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Role of Bicycles in Public Transportation Access

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ABSTRACT

Bicycles play a vital role in access and egress for rail and express bus services in Japan and northwestern Europe as well as in a growing number of communities in the United States. Suburbanization has been a driving force for the growth of bicycle-transit linkage. In many suburban towns in Japan, West Germany, Denmark, and the Netherlands, 25 to 50 percent of rail station access trips and up to 20 percent of station egress trips are made by bicycle. The number of trips involving a combination of bicycles and public transportation has quadrupled in Japan and doubled in Denmark since the early 1970s. In the United States, high bicycle theft rates have restrained similar growth except for transit systems that have made special provisions for bicycle access. Significant use of bicycles for transit access is found only where bicycle theft rates are relatively low or where secure bicycle parking has been provided at transit stops. The evolution of transit access systems is discussed and park-and-ride versus bike-and-ride transit access are compared with regard to capital and operating costs, air pollution and energy use, impacts on transit ridership, implications for transit stop siting, and other factors. It is concluded that American transit agencies could substantially increase suburban transit use without increased operating costs by improving bicycle-transit integration. Bike-and-ride development is far more cost-effective than park-and-ride development.

This study arose out of research begun at Public Technology, Inc., the technical arm of the National League of Cities. A search for information about bicycle-transit linkage revealed that little information has been available on the experiences of American transit agencies. Even less information has been available in English regarding the role of bicycles as an access and egress mode to public transportation in other mature industrialized societies. Although the number of U.S. transit operators initiating bicycle-transit linkage programs has been growing, no body of information has existed to guide these efforts.

The collection of both descriptive and analytical data on bicycle-transit linkage was carried out through the course of 8 months of research, site visits, and meetings with transit agency and government officials, businessmen, and citizen activist leaders in Japan, the Netherlands, West Germany, and Denmark. Additional research was conducted over a 2-year period in the United States.

A more extensive presentation of the research findings is contained in a recently released book, Bicycles and Public Transportation: New Links to Suburban Transit Markets, published by the Bicycle Federation, Washington, D.C. (1).

BACKGROUND

The traditional market base for public transportation has been eroded by the shift of population and employment growth from dense urban centers to suburbs and small cities. Although transit agencies have expanded their routes and services into these new areas of growth, it has become ever more difficult to provide cost-effective public transportation within walking distance of the places to which people want to go. Suburban growth has far outpaced the development of suburban transit services.

Suburbanization and deurbanization have not been confined to the United States but are common trends in Japan and Europe as well. By 1980 one-third of all Western European cities with more than 200,000 residents were losing population (2). Between 1960 and 1971, all major Dutch metropolitan areas showed significantly faster rates of employment growth in suburban areas than in their urban cores, with a decrease in absolute employment in two out of seven metropolitan regions (2). Similarly, the fastest rates of population and employment growth in Japan are in the areas at the fringe of metropolitan regions, whereas the population of major urban cores has been declining since the mid-1960s (3).

With more people living at greater distances from transit routes than at any time in the past century, the mainstay of transit access and egress, walking, is being replaced increasingly by other access and egress modes in Japanese, European, and American suburban areas, particularly for express bus and rail services. Both automobiles and bicycles are being used to expand the access service areas of bus and rail lines where closely spaced routes are uneconomical, often supplementing or substituting for feeder bus services. In a growing number of communities, bicycles are also assuming a significant role in transit egress, allowing people to travel by public transportation to locations several kilometers from the nearest transit route.

Throughout the United States, northwestern Europe, and Japan, suburbanization has brought with it the diversification of transit access and egress systems. However, differences in transportation policies and infrastructure, travel habits, crime rates, and cultural attitudes have led to local differences in the way travelers get to and from suburban public transportation. Park-and-ride, kiss-and-ride, and bike-and-ride travel--involving access to transit as an automobile driver, passenger, or cyclist--can each be found in varying proportions in suburbs throughout mature industrialized societies. In many places one can also observe dual-mode transit egress systems--bicycles accommodated on transit buses, bicycle rental services at rail stations, and recently revived programs permitting bicycles aboard trams and rail vehicles, a concept that originated in the late 19th century (4, p.222; 5).

In suburban areas of northwestern Europe and Japan, bicycles have come to play a major role in transit access and egress. Although automobile access to transit has also grown in these areas in recent years, park-and-ride and kiss-and-ride transit access remain clearly subordinate to bike-and-ride travel in most Japanese and European communities. In the United States, however, the automobile accounts for the majority of access trips to suburban rail and express bus services in many communities. Except for a few communities, bicycles play an insignificant role in American transit access.

