They can work. What is needed now is further expansion of these applications to other locales that are confronted with similar pressures: to unclog streets, to comply with air quality standards, to encourage the use of more energy-efficient modes, and at the same time not to impair the mobility and safety of highway users.

The challenge is whether we will take the initiative and use our expertise in employing traffic management techniques to influence the highway user to switch from the most inefficient highway travel mode (one person per automobile) to the much more efficient modes (car pools and buses).

We must be willing to implement techniques that can solve several problems simultaneously. Preferential treatment for high-occupancy vehicles is one of those rare solutions that offers relief from the intricate problems of energy consumption, urban congestion, and air and noise pollution at maximum benefit with minimum harm.

PEDESTRIAN AND BICYCLE PROVISIONS OF TRANSPORTATION SYSTEM MANAGEMENT

Walter H. Kraft
Edwards and Kelcey, Inc.

Walking and bicycle transportation modes can complement the transportation network and yield desirable social, economic, environmental, and health benefits. Among the actions that should be considered to ensure the efficient use of existing street space are the appropriate provisions for bicycle and pedestrian facilities such as bicycle paths and exclusive lanes, pedestrian malls and other means of separating pedestrian and vehicular traffic, and secure and convenient storage areas for bicycles. This paper estimates that potential for travel by walking and bicycle modes and hypothesizes that this potential will continue to increase. The various options for pedestrian and bicycle facilities are described and examples are given. Pedestrian and bicycle provisions included in the transportation system management elements of the Tri-State and Delaware Valley regions are described.

The development of pedestrian and bicycle facilities in this country has traditionally been affected by advances in technology. Historically, walking distances have determined the patterns of human settlements. The development of rail and roadway systems lessened the need to live close to one's work or market area. Transportation networks developed to meet the demands brought about by the segregation of land uses and the desire by many people to live in a suburban or exurban environment. This network, which relied primarily on the automobile and the accompanying highway system, gave minimal attention to alternate transportation modes. Subsequently, the needs of the pedestrian and the bicyclist have been largely ignored. It is interesting to note that in the earlier part of the twentieth century bicyclists were one of the major forces behind the "good roads movement" that eventually benefited the automobile.

In recent years, we have recognized that a single mode of transportation, such as the automobile, cannot solve all urban transportation problems. We have also developed a heightened sensitivity to natural surroundings and increased concern about energy depletion and our dependence on foreign energy sources.

Since our basic transportation systems have been developed and represent a substantial investment, to scrap them and start anew is not feasible. The basic objective then becomes one of making better use of existing facilities. Traditionally, better use has meant an increase in highway capacity by improved signs, signal controls, and other techniques. Recently, there has been an increased effort to improve use of public transportation facilities. The major emphasis is on moving people, not vehicles.

Since the 1960s, the bicycle has been increasingly used as a transportation as well as a recreational vehicle, and facilities for bicyclists and pedestrians are being planned and built in many urban areas. Although biking and walking are not expected to replace the automobile or public transportation as major modes of transportation, they can complement the transportation network and yield desirable social, economic, environmental, and health benefits.

As stated in the September 17, 1975, issue of the Federal Register (1),

> Automobiles, public transit, taxis, pedestrians and bicycles should be considered as elements of one single urban transportation system. The objective of urban transportation system management is to coordinate these individual elements through operating, regulatory, and service policies so as to achieve maximum efficiency and productivity for the system as a whole.

The purpose of this paper is to discuss the options that are available for providing adequate facilities for pedestrians and bicyclists. But, first, the potential for travel by pedestrian and bicycle modes is discussed and considered in the context of the total system.

POTENTIAL FOR TRAVEL BY PEDESTRIAN AND BICYCLE MODES

In 1975, the population of the United States was about 214 million persons. If it is assumed that 10 percent have handicaps that prevent them from walking and another 8 percent are too young to walk, then the total number of persons potentially able to travel by walking is about 176 million. In general, travel by all other modes requires at least one pedestrian link for access to the primary mode, circulation within major activity centers, or modal transfer. Therefore, the potential of travel by a pedestrian mode is great and can be expected to increase.

