguingly toward a "power law" relationship of approximately 0.6 between cyclist numbers and cyclist safety. According to this relationship, the probability that a motorist will strike an individual cyclist on a particular road declines with the 0.6 power of the number of cyclists on that road. Say the number of cyclists doubles. Because 2 raised to the 0.6 power is 1.5, each cyclist would be able to ride an additional 50% without increasing his or her probability of being struck. (The same phenomenon can be expressed as a one-third reduction in per-cyclist crash risk per doubling in cycling volume given that the reciprocal of 1.5 is 0.67.)

The implications for cycling are profound. Countries that have based safety promotion on cyclist behavior modification (e.g., the United States) might reconstruct safety in a social context. One consequence would be to deemphasize helmet use in favor of jump-starting broader participation in cycling so as to stimulate a "virtuous circle" in which more cycling begets greater safety, which in turn encourages more cycling. In addition, countries such as China might reconsider policies that threaten to erode large-scale cycling, lest safety in numbers in reverse leads to a downward spiral as in the current U.S. situation, where bike riding is limited to small numbers of enthusiasts and to others who have no alternatives.

8. *BICYCLE POLICIES*

Policies to support and "grow" bicycling fall into three categories: cycling infrastructure, cyclists' rights, and disincentives to driving.

Cycling infrastructure policies aim to attract cycle trips by providing "facilities" such as on-street bicycle lanes, off-street bicycle paths (e.g., "greenways") with separate rights-of-way, bicycle parking, and integration with the metropolitan or regional transit system. Constructing and maintaining such facilities has proven to be politically popular in some states and localities in the United States and absorbed most of the $2 billion spent on bicycle programs from 1992 to 2002.

Cyclists' rights initiatives seek to improve the legal standing of cycling and, thus, to make cycling safer and more socially validated. It is believed that exerting closer authority over driver conduct through the legal system, police enforcement, and cultural shifts would directly reduce the threat to bicyclists and so encourage cycling.

Disincentives to driving are policies to make driving less attractive economically and logistically and, therefore, to reduce the level of motor traffic. Measures falling under the rubric of "social pricing" of automobiles include gasoline taxes, "carbon" taxes on fossil fuels, road pricing (fees on each kilometer driven), and restructuring auto insurance and local road taxes to pay-per-use.

That these three kinds of initiatives are complementary is seen by examining Germany and The Netherlands, which have used all three to maintain and restore bicycling since the early 1970s. No single approach is sufficient, and each supports the others by increasing opportunities and rewards for cycling and establishing a social context in which cycling is "valorized" as appropriate and praiseworthy rather than viewed as deviant behavior.

9. BICYCLE PROSPECTS

Strong societal currents are pushing bicycling forward, yet equally mighty forces are suppressing it. Much hangs in the balance, both for billions of the earth's peoples who may wish to master their own mobility through cycling and for our planet's ecological and political well-being.

Each trip cycled instead of driven conserves gasoline and stops the addition of climate-altering carbon dioxide to the atmosphere. The potential effects are large given that passenger vehicles account for nearly one-third of global petroleum consumption and generate more than one-eighth of carbon dioxide emissions. "Green cars" are no more than a palliative; a world in which everyone drove at the U.S. per capita rate would emit more carbon dioxide than is currently the case, even if autos could be made to be five times more efficient.

Thus, sustaining the earth's climate and political equilibrium requires robust alternatives to the American model of one car per journey. Moreover, bicycles conserve several times over, and not just at the per-trip level, by encouraging the substitution of proximity for distance and adding to the efficiency advantage of dense urban settlements over sprawling suburbanized land-use patterns. Therefore, ecological imperatives are a potent reason to maintain bicycling in China and other developing countries as well as to foster it in automobile-dependent societies such as the United States.

Health promotion is a major rationale as well. As noted, road traffic accidents are or soon will be among the world's half-dozen leading causes of death and disability. Sedentary lifestyles, including substitution of motorized transport for walking and cycling, are also recognized as a cause of fast-growing obesity and of ill health generally. In contrast, cycling provides the opportunity to obtain physical activity in the course of daily life while enhancing personal autonomy and aiding mental health.

Yet motorization itself is a powerful suppressant to cycling, and not just in the often-lethal competition between cars and bikes. Just as pernicious is the automobile's grip on transportation's "mindshare"—the automatic equating of mobility with motor vehicles and of motor vehicles with success—that leaves bicyclists, both individually and institutionally, on the outside looking in.

Large-scale cycling seems reasonably assured in the countries of Northern Europe that view it as integral to national objectives of reducing greenhouse gases, sustaining urban centers, and promoting health and self-guided mobility. Preserving mass cycling in China and developing it in the United States will probably require dethroning the automobile as the symbol and engine of prosperity and sharply reducing its enormous financial and political power—a tall order.

The bicycle—a pinnacle of human efficiency and an icon of vernacular culture for more than a century—will survive. Whether it will again flourish may make a difference in how, and whether, humanity itself survives.

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