What accounts for these differences between America versus Europe and Japan in the evolution of suburban transit access systems? What are the effects of basing suburban transit access on one mode or another or on some balanced mix of modes? Is a different mix of transit access modes feasible, practical, and desirable for suburban public transportation in America? These are the central questions of this research effort.

RESEARCH FINDINGS

Growth of Bicycle Access to Japanese Rail Stations

Rapid suburbanization began in Japan in the mid-1960s, accompanied and fostered by rising incomes and increased automobile ownership. High land costs near railway stations, even in distant suburbs, led many new residents to settle in areas beyond walking distance of rail stations and feeder bus services. Deficiencies in feeder bus services, for example, excessive spacing between routes, overcrowding in peak hours, rising fares, and slow travel speeds due to congestion in town centers, encouraged many suburban commuters to explore other ways of getting to rail stations.

With an extremely low crime rate, commuters were able to park bicycles outside their stations in any open space without strong locks or supervision. Undeterred by the lack of designated bicycle parking, bike-and-ride commuters swamped hundreds of rail stations with literally thousands of bicycles. Between 1975 and 1981, the number of bicycles parked daily at Japanese railway stations more than quadrupled to 1.25 million, with growth continuing at a rate of 21 percent a year (6,7).

This phenomenal growth in the number of bicycles parked at rail stations created strong pressure on transit agencies and Japanese local and federal governments to provide increased bicycle parking. "Bicycle pollution" became a buzz word to describe the chaos caused by thousands of bicycles parked in disorder at rail stations.

The Japanese Ministry of Construction responded to the bicycle-pollution problem in the mid-1970s by establishing several programs for construction of new bicycle parking garages. Further action was taken by the Japanese Diet, which in 1980 passed a major law concerning bicycle parking. An ongoing program was established under this law to encourage the private sector, local government, and the railways to build new bicycle parking garages at rail stations by using federal subsidies (8,p.13).

Between 1978 and 1981, more than 730,000 new bicycle parking spaces were constructed at Japanese rail stations. By 1981 there were 636 bicycle parking facilities at Japanese rail stations, each with a capacity of more than 500 bicycles. These were augmented by 5,456 facilities, each designed for less than 500 bicycles. At 20 Japanese rail stations, more than 3,000 bicycles were parked each workday; another 208 stations accommodated 1,000 to 3,000 bicycles daily. Nationwide, nearly 30 percent of the 1.25 million bicycle parking spaces at Japanese rail stations were controlled by private-sector firms in 1981, thanks in part to government incentives and grants encouraging such investments (6,7).

As suggested in Figure 1, bicycles play a major role in rail station access outside of central city areas, typically accounting for one-half to one-sixth of the access trips in areas at the fringe of metropolitan regions and for one-sixth to one-tenth of the access trips in suburban towns. Automobiles play a smaller role in rail station access, typically serving 5 to 10 percent of access trips in suburban and fringe areas.

Growth of Bicycle Access to European Transit Services

As in Japan, the shift of population and employment

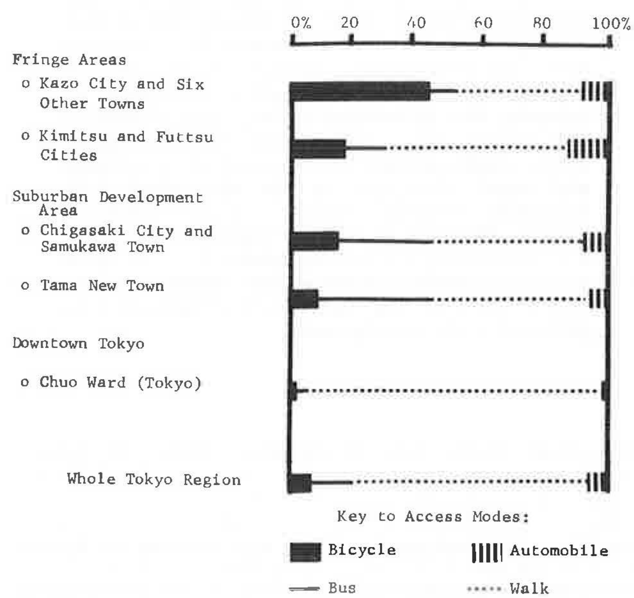

FIGURE 1 Mode of access to Tokyo area rail stations, 1978 *(9)*.