Estimates are that in 1975 there were 75 million bicycles in use and 100 million users and that there is a potential market of 75 million new customers consisting of 25 million who use but do not own bicycles and 50 million who neither own nor use bicycles (2). The potential for bicycle travel is great and can be expected to increase.

It is important to know the potential for travel by

Table 1. Characteristics of bicycle trips by adults in 1974.

Trip Purpose	Percent of Total Trips	Percent of Total Kilometers	Average Person Trips per Month	Average Round Trip Distance (km)
Work and school	33.1	34.9	13.8	13.0
Recreation and touring	29.3	84.3	7.1	35.7
Utility	17.6	10.3	7.5	7.2
Exercise	16.1	21.4	9.1	16.4
Racing	3.9	9.9	9.3	32.0

Note: 1 km = 0.6 mile.

Figure 1. Average number of months bicycles were ridden in 1974.

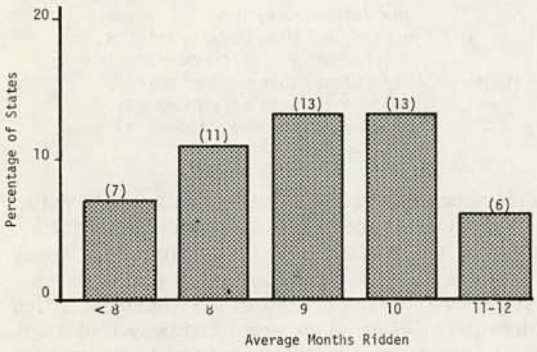
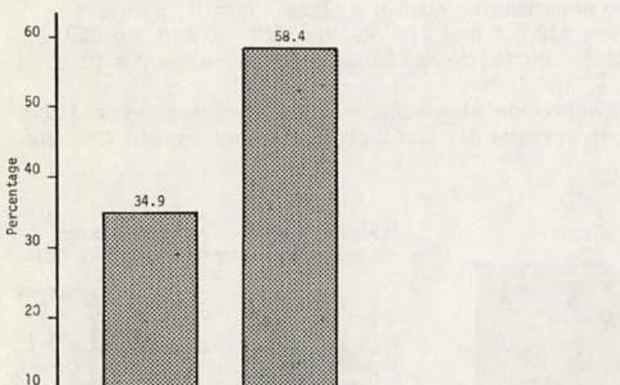


Figure 2. Type of facilities on which bicycles were ridden in 1974.



pedestrian and bicycle modes, but it is also important to know about the characteristics of travel by these modes. Characteristics of pedestrian travel have been widely reported and are fairly well known. For this reason, I will concentrate on some characteristics of bicycle travel.

About 43 percent of all urban work trips are less than 6.5 km (4 miles) in length (3). This is a distance that could easily be traveled by bicycle in a relatively short amount of time. The results of a nationwide survey of regular adult bicycle users are given in Table 1 (4). The average round trip for work and school trips is 13 km (8.1 miles). Work and school trips account for 33.1 percent of total bicycle trips and utility trips for 17.6 percent (i.e., shopping, personal business), indicating that 50.7 percent of total bicycle trips were made for transportation purposes.

Figure 1 (4) shows that the average number of months bicycles are ridden in all states is 9. Even respondents in Alaska reported that they rode an average of 6 months. Respondents reported that their average age was 37.7 years and that the largest percentage of their trips were made on minor streets as shown in Figure 2 (4).

Other studies have found that an average of 35 percent of the population in Pennsylvania, Tennessee, and the District of Columbia are bicycle users (5, 6, 7). In these studies, a bicycle user was defined as a person having ridden a bicycle at least once during the previous year. If it can be assumed that the national percentage of bicycle users is 35 and that all 43 percent of the urban trips under 6.5 km (4 miles) can be made by bicycles, then the potential for the bicycle as a transportation mode is 15 percent of all urban work trips. Of course, this number should be cautiously used since those persons who have never ridden a bicycle are potential users and some of the trips under 6.5 km (4 miles) will be made by walking.

Figure 3. Placement of the bicycle path.

