A FRAMEWORK FOR INVESTING IN URBAN BICYCLE FACILITIES

Carl E. Ohrn and Richard C. Podolske,
Barton-Aschman Associates, Inc., Minneapolis

The bicycle as a transportation and recreation mode has explosively entered the public's consciousness. Accompanying this phenomenon has been a rash of problems including a sharp increase in accident rates and thievery. There is a need to provide facilities that will reduce these problems and accommodate the expected increase in bicycling popularity. This paper raises four basic questions, the answers to which will assist in planning urban bicycle facilities on a more organized basis with a minimum of misdirected effort and a maximum amount of coordination. How much money should be invested in bicycle facilities? What types of trips are the best candidates for bicycling? What type of bicycle facilities should be provided? Where should these bicycle facilities be placed? At this stage of urban bicycle facility planning, these questions are only beginning to be asked and are far from being resolved. Planning and engineering of bicycle facilities are essentially in a shakedown period in which many good and bad ideas will be tested before the best solutions surface and become the norm.

•ASSEMBLY-LINE techniques brought about a dramatic drop in the cost of the bicycle in the mid-1890s. With this, America's first "bicycle craze" was on, and, like today, bicycle advocates were clamoring for better conditions for bicycling. Albert Pope, a prominent bicycle manufacturer of the time, estimated that it cost an astronomical $1½ billion annually to feed the nation's horses and mules. He contended that the American farmer would save $700 million annually on fodder if $20 billion were invested in surfaced roads because they would eliminate the need for so much horsepower (4). His ulterior motive, however, was to improve conditions for bicycling.

The League of American Wheelmen took up the cause for better roads with such zeal that in 1902 it changed its name to the American Road Builders' Association to ensure the best possible bargaining posture. Joining the League and other bicycle advocates were supporters of the new rich man's toy, the automobile. It is ironic that the successful pioneering efforts of bicyclists to improve road surfaces helped spawn the automobile era. Today, the most serious deterrent to good bicycling conditions is conflicts between bicycles and automobiles due to their sharing the same road surface.

In spite of this deterrent to bicycling, the current U.S. bicycle boom is unprecedented in magnitude. It has been estimated that a maximum of 400,000 bicycles were sold annually during the peak of the first bicycle boom in the 1890s, as opposed to 13.7 million bicycles in 1972 (4, 5). If it is assumed that the average price of a new bicycle with accessories is $80, bicycle manufacturing has become a billion dollar a year industry.

The governmental response to this current popularity can be characterized as minimal, piecemeal, and uncoordinated. Even though annual bicycle sales currently average $5 for every man, woman, and child in the country, fewer than 10 percent of the nation's cities have provided any kind of facility to enhance the use of bicycles. Of those facilities that are provided, most are in the form of signed routes offering relatively little protection to the bicyclist. Fewer than 1 percent of all cities have ex-

Publication of this paper sponsored by Committee on Social, Economic and Environmental Factors of Transportation.

clusive bicycle lanes in operation (6). Where there are bicycling facilities, they frequently have been constructed with dramatically varying design standards and with little regard for their integration into a system covering the entire urban area. In many cities there appears to be a decided lack of coordination between advocates of bicycle systems and those in charge of providing other related transportation and recreational facilities.

To begin planning urban bicycle facilities on a more organized basis, with a minimum of misdirected effort, and with a maximum amount of coordination requires that at least four basic questions be resolved.

1. How much money should be invested in bicycle facilities?
2. What types of and how many trips are candidates for bicycling?
3. What types of bicycle facilities should be provided?
4. Where should these bicycle facilities be placed?

At this stage of urban bicycle facility planning, these questions are only beginning to be asked and are far from being resolved. Planning and engineering of bicycle facilities are in a shakedown period in which many ideas will be tested before the best solutions surface and become the norm. This paper adds one more perspective on the problem in hopes that the bicycle will finally receive a fair test of its considerable potential within the United States.