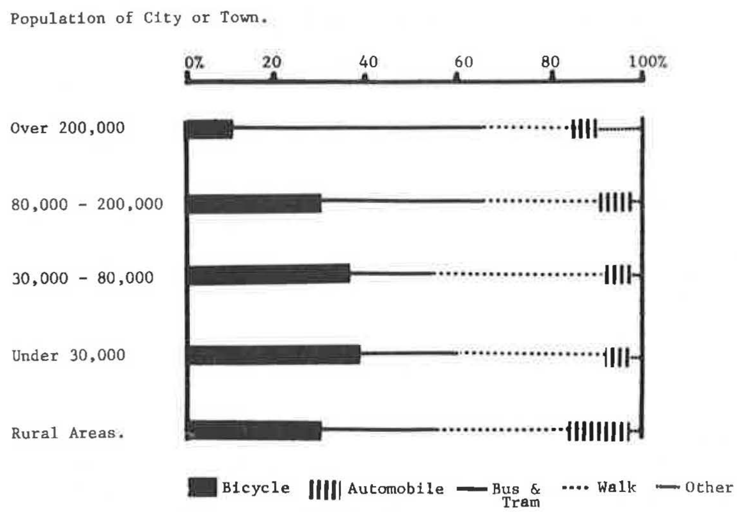

FIGURE 2 Mode of access to Dutch rail stations, 1968.

growth to suburban areas and small cities and towns has brought about major changes in the modal composition of transit access trips in Europe, particularly for rail services. As suggested in Figure 2 [data from Dutch national railway, Nederlandse Spoorwegen (NS)] bicycle access to transit has been most important in suburban areas, satellite cities, and large towns in the Netherlands. Although only 11 percent of access trips to Dutch rail stations in cities with more than 200,000 population were made by bicycle in 1968, more than one-third of station access trips in cities and towns with less than 200,000 population were by bicycle in this same year.

As more people have moved from dense urban centers to lower-density areas where feeder bus and tram services are less widely available and offer lower quality of service, the share of rail station access of bus, tram, and walking has declined. Bicycle and automobile access have increased in importance. As shown in Figure 3, the share of rail station access trips made by bicycle in the Netherlands has doubled since 1960 (9,10); 36 percent of Dutch railway passengers, as well as 10 to 20 percent of regional bus passengers, bicycled to their transit boarding point in 1981. In contrast, automobiles provided rail station access for only 1 out of 10 Dutch rail passengers in this same year (9,10).

Similar changes in the composition of rail station access trips have been noted in Denmark and West Germany since the early 1970s (11, p.90; 12, p. 48). The share of all travel involving a combination of bicycles and transit more than doubled in Denmark in the 1970s (12, p.48). By 1981, one out of seven rail passengers in the Copenhagen region arrived at the station by bicycle. In some West German and Dutch suburban towns bicycles account for roughly half of all railway access trips (9,13), as shown in Table 1. The increased use of bicycles for suburban transit access has led transit agencies, railroads, and local and federal governments to develop extensive bicycle parking at transit stations in northwestern Europe.

In the Netherlands more than 160,000 bicycle parking spaces are available at rail stations nationwide, including 90,000 covered and guarded spaces at 80 of the principal railway stations (9). The Dutch national railway, NS, recently installed 10,000 secure bicycle lockers at low-volume stations to stem the growing problem of bicycle theft from unguarded bicycle racks. At least 10 bicycle parking racks are provided at each of more than 200 bus stops served by companies affiliated with the Exploitatieve Samenwerking Openbaar (ESO), the coordinating body for interurban and nonmetropolitan bus operators in Holland. According to ESO planners, 10 to 20 percent of ESO bus patrons use bicycles to reach the bus stop.

In both West Germany and Denmark, more than 50,000 bicycle parking spaces are available at rail and bus stops nationwide. The city of Odense, Denmark, has provided extensive bicycle parking at most suburban bus stops in the region. A number of guarded bicycle parking garages at rail stations, accommodating from several dozen to more than 1,000 bicycles each, can be found throughout Denmark and West Germany.

Bicycle use for transit egress has also expanded considerably. The growth of employment in suburban areas poorly served by transit has led an increasing number of commuters to store a second bicycle overnight at a transit stop near their workplace in locations where secure parking is available. The use of rental bicycles at rail stations in Japan and Europe by both recreational cyclists and commuters has grown substantially. In dozens of cities it is now possible for cyclists to carry bicycles on board buses, trams, or railways, making it possible to travel almost anywhere throughout certain metropolitan and rural areas without the need for an automobile. In the Netherlands, 1 out of 10 railway trips is completed by using a bicycle for station egress at the nonhome trip end (10). Clearly the bicycle has become an important element in the continued vitality of suburban public transportation in Japan and northwestern Europe.