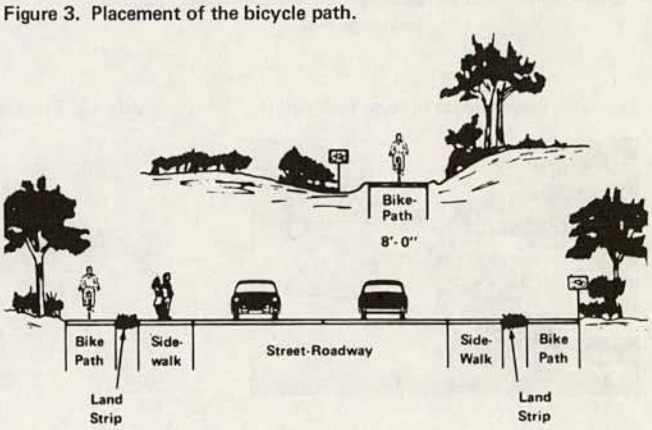


Figure 4. Belt Parkway Bike Path in New York City.

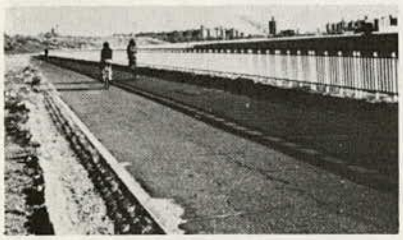


Figure 5. Bicycle path at the University of Colorado in Boulder.

Figure 6. Brooklyn Bridge Bike Path in New York City.

OPTIONS FOR PEDESTRIAN AND BICYCLE FACILITIES

Of the four transportation system management options discussed below for pedestrian and bicycle facilities, three deal with bicyclists and one with pedestrians. In all cases, the use of these options is to promote walking and bicycling as alternatives to using the private automobile for short trips. A major concern is the separation or minimization of conflicts that arise between these modes and the vehicles used for the other modes.

Figure 7. Placement of the bicycle lane.

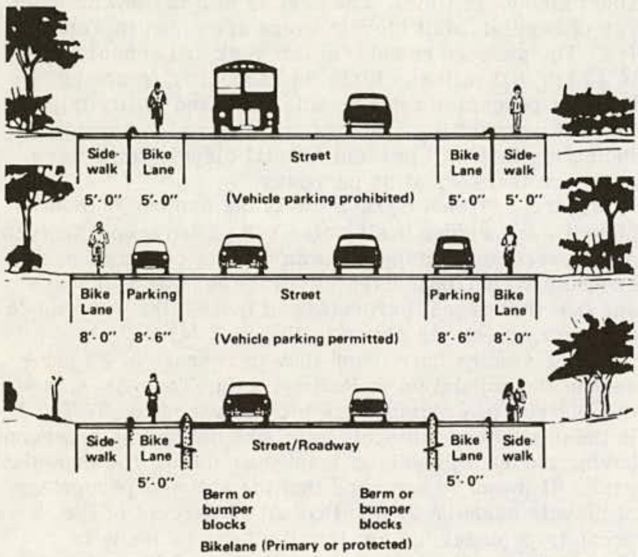
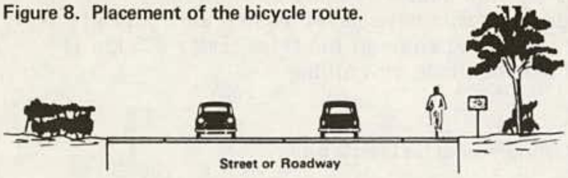


Figure 8. Placement of the bicycle route.



Bicycle Paths and Exclusive Lanes

Bikeways can be divided into three major classes:

Class	Name	Description
1	Path	A facility set aside for the exclusive use of bicycles on a completely separate right-of-way.
2	Lane	A restricted right-of-way for the exclusive or semiexclusive use of bicycles usually within the limits of a vehicular roadway and on which vehicle parking and cross flows by vehicles and pedestrians may be permitted.
3	Route	A right-of-way that is shared with motor vehicles or pedestrians and that may be signed or marked as a bicycle route.

Figure 3 (15) shows the class 1 facility or bicycle path, which is the most desirable type of bikeway from the standpoint of limited conflicts with other modes. It has been the least desirable type of facility in some states where bicyclists have been forced to use these facilities when they are parallel to an adjacent roadway. In most cases, bicycle paths are located in parks, adjacent to controlled access highways, or on abandoned railroad rights-of-way. Because of the intense competition for space, they have limited use in developed urban areas. The construction cost of a class 1 facility ranges between $12 000 and $19 000/km ($20 000 and $30 000/mile). Photographs of bike paths are shown in Figures 4, 5, and 6.