HOW MUCH MONEY SHOULD BE INVESTED IN BICYCLE FACILITIES?

A major deterrent to the commitment of substantial funds for bicycle facilities is the haunting question, Is the bicycle boom a fad? Most available evidence indicates that it is not.

Current Sales

The current rise in the popularity of bicycles has frequently been called a boom or explosion. This labeling of the phenomenon is inappropriate inasmuch as bicycle sales have approximated or exceeded 7 million annually for at least the past 5 years (Table 1) (5). Moreover, bicycle sales have increased or decreased on an annual basis similar to the more firmly established automobile. If the bicycle phenomenon were a fad, this sales pattern would not have been sustained over such a period of time.

Upward Long-Term Trend

Although sales of bicycles have been cyclic, every major bicycle sales boom has been larger than the previous one. For example, after the bicycle "dark ages" in the 1920s, when the American public adopted the automobile en masse as the primary means of transportation, the bicycle enjoyed a major revival. By 1935, bicycle factories were manufacturing more than 600,000 bicycles. In 1936, more than a million bicycles were sold. During World War II, the bicycle was seen as a partial solution to the problem of gasoline rationing; however, this idea was never carried out, for bicycle production nearly ceased in favor of more urgent war material production. Shortly after the war, another bicycle boom occurred; by 1948, it was estimated that over 12 million bicycles were in use (4). Again, in the 1950s, bicycling became popular partly on the advice of Dr. Paul Dudley White who became the evangelist of the "health-through-cycling" cause. At this time, however, only 15 percent of the nation's population were bicycling. By 1960, this figure rose to 20 percent and, by 1970, to approximately 37 percent (5). If the 1950 to 1970 trend continues, approximately half of the nation's population will be bicycle riders by 1980.

Market Saturation

Like all product sales, there is a point at which the bicycle market will be saturated. However, available evidence indicates that the market is nowhere near saturation in the United States. In the Netherlands, for example, where bicycling conditions are nearly ideal, 76 percent of the nation's population are bicyclists. A similar situation exists in frequently cited Davis, California, where three-fourths of the town's population are bicyclists (2). Whereas conditions in all American cities will not be so ideal, there is sufficient evidence to indicate that there still is a large, untapped bicycle sales market.

If the current popularity of bicycling is not a fad, there is a need to develop a means to justify reasonable levels of expenditures for bicycle facility development in urban areas. One point is clear: Traditional "pay-as-you-go" transportation economics will not work as a means for justifying expenditures on bicycle facilities. The bicycle does not produce revenue in its own right, either through the fare box as in mass transit or through gasoline taxation as in the case of the automobile. Even if the bicycle could produce revenue, an economic test would not be completely fair, given the currently underdeveloped state of bikeways. The potential of bicycle use will be unknown in the United States until safe systems are implemented to test bicycling in different situations. This is particularly true in the category of purposeful trip-making.

Given that traditional transportation economics will not work, what justifications are there for supporting long-term investments in bicycle facilities? Among those methods that might be considered are

1. A "quality of life" rationale,
2. Environmental quality and preservation,
3. Economic substitution for the automobile,
4. Relationship to other recreational expenditures,
5. Expenditures as a function of bicycle sales, and
6. Expenditures as a percentage of the total transportation budget.

A brief description of these approaches follows.

Quality of Life

Numerous experts have contended that bicycling is a pleasurable and effective form of exercise. Perhaps most overlooked under this rationale is the notion that variety is the spice of life. The mere opportunity to ride a bicycle because a person may feel like it has some value in our affluent society. Although all of these factors could be used to justify expenditures on bicycle facilities, they defy easy quantification and, consequently, have limited utility in the bicycle advocate's tool kit for obtaining bicycle facility development funds.

Environmental Quality and Preservation

Numerous environmental reasons such as reduction of air and noise pollution and economy of fuel resources have been advocated as a means for justifying expenditures on bikeways. However, these benefits would be extremely difficult to measure in the short run; and, given the long-term trend toward increased use of motor vehicles, there is considerable doubt whether even dramatically increased use of the bicycle would cause a reduction in pollution in the long run.