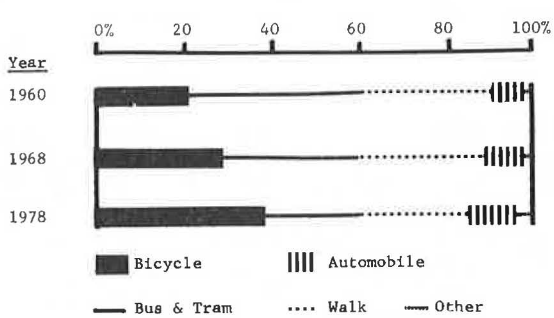

FIGURE 3 Change in distribution of rail station access modes in the Netherlands, 1960-1978 *(9, 10)*.

TABLE 1 Percentage of Transit Access and Egress by Bicycle and Automobile

		Percentage of all Access and Egress Trips by Mode			
		Access Trips		Egress Trips	
Location	Year	Bicycle	Automobile	Bicycle	Automobile
Netherlands					
National sample of Dutch rail stations *(9)*					
Home-based trips (all)	1982	36	11	10	5
Work trips	1982	43	17	11	3
School trips	1982	56	4	22	1
Recreational travel	1982	34	10	6	7
Rail stations, six midsized Dutch towns *(10)*	1980	47	14	20	3
Denmark					
S-Bane, Copenhagen, Denmark	1979	15	7	7	1
Heavy rail line, Helsinger-Copenhagen, Denmark	1979	21	6	8	3
West Germany					
West German railway stations *(11)*					
Hassloch (Rhein-Neckar region)	1979	43	N.A.	N.A.	N.A.
Bohl-Iggelheim (Rhein-Neckar region)	1979	31	N.A.	N.A.	N.A.
Eichenau (Munich region)	1976	25	N.A.	N.A.	N.A.
Olching (Munich region)	1976	23	N.A.	N.A.	N.A.

Note: Source for Danish data: DSB (Danish State Railways), Copenhagen, Denmark.

Bicycle-Transit Integration in America

Although the linkage of bicycles with public transportation in the United States has grown substantially since the early 1970s, it remains quite underdeveloped in relation to Europe and Japan. Only a handful of American transit agencies and local governments have installed secure bicycle parking at rail and bus stops. However, in a growing number of communities scattered from Connecticut and New Jersey to Illinois and California, secure bicycle parking is enabling 5 to 10 percent of suburban railway and express bus passengers to rely on bicycles for transit access (14-17).

Thanks to the provision of 2,000 secure bicycle racks and lockers at its San Francisco area stations and a bike-on-rail program that permits bicycles inside passenger coaches except for peak-direction peak-period travel, the Bay Area Rapid Transit (BART) carries thousands of passengers daily who regularly use bicycles for station access. At some suburban BART stations, 5 percent of the passengers arrive by bicycle, according to planners at BART. Surveys conducted by the California Department of Transportation (Caltrans) have shown that 40 percent of the cyclists renting bicycle lockers at Southern Pacific Railway stations between San Francisco and San Jose are storing bicycles overnight in their lockers, enabling them to cycle from the station to remote employment centers each workday. In Santa Barbara, California, the introduction of buses towing bicycle trailers attracted more than 42,000 passengers with bicycles in 1981, boosting ridership substantially and diverting thousands of passenger trips from automobiles to transit (18).

Despite the great promise shown by these efforts to promote bicycle-transit linkage in America, transportation planners and managers have given little attention to the potential role of bicycles in expanding suburban transit markets and reducing the financial, energy, and environmental costs of transit access systems. In sharp contrast to the multimodal approaches pursued in Japan and Europe, the development of suburban transit access systems in America has focused almost entirely on the construction of park-and-ride lots. Indeed, in countless American suburbs, the majority of passengers on express buses and railways rely on automobile access and are offered no other workable transit access alternatives. Yet roughly half of all Americans using park-and-ride lots travel access distances of less than 2 miles (19).

Bicycle Theft and Bicycle Parking

Although many factors influence the demand for bicycle access to suburban express bus and rail services, it appears that one of the most significant factors is the availability of secure bicycle parking conditions. Such conditions are found either where bicycle theft rates are low or where secure parking facilities have been provided. The availability of secure bicycle parking conditions does not guarantee any particular level of bike-and-ride demand. However, secure parking conditions are necessary if latent bike-and-ride demand is to be realized.