On streets where motor vehicle volumes exceed 2000 on an average day and bicycle volumes exceed 200, con-

Figure 9. Bicycle route in New York City.

Figure 10. Bicycle route in Miami.

Figure 11. Lane in Newark for buses, bicycles, and other vehicles turning right.

Figure 12. Pedestrian facilities on the Avenue of the Americas in New York City.

Figure 13. Nicollet Mall in Minneapolis.

Figure 14. Lexington Mall in Baltimore.

sideration should be given to the creation of class 2 bicycle facilities (8). Figure 7 (15) shows the location of bicycle lanes. These facilities provide a lane for the exclusive use of bicycles except where motor vehicles must cross at intersections, park, or enter driveways. Some experienced bicyclists do not like bicycle lanes, for they feel that they are restricted from mixing with the motor vehicle traffic and are forced to conflict with this traffic at intersections and driveway entrances in a fashion that can create more problems than it solves. Class 2 facilities are best suited for accommodating sizable bicycle demands in areas where there are few intersections and where motor vehicle traffic travels at speeds greater than those attainable by bicyclists. However, in urban areas where traffic speed is in the range of 16 to 40 km/h (10 to 25 mph), the cyclist may be better off riding in the overall traffic stream. The class 2 facility can cost between \$1200 and \$1900/km (\$2000 and \$3000/mile) to construct depending on the method selected to delineate the bicycle lane (i.e., paint stripe, physical barrier) from the motor vehicle lanes.

Figure 8 (15) shows the most common form of bicycle facility, which is the signed bicycle route or the class 3 bicycle facility. The major advantage of the bicycle route is that motorists are given formal notice by the use of standard signs that cyclists may be present. Although class 3 facilities are generally located on streets carrying little traffic, many cities have instituted bicycle routes on major avenues, such as Third Avenue in New York City (Figure 9). Such facilities can generally be implemented at a cost of \$300 to \$650/km (\$500 to \$1000/mile). Other examples of bicycle routes are shown in Figures 10 and 11.

Signed bicycle routes are not exclusive lanes for bicyclists. Furthermore, most commuter bicyclists will select any route, signed or unsigned, that is most desirable to them (i.e., one that is fastest or has fewest automobiles). Therefore, the class 3 facility is best applied in areas where the street systems are such that most bicyclists in the area tend to use the signed route or where there are points of interest that will attract recreational bicyclists.

In most cases, the creation of a bicycle transportation system requires a combination of the three classes of bikeways in a manner determined by needs, competition for space, and fiscal realities. The true value of a bicycle transportation system is determined by the cost savings that will be accrued by an increase in bicycle commuters and a decrease in automobile commuters. Planners of new residential subdivisions and in-town plazas should consider the bicycle as part of the transportation system and thereby foster the use of this efficient and nonpolluting means of moving people.

Pedestrian Malls and Other Means of Separating Pedestrian and Vehicular Traffic

Pedestrian travel involves a conflict between people and natural or man-made elements. The pedestrian has had to suffer the natural elements of cold, heat, dust, rain, snow, and wind and the man-made elements of vehicular transportation. Means have now been developed that allows the pedestrian to travel within a controlled environment thereby mitigating the effects of the natural elements. Conflicts with man-made elements can be eliminated by a physical or time separation (10).