Economic Substitution for the Automobile

The cost of constructing bikeways could be compared to the cost of building additional streets, highways, and parking lots. If the number of person trips per dollar of investment on bicycle facilities were higher than the corresponding ratio of person-trips to dollars spent on streets and highways, it might be argued that bicycle expenditures on a large scale would be justified. In this vein, it is interesting to note that the British have concluded that the passenger-carrying capacity of a 12-ft (3.7-m) cycleway exceeds the capacity of a 24-ft (7.3-m) carriageway and that one cycleway accordingly saves one 12-ft (3.7-m) lane of carriageway (3). Added to this argument could be the less demanding parking requirements of the bicycle. However, there are so many factors to consider in this complicated bike-versus-automobile relationship that it would be difficult to deal with this type of economic analysis on a quantitative basis.

Relationship to Other Recreational Expenditures

A comparison could be made between participant hours of bicycling and participant hours in other sports such as golfing, tennis, or swimming. Based on this comparison, a determination could be made of the level of public expenditure versus recreational hours. The probable result of such an analysis would be that expenditures on bicycle facilities are comparatively deficient. As a rough measure of the need for bicycle facilities, the Bureau of Outdoor Recreation in 1970 recommended a minimum standard of 50 miles (80 km) of cycle paths for every 100,000 city dwellers (4). Translated to U.S. urban areas, this amounts to approximately 75,000 miles (121 000 km) of cycle paths.

Expenditures as a Function of Bicycle Sales

It could be argued that, for every bicycle sold, an increment of investment should be made on bicycle facilities. For example, if we assume a sales volume of 10 million bicycles per year at an average cost of $80 per bicycle including accessories, $800 million is spent annually on the purchase of bicycles. If this money were matched by expenditures for bicycle facilities (about the situation with the automobile) there would be approximately enough money to annually finance 80,000 miles (129 000 km) of paved bicycle paths (assuming a cost of $10,000 per mile) within the United States.

Expenditures as a Percentage of Total Transportation Budget

With Oregon leading the procession, there is increasing pressure to tap a specified percentage of Highway Trust Fund money generated by gas taxation to construct bicycle facilities. Currently, total state gas tax revenues amount to more than $7 billion annually (7). If 1 percent of this amount is tapped, there would be $70 million available annually for bicycle facilities.

WHAT TYPES OF AND HOW MANY PERSON-TRIPS ARE CANDIDATES FOR BICYCLING?

As is the case with all public investments, those organizations appropriating funds for bicycle facilities want to receive the greatest benefit per dollar spent. Accordingly, a preliminary attempt was made to determine which types and what volumes of trips were most likely to be made by bicyclists if safe and convenient facilities were provided. This investigation was limited exclusively to purposeful trip-making; it was assumed that recreational use of the bicycle would continue to be popular and that this use of the bicycle could be accommodated without extensive new facilities. It is important to recognize that the number of purposeful bicycle trips being made today is not a valid indication of the number of such trips that might ultimately be expected. Without a good system for bicyclists, the fear of having an accident caused by competing with the automobile for street space is probably the greatest deterrent to purposeful bicycle riding.

The definition of an adequate bicycle system is open to considerable debate. The spacing of bicycle facilities, their location within an urban area, and their design are all very important considerations. However, for the purposes of this analysis, it was assumed that the bicyclist could travel anywhere in an urban area with minimum concern for his personal safety.

Effect of Selected Factors on the Use of the Bicycle

There is no single indication of whether a person will use a bicycle to accommodate his or her travel desires. Furthermore, isolating one factor for a particular trip purpose becomes very difficult without an empirical data base. However, in an attempt to speculate on the kinds of travel desires that would most likely be accommodated by the bicycle, some preliminary criteria were analyzed. These criteria are given in Table 2 along with some subjective ratings of their impact by trip purpose.