Bicycle theft, like most crimes, occurs at a significantly higher rate in the United States than in most other mature industrialized societies. A comparative analysis of the frequency of bicycle theft, shown in Table 2, reveals that the per-capita bicycle theft rate in the United States is roughly an order of magnitude greater than the rate observed in Japan in 1970, five times greater than the current

TABLE 2 Bicycle Theft: An International Comparison

Country	No. of Reported Bicycle Thefts	Year	Total Estimated Bicycle Thefts[a]	Estimated Bicycles Stolen per 100,000 Population
Japan	115,000	1970	115,000[b]	100
	246,000	1980	246,000[b]	212
Denmark	21,000	1981	75,000[c]	494
West Germany	323,204	1979	323,204[d]	527
United States	674,654	1979	2,595,000[e]	1,153

[a]All data on bicycle theft are somewhat unreliable because of underreporting of minor thefts without personal contact. Because of differences in social values and attitudes, the rate of underreporting varies widely between different nations. These data have been adjusted to account for underreporting where this is significant.
[b]Estimate given by officials of the Japanese Transport Ministry and the Secretariat of the Prime Minister. According to several Japanese officials, most crime, including bicycle theft, is reported to police in Japan.
[c]Reported bicycle thefts are from insurance company reports. Estimated bicycle theft data are from estimates of the Danish Transport Ministry and officials of DSB.
[d]From report by Schafer *(20*, p. 254), who reports that the overwhelming majority of (West German) bicycle thefts are reported to police.
[e]Reported bicycle theft data from Uniform Crime Reports *(21)*. According to U.S. Justice Department surveys, 74 percent of personal larceny crimes without contact were unreported to police. This estimate has been used to derive total estimated thefts.

rate in Japan, and more than double the current theft rate in Denmark and West Germany.

Because people will park their bicycles at a transit stop only if they are reasonably assured that it will not be vandalized or stolen, the absence of secure bicycle parking facilities deters bike-and-ride travel only in regions with a high incidence of bicycle theft. In circumstances where bicycle theft and the adequacy of the bicycle parking supply do not constrain the growth of bike-and-ride travel, the true potential of bicycle access to transit is revealed. Such conditions have prevailed in Japan, where theft rates have been low and where bicycle parking has been installed primarily to restore order to rail station squares (22).

The growth of bicycle access to transit in northwestern Europe similarly occurred in an environment with a low bicycle theft rate relative to the United States. Although in the past several years, bicycle theft has become a greater problem, particularly in urban areas of the Netherlands, transit agencies and governments have responded by constructing secure bicycle parking garages and bicycle lockers at numerous rail stations.

The absence of secure bicycle parking at most transit stops in America has exposed potential bike-and-ride travelers to generally unacceptable risks of bicycle theft. As noted in a recent U.S. Department of Transportation study (23), "Fear of theft is a significant disincentive to bicycle transportation.... A recent Baltimore Maryland, survey of cyclists [(24)] discovered that 25 percent of those polled had had their bicycle stolen. Twenty percent of those who had been theft victims reported that they gave up bicycling as a result of the experience." In a survey conducted by Barton-Aschman Associates in Pennsylvania, it was found that half of all bicycle commuters were afraid that their bicycles would be stolen at work (25). Bicycle thefts are at least three times more common than automobile thefts in the United States, and although three-fourths or more of all stolen cars are recovered, less than one-fifth of stolen bicycles are restored to their owners (23).

Thanks to relatively low crime rates, the consumer demand for bicycle parking at transit stops in Europe and Japan was manifested physically for all to see. In the United States, however, widespread bicycle theft and vandalism prevents cyclists from parking at most transit stops unless they are equipped with secure bicycle storage. Only a supply-push strategy--installing and marketing secure bicycle parking at transit stops--can release the latent demand for bike-and-ride services in America.

Many types of bicycle parking facilities have been successfully employed to provide secure parking conditions. Different types of facilities are needed to meet different local conditions.

Transit stop bicycle lockers, which fully enclose the bicycle, have been successfully demonstrated by many U.S. transit agencies and state and local governments to meet the needs of regular bike-and-ride commuters. Coin-operated bicycle lockers and lockers secured by user-supplied locks, which would be most useful for occasional bike-and-ride commuters, have proved troublesome in the United States because of abuse (14), although these have operated successfully in Europe.