The physical separations can be either horizontal or vertical. Types of horizontal separation are the sidewalk, partial mall, street closing, or full mall. An example of this type of separation is the redesigned portion of the Avenue of the Americas in New York City (Figure 12). In this project, sidewalks of 3 to 4.6 m (10 to 15 ft) are defined by a double row of trees providing an uncluttered path for pedestrians. Newly created pedestrian spaces were formed by straightening out streets and using the former roadway area for a miniplaza or sidewalk. Other examples are Nicollet Mall in Minneapolis, where sidewalk areas have been widened for pedestrians and only transit vehicles are permitted on the roadway portion of the street (Figure 13), and Lexington Mall in Baltimore (Figure 14), which is currently two blocks long and will be extended to three. Its character was always that of a pedestrian street. When the mall is extended to a length of three blocks, it will tie together Charles Center, another pedestrian area (Figure 15), with major department stores and a station on the new transit system. Other types of horizontal separations include permanent street closings that ban all vehicles or those that may permit truck deliveries. One such example is located in an urban renewal area in Jersey City and is shown in Figure 16. Vertical separation of pedestrian and vehicular systems may be done below or above ground. The pedestrian mall at the Place Ville-Marie in Montreal is below ground (Figure 17). Pedestrian bridges or skyways have been built in San Juan, Minneapolis, Newark, and Denver (Figures 18, 19, 20, and 21). Many skyways, such as the one in Denver, have commercial establishments located within them. Skyways have many times helped to revitalize the business areas of the downtown community, but they should be located where there is heavy pedestrian travel.

Pedestrians and vehicles can also be separated by time either by separate signal phases for vehicles and pedestrians or temporary street closings. Examples of temporary street closings are Nassau Street in New York City and Royal and Bourbon Streets in New Orleans (Figures 22 and 23).

In all cases, the separation of pedestrians and vehicles has increased the safety of pedestrians and improved the pleasantness of walking. Other benefits of carefully planned pedestrian zones include reduced traffic congestion, reduced air and noise pollution, reversed slump in retail sales, and recaptured ambience that only cities have (10).

Secure and Convenient Storage Areas for Bicycles

One of the most difficult problems a bicyclist faces is the lack of secure bicycle parking facilities. Reports submitted from 1723 cities in the United States reveal that more than 0.5 million bicycles are stolen annually (11). Police in California estimate that the value of stolen bicycles during 1971 was \$22.3 million. The current resale value of a multispeed bicycle ranges between \$40 and \$300, which may encourage the professional bicycle thief to take more frequent and higher risks. At the present time, the bicyclist is at a disadvantage to the professional bicycle thief. The thief has available a variety of tools that include metal cutters, hacksaws, pry bars, and hammers. A bicycle is usually secured to a stationary object (Figure 24). The question of how secure the bicycle is or how stationary the object is is usually answered when the bicyclist returns to the parking place. There are three methods of securing a bicycle: chaining and locking the bicycle to a fixed object; locking the bicycle in a rack; and locking the bicycle in a locker.

Table 2 (12) gives the results of tests conducted by prying, smashing, bolt cutting, shear cutting, and hacksawing various locks and chains. Most locks or chains were cut in fewer than 30 s. The most successful type of lock was the Citadel, which required 13 min of hacksawing.

Figure 15. Charles Center in Baltimore.

Figure 16. Restricted Street in Jersey City.

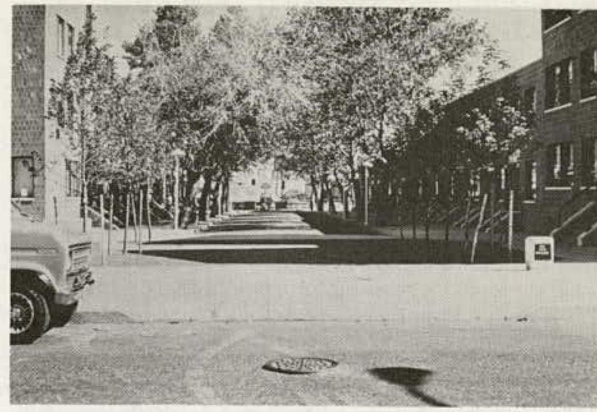


Figure 17. Below-ground pedestrianway in Place Ville-Marie in Montreal.

Figure 18. Pedestrian bridge in San Juan.

Figure 19. Pedestrian bridge in Minneapolis.

Figure 20. Pedestrian bridge in Newark.

Figure 21. Pedestrian bridge in Denver.

Figure 22. Nassau Street closed in New York City.

Figure 23. Royal Street closed in New Orleans.

Figure 24. Bicycle secured to stationary objects.