Although criteria such as average trip length and age of trip-maker are obviously of

Table 1. Bicycle and automobile sales.

Year	Bicycle Sales (millions)	Automobile Sales (millions)
1967	7.5	10.0
1968	7.1	9.7
1970	6.9	8.1
1971	8.9	10.7
1972	13.7	11.0

Table 2. Effect of selected factors on the probability of bicycle use for functional trip purposes.

Factors Affecting Bicycle Use (typical conditions)	Work	Shopping	School		Personal Business	Recreation[a]	
			Grade	College		Outdoor	Indoor[b]
Flexibility of schedule	Considerable discouragement	Moderate encouragement	Considerable discouragement	Considerable discouragement	Considerable encouragement	Moderate encouragement	Moderate discouragement
Average trip length	Considerable discouragement	Considerable encouragement	Considerable encouragement	Moderate discouragement	Considerable encouragement	Moderate encouragement	Moderate encouragement
Age of trip maker	Limited effect	Limited effect	Considerable encouragement	Considerable encouragement	Moderate discouragement	Moderate encouragement	Limited effect
Availability and cost of automobile parking	Considerable encouragement	Considerable discouragement	Limited effect	Considerable encouragement	Moderate discouragement	Considerable discouragement	Limited effect
Cargo needs of trip	Limited effect	Moderate discouragement	Limited effect	Moderate discouragement	Limited effect	Moderate discouragement	Limited effect
Street congestion[c]	Considerable encouragement	Moderate discouragement	Limited effect	Moderate encouragement	Moderate discouragement	Moderate discouragement	Moderate discouragement
Quality of pedestrian system	Limited effect	Considerable encouragement	Moderate encouragement	Moderate encouragement	Considerable encouragement	Moderate encouragement	Moderate encouragement
Availability of transit	Moderate discouragement	Considerable encouragement	Moderate discouragement	Moderate encouragement	Moderate encouragement	Considerable encouragement	Moderate encouragement

[a]Trip to a recreational activity as opposed to a recreational bicycle trip.
[b]Social gathering, visiting friend, theater, etc.
[c]Assumed bicycle system would provide safe and uncongested route for the bicyclist.

Table 3. Daily home-based vehicular trips that could be attracted to the bicycle (9).

Trip Purpose	Number	Percentage Less Than 6 Min in Duration[a]	Percentage Less Than 6 Min in Duration That Could Be Made by Bicycle	Percentage Attracted to the Bicycle[a]	Number Attracted to Bicycle Use Given Proper Facilities
School	160,000	20.1	50.0	10.0	16,000
Recreation	917,000	35.0	35.0	12.0	100,000
Personal business	666,000	40.5	30.0	12.0	81,000
Shopping	566,000	48.6	20.0	9.7	55,000
Work	829,000	18.9	10.0	2.0	16,000
Medical	48,000	14.0	5.0	0.7	—[b]
Total	3,086,000				268,000

[a]Low percentages in this category are due to the high percentage of pedestrian trips, which are not counted.
[b]Less than 1,000 trips, not significant.

Table 4. Home-based vehicular trips by purpose and mode (9).

Trip Purpose	Assumed Percentage of Bicycle Trips	Estimated Percentage of Trips				Effect of Increased Bicycling on Present Travel Modes
		Automobile		Transit	Other[a]	
		Driver	Passenger			
Personal business	12.0	71.3	22.9	1.9	3.9	Reduce auto passengers and drivers
Recreation	12.0	39.1	57.1	0.9	2.9	Reduce auto passengers
School	10.0	15.7	20.5	4.6	59.2	Reduce school bus trips and auto passengers
Shopping	9.7	64.6	31.3	1.2	2.9	Reduce auto drivers
Work	2.0	75.7	14.3	5.4	4.6	Reduce auto passengers and transit
Medical	0.7	47.7	40.8	8.8	2.7	Negligible

[a]Includes trips by truck, motorcycle, and school bus.