Secure bicycle racks, which offer theft protection to the bicycle frame and to one or both bicycle wheels, have been provided at a number of U.S. transit stops. In many locations, these have provided adequate security. However, in higher-crime locations many bicycles have been vandalized while secured in such racks. Whenever possible, bicycle racks at transit stops should be sited in locations with high visibility, preferably where a station attendant or pedestrians will provide informal deterrence to vandals and thieves.

Guarded bicycle parking facilities are common in Europe and Japan but have not yet been employed in the United States. Such facilities can be more economical than bicycle lockers if a current employee, such as a station attendant, can be assigned the added role of parking guard or if the number of parked bicycles is sufficient to generate adequate daily revenues. Ninety thousand guarded bicycle parking spaces are provided at Dutch railway stations for a monthly operating cost of $5.25 per space. The smallest of these bicycle parking garages holds 134 bicycles. The Dutch bicycle parking attendants earn an average of more than $17,000 per year. The demonstration and evaluation of guarded bicycle parking at rail stations with substantial bike-and-ride demand should be undertaken in the United States, because such facilities can serve regular, occasional, and first-time bike-and-ride commuters equally well, unlike leased lockers and racks (1).

Implications of Bicycle-Transit Linkage for U.S. Transit Agencies

Several surveys have indicated that many more American rail commuters would use bicycles for station access if secure parking were installed. More than 40 percent of the passengers polled by the New Jersey Department of Transportation at five commuter rail stations would consider cycling to the station if such facilities were available (15). In a survey by the Connecticut Department of Transportation, it was indicated that 23 percent of the passengers on the New Haven commuter rail line would use protected bicycle parking if it were installed at their station (14). Moreover, roughly half of the passengers who expressed an interest in bicycle parking in both of these surveys currently park their automobiles in the filled-to-capacity station park-and-ride lots. Provision of bicycle parking could thus make additional park-and-ride capacity available.

Improved bicycle-transit linkage can also expand the market penetration for express bus and rail services. In a survey by Caltrans of those who use bicycle lockers at park-and-ride lots in the San Francisco region, it was found that 68 percent of the bike-and-ride travelers at lots served by buses and 30 percent of the bike-and-ride travelers at lots served by railways formerly drove automobiles to make their trip.

In Santa Barbara, California, a comprehensive bicycle-transit integration system combining the provision of bicycle parking at bus stops and a bike-on-bus service dramatically boosted transit market penetration in areas beyond walking distance of bus routes. Ridership on the demonstration project bus routes rose by 46 percent in 1980, whereas the level of bus service increased only 19 percent and systemwide ridership grew by 15 percent. The share of access trips made by bicycle to these routes jumped from 1.5 to 23 percent over 2 years. In the Santa Barbara region as a whole, 7 percent of employees, 14 percent of households, and 23 percent of the student population used a bicycle to reach a bus stop during the 2 year demonstration project (18).

The potential market for bicycle-transit integration in the United States is quite large. Approximately 100 million Americans own bicycles. Although precise data are unavailable, data from the 1977 National Personal Transportation Study suggest that approximately 16 to 24 million U.S. workers live more than 0.25 mile (400 m) and less than 2 miles (3200 m) from the nearest public transportation route (26).

Few of these workers now use transit to get to work, in part because of the lack of an inexpensive, convenient, and fast transit access system suited to trips of this distance. Although 13 percent of U.S. workers living within 0.50 mile (800 m) of a transit route commute by public transportation, this figure falls to 4 percent for those living 0.5 to 2 miles away from a rail or bus stop. Indeed, only one-fourth of all transit commuters in the United States live beyond a 0.25-mile walking distance from transit (26, Tables A-16, A-17, and pp. 19-20).

If public transportation is to serve a larger market in suburban areas without a prohibitively expensive expansion of collection and distribution routes, opportunities for transit access and egress by private modes of transportation must be expanded.

Park-and-Ride Versus Bike-and-Ride

Park-and-ride services have undergone a dramatic expansion in the United States over the past two decades and are now a vital element in suburban transit services. Although park-and-ride transit access trip lengths can range up to 5 miles (8 km) or more, average access trip lengths range from less than 2 miles (3.2 km) to about 3.5 miles (5.6 km) for remote park-and-ride lots (19,27). By expanding the access service area of express transit services, park-and-ride lots have boosted suburban transit use in many communities, attracting choice riders. However, further development of park-and-ride services to increase suburban transit market penetration will only be achieved at a substantial cost, with likely diminishing returns.