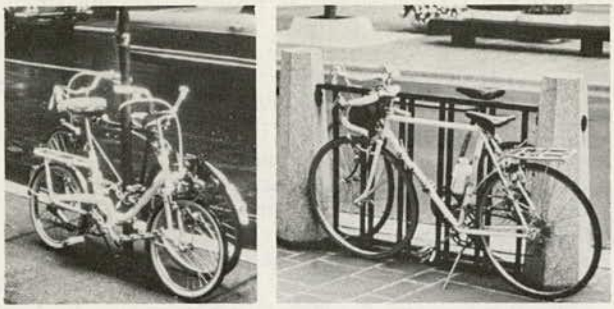


Table 2. Destruction tests of bicycle chains and locks.

Product	Pry Bar	Smashing	Bolt Cutters	Shear Cutters	Hacksaw
Citadel lock	—[a]	—[a]	—[a]	—[a]	780
9.5-mm through-hardened chain	—[a]	—[a]	95	—[a]	—
Kryptonite	—[a]	—[a]	—[a]	16	—
9.5-mm case-hardened chain	—[a]	—[a]	2	—[a]	—
Spoiler lock	—[a]	—[a]	30	1	—
Campbell cable	—[a]	—[a]	12	1	—

Notes: 1 mm = 2.54 in.
The Transportation Research Board does not endorse products or manufacturers. Trade names are given in this report because they are considered essential to its object.
[a]Not cut.

Figure 25. Bicycle secured in racks.

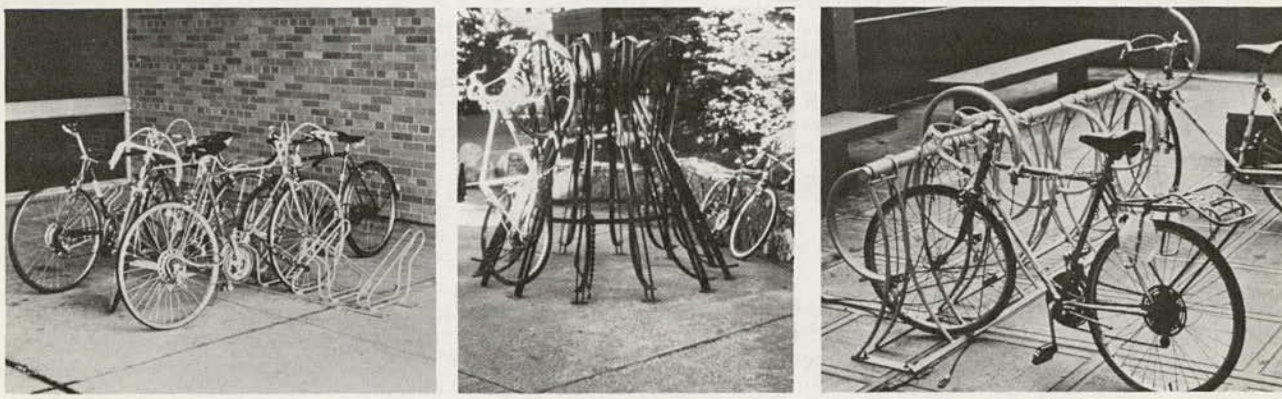
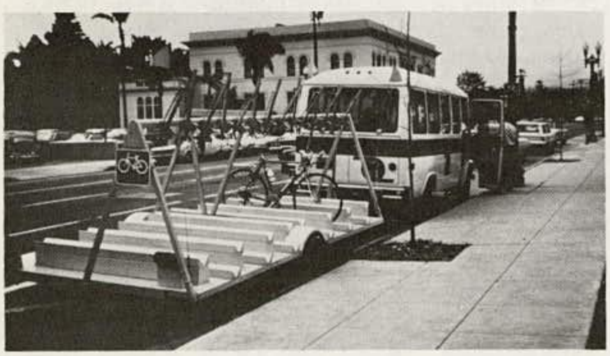


Figure 26. Santa Barbara bike bus.



There are many different types of bicycle parking racks (Figure 25). Some have integral coin-operated locks, and others require that the bicycle be locked and chained to the rack. One system employs a curved steel arm that springs over the bicycle frame and clamps around it. A woven steel aircraft cable both encircles the wheel rim and joins the frame clamp with a padlock. Another type of system is to enclose the bicycle in a cabinet. This method has two advantages: The bicycle is removed from visual temptation, and the bicycle is removed from access. The lockers are coin operated and can be installed in many different arrangements. A single automobile parking space will accommodate as many as eight locker units.