Despite the intense promotion of park-and-ride systems for energy conservation and pollution reduction, bike-and-ride systems have been found to be a far more cost-effective strategy to pursue these objectives. A major American engineering consulting firm involved in park-and-ride lot planning and construction estimates the typical construction cost of park-and-ride lots at $3,640 per automobile space, excluding land costs. Where drainage structures or cut-and-fill work are required, the cost may be as much as twice this amount (1). In contrast, secure bicycle parking typically costs $50 to $500 per space for capital construction, excluding land costs (which are lower because of reduced space requirements).

Operating expenses show similar differentials between automobile and bicycle parking, ranging from 2:1 to 10:1. Although a typical unattended park-and-ride lot costs $150 or more per year for operations and maintenance, this figure ranges from a few dollars to about $70 per year for bicycle parking (1). In contrast, covered, enclosed, and guarded bicycle parking in the Netherlands requires $64 a year in operating and maintenance costs, including a modest profit for the contract operators. The vast difference in costs between automobile and bicycle parking has major implications for suburban transit access policy and transit cost containment.

From the perspective of transit route planning, bike-and-ride systems offer far greater flexibility in siting transit stops that do park-and-ride systems. Automobile parking typically requires as much as 330 ft² (30 m²) of land per space, compared with 6 to 12 ft² (0.5 to 1.0 m²) needed for ground-level bicycle storage spaces (24,27). As a result, park-and-ride lots are often constrained in size or location. Typically either they offer inadequate capacity relative to the potential demand for private vehicular access at a transit station or they must be sited in remote locations unsuited for pedestrian access. In contrast, bicycle parking may be readily sited in congested areas around rail stations and in traffic-sensitive residential areas.

As a strategy to reduce both air pollution and energy use, bicycle-transit linkage is far more cost-effective than further park-and-ride lot development. In a recent study by the Chicago Area Transportation Study it was found that the installation of secure bicycle parking at rail stations would reduce hydrocarbon emissions at a public cost of $311/ton ($0.34/kg) compared with $96,415/ton ($106/kg) for an express park-and-ride service, $214,959/ton ($237/kg) for a feeder bus service, and $3,937/ton ($4.34/kg) for a commuter rail carpool matching service. Similar differentials were found for carbon monoxide reduction costs (28).

Although automobile access trips to transit involve cold-start vehicle operation and the associated fuel use rates are several times higher than the average for all automobile travel, bicycle access trips require no petroleum at all. A preliminary analysis, shown in Table 3, reveals that for each American park-and-ride commuter diverted to bike-and-ride travel, gasoline use may be reduced by an average of roughly 75 gal (285 L) per year. A similar analysis reveals that by diverting automobile commuters to bike-and-ride travel, average savings may amount to roughly 400 gal (1500 L) of gasoline each year for every new bike-and-ride commuter. Although these diversions to bike-and-ride travel would likely result in some additional home-based use of automobiles by other household members, reducing fuel savings, the net energy savings remain substantial. If only 0.5 percent of the U.S. workers who now live 0.25 to 2 miles from a transit route and commute by automobile could be attracted to bike-and-ride travel, nationwide gasoline savings of roughly 20 to 40 million gal (75 to 150 million L) per year would likely be achieved. The diversion of 10 percent of existing automobile park-and-ride commuters to bike and ride could similarly result in

TABLE 3 Estimated Energy Effects of Bike-and-Ride Service Development in the United States

Estimation	Explanation
Diverting Automobile Commuters to Bike and Ride	
22 miles	Average two-way daily commuting distance for noncentral area SMSA automobile commuting trips *(27)*
x 0.074 gal/mile	Fuel use rate based on fleet fuel economy of 17 miles/gal with assumed reduction to 0.8 efficiency due to cold-start factor *(1)*
1.63 gal/day	Fuel savings per day for each automobile commuter diverted to bike and ride
x 250 workdays/year	
407 gal/year	Fuel savings per year for each automobile commuter diverted to bike and ride
Diverting Existing Park-and-Ride Commuters to Bike and Ride	
4.0 miles	Average two-way daily automobile access distance for this group (assumed)
x 0.147 gal/mile	Fuel use rate based on fleet fuel economy of 17 miles/gal with assumed reduction to 0.4 efficiency due to cold-start factor *(1)*
0.59 gal/day	Fuel savings per day for each park-and-ride commuter diverted to bike and ride
x 250 workdays/year	
147 gal/year	Fuel savings per year for each automobile commuter diverted to bike and ride

Note: 1 mile = 1.6 km; 1 gal = 3.8 L.

gasoline use reductions of more than 1 million gal (3 million L) per year nationwide.

Despite the importance of the automobile in American transportation, one-third of all citizens do not possess a driver's license. Even in suburbia, some 12 percent of all households lack an automobile, and many households with two wage earners must make do with one family automobile. Although not suitable for everyone in these market segments, bike-and-ride travel may offer a strong appeal to many such people.

In the evaluation of a federally sponsored demonstration project testing bicycle-transit linkage strategies in Santa Barbara, California, for example, it was found that only one-fourth to one-third of the passengers who parked bicycles at bus stops had an automobile available for their trip without imposing inconvenience on other household members. However, three-fourths of the bike-and-ride travelers came from households owning one or more automobiles compared with 80 percent of general transit users and 90 percent of all households in the Santa Barbara region (18).

In other words, although bike-and-ride services do attract those who use them by choice, they also attract many people from households where mobility is restricted by limited automobile availability combined with poor pedestrian access to suburban transit.

CONCLUSIONS

The experience in Japan, northwestern Europe, and a handful of American communities clearly suggests that bicycles can play a vital role in providing access to suburban express transit routes, both bus and rail. Bike-and-ride services can appeal to many travelers who have automobiles available for their journey and can also attract passengers who are not well served by the existing pedestrian and automobile transit access systems, thereby increasing suburban transit market penetration. Moreover, bicycle access to transit can be encouraged at a far lower cost than automobile access.

Although both automobiles and bicycles have a role in expanding the service areas of transit in lower-density areas, each provides complementary functions. An overreliance on automobile access to transit substantially increases the cost of the public transportation access system, reduces the mobility of those without automobiles, and neglects opportunities for greater fuel conservation and air pollution reduction.

The investments required to develop more multimodal transit access systems in America are modest and affordable. With the passage of the 1982 Surface Transportation Assistance Act, 100 percent funding for bicycle programs and facilities is now available from federal gasoline tax revenues. Programs designed to increase bicycle access to transit, including parking construction and marketing, qualify under this new law. If transit agencies or local governments apply to their state governments for such funds, they will be able to establish more balanced transit access systems without straining overextended operating budgets or requiring scarce local matching funds. A number of other federal funding programs, including transit capital grants, are also available to finance transit access system improvements.

Bicycle-transit linkage will likely contribute only modestly to the growth or stabilization of U.S. suburban public transportation. However, as suggested in this paper, the greater integration of bicycles with transit opens up new opportunities for transit agencies at low cost in markets that have until now been neglected or penetrated only by relying on the more expensive strategy of park-and-ride services.

The fiscal austerity of the 1980s demands new approaches to transit development and the application of numerous small-scale, locally appropriate, low-cost strategies to promote better coordination between different transportation modes. Bicycle-transit integration has an important role to play in this larger context by helping to adapt transit to its modern nemesis, the suburb.

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Bicycle-Motor Vehicle Accidents in the Boston Metropolitan Region

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ABSTRACT

The Metropolitan Area Planning Council, the regional planning agency for the Boston metropolitan area, studied bicycle-motor vehicle accidents occurring within Route 128, a major beltway encircling 35 communities. A sample of one of every four accidents reported to the Massachusetts Registry of Motor Vehicles in 1979 and 1980 was chosen for review. Data were collected by a paid intern and by six volunteers who reviewed bicycle accidents occurring within their individual communities. This sampling technique resulted in a distribution of accidents by month and location statistically almost identical with the distribution for all accidents in the study area. The accidents were classified by using a modified version of the classification system developed by Kenneth Cross. The accident class with the highest frequency involved a motorist turning right or left at an intersection and hitting a bicyclist coming from behind or from the opposite leg of the intersection. Virtually as frequent was the accident in which a motorist entered an intersection and struck a cyclist emerging from the orthogonal leg. These accidents occurred primarily among cyclists more than 18 years of age. Accidents in which the cyclist entered the road at a midblock location (bicycle ride-out) also occurred with some frequency, particularly among children younger than 11. Frequencies of key variables such as time of accident were also obtained. Recommendations include publicity of the study results, education of bicyclists and motorists, increased enforcement of traffic laws, and improved record keeping for ongoing classification of bicycle-motor vehicle accidents.

In 1982, in response to the request of the Environmental Protection Agency (EPA) for the development of reasonably available control measures (RACMs) to reduce air pollution in the Boston metropolitan