Other Measures to Facilitate Bicycle Use

Other means to facilitate the use of bicycles as a mode of transportation include encouraging persons to use bicycles to go to or from other modes. The Port Authority Trans-Hudson Corporation (PATH) linking Newark, Jersey City, and Hoboken with Lower and Midtown Manhattan permits bicyclists to take their bicycles on the rail rapid system during off-peak hours. This does not help during the commuter rush, but it does provide for a line-haul function between city centers and permits the bicycle to be used as a local distribution vehicle. Many rail systems do not permit bicycles in the transit vehicles.

Other means are being developed to provide a line-haul function by bus to permit the bicycle to be used as a local distribution vehicle. One of these was developed by David Eggleston of San Diego State University. It includes a bicycle trailer that is capable of carrying eight bicycles and is towed by a nine-passenger van (Figure 26).

Another means of encouraging bicycle commuting is to provide park-and-ride facilities at both ends of the trip so that drivers are encouraged to put bicycle racks on their automobiles and use them as a local distribution vehicle.

PEDESTRIAN AND BICYCLE PROVISIONS IN CURRENT TSM ELEMENTS

Provisions for pedestrians and bicycles included in current TSM elements are described below for two regions.

In the Tri-State Metropolitan region, which includes portions of Connecticut, New Jersey, and New York, bikeways are being planned or constructed at four locations in New York State and 40 locations in New Jersey (13). In New York City, plans are being developed for pedestrian facilities on Fulton Street in downtown Brooklyn, underground pedestrian ways in lower Manhattan, and a pedestrian mall in the Times Square area. Studies are being conducted of pedestrian movement in the Herald-Greeley Square areas, pedestrian street space in Coney Island, pedestrian mobility in the Jamaica Commercial Center, and conflicts between vehicle and pedestrians in the Midtown Manhattan area. In New Jersey, pedestrian facilities being planned include a pedestrian shopping mall in Paterson and a pedestrian mall in Jersey City. Provisions have been or are being made for bicycle parking facilities at many locations in the Tri-State area.

In the Delaware Valley region, most bikeway planning is taking place in New Jersey. Existing Pennsylvania bike paths are confined to state parks, notably the Ridley Creek, Tyler, and Valley Forge areas. Most of the existing facilities devoted to the separation of pedestrians and motor vehicles are concentrated in the Philadelphia central business district including the Underground Concourse System, which connects approximately a 2.6-km^2 (1-$mile^2$) area of downtown Philadelphia. Another prominent and relatively new addition is the Chestnut Street transitway, which was opened in November 1975. Other pedestrian facilities include new highrise commercial buildings and the University of Pennsylvania hospital complex. At the present time, there is no planned program for the provision of bicycle parking facilities.

ACKNOWLEDGMENTS

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PARKING MANAGEMENT STRATEGIES

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This paper provides an overview of the range of parking management strategies. Particular emphasis is placed on describing the strategies and the considerations pertinent to their implementation in specific metropolitan areas. Because of the current interest in transportation system management, the paper is organized around the categories of parking management and control actions identified in the TSM regulations.

Increasing recognition is being given to the important role that the availability and quality of parking can play in shaping the overall service provided by the urban transportation system and in achieving other community objectives. The usefulness of the automobile can be impeded if the driver is unable to find convenient and reasonably priced parking in the vicinity of his or her final destination. Similarly, the ease of access to a transit station and the difficulty of driving and parking near the final destination are important factors influencing a traveler's choice of mode. Consequently, there has been an increased recognition—particularly at the federal level—that public policies influencing the availability and pricing of parking can be used to achieve air quality, energy conservation, and congestion reduction.

FEDERAL PARKING MANAGEMENT INITIATIVES

Environmental Protection Agency

Both the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation (DOT) have undertaken parking management initiatives. In late 1973, EPA promulgated or approved transportation control plans for 30 major urban areas. Some of these included parking management initiatives with respect to both the price and the availability of parking.

Parking surcharges were promulgated by EPA in the