considerable importance, perhaps one of the most underrated factors in determining the purposeful use of the bicycle is the degree of flexibility in trip scheduling. Trips that are most likely to be made by the bicyclist are those that are flexible on both an hourly and a daily basis. This is principally due to weather and traffic conditions, which are often cited as the greatest deterrents to bicycle use. The greater the chance of delaying a trip to avoid precipitation, temporarily unfavorable temperatures, or traffic congestion is, the greater the chance of completing it by means of a bicycle will be. Thus, work trips and school trips with rigid scheduling requirements (as opposed to shopping and personal business trips that might be delayed or postponed) are not particularly good candidates for bicycling based on this criterion. It is also important to consider that work and school trips involve a certain amount of routine. When a given mode of transportation frequently cannot deliver (such as a bicycle in inclement weather), the commuter is likely to switch to another mode of transportation on a permanent basis.

To determine a preliminary order of potential magnitude of purposeful bicycle trip-making, we analyzed travel characteristics in a typical large metropolitan area, the Minneapolis/St. Paul SMSA (Table 3). Only those vehicular trips that were 6 minutes or less in duration were considered to be candidates for bicycling. The 6-min trip was based on an assumed automobile operating speed of 20 mph (32 km/h); a corresponding bicycle trip would be 12 minutes at 10 mph (16 km/h) or 2 miles (3.2 km) in length. (This is the practical limit of heavy bicycle use based on analysis of bicycle user characteristics in other American and European cities.) Then, it was assumed that a percentage of these short trips could be accommodated by the bicycle based on the subjective criteria developed in Table 2. Not surprisingly, recreational trips were most likely to be attracted to the bicycle mode on a given day. The next largest trip categories were shopping and personal business trips. Somewhat surprisingly, work and school trips, which are receiving a lot of attention from bicycle planners, ranked relatively low in bicycle travel magnitudes based on this analysis.

Although the data developed in this exercise were based on a very empirical base, it should be recognized that the potential for purposeful bike riding is considerable in relation to current levels of transit use. For example, the 268,000 daily bicycle trips estimated would be 65 percent more than the 163,000 daily transit trips in the Twin Cities area in 1970. This observation might receive serious consideration by those who are looking for low-cost alternatives to moving people other than by automobile. Whereas transit is extremely useful for moving large volumes of people, especially to concentrated points, bicycles could serve as a supplemental mode of transportation for moving people to dispersed points within a 2-mile (3.2-km) radius.

Impact on Modal Split

Increased use of the bicycle may generate new trips, but certain trips that are currently made by the automobile, transit, or pedestrian mode will be made by the bicycle. An overwhelming percentage of all vehicular trips in the Minneapolis-St. Paul metropolitan area are by the automobile (Table 4). This is, of course, a typical situation in most metropolitan areas in this country. From the pool of automobile users, it is expected that the automobile passenger is the most likely potential convert to the bicycle. In many cases, the automobile passenger is a captive rider, for he may not have ready access to an automobile or may not consider the transit alternative sufficiently convenient. The attraction of a sizable number of automobile passengers to bicycles could have an effect on the transportation system, for in many instances as many as 10 percent of the total automobile trips are solely for the convenience of the passenger.

A much smaller number of bicycle trips might be attracted from transit inasmuch as a relatively small percentage of total trip-making in the metropolitan area is by transit. However, the percentage of trips that might be diverted from transit to the bicycle might be considerably greater than those diverted from the automobile. Transit trips are typically shorter than automobile trips and often involve a substantial amount of time in waiting and transferring. Under these conditions, transit trips are particularly vulnerable to diversion to the bicycle mode.

WHAT TYPES OF BICYCLE FACILITIES SHOULD BE PROVIDED?

Now that we have investigated which types of trips could be accommodated by bicycling, attention is directed toward selecting those facilities that would yield the most benefit per unit of investment. At least four criteria should be considered in the selection of facilities.

1. Safety—Provision of bicycle facilities should be based on the degree of safety offered to bicyclists, principally protection from motor vehicles.
2. Environmental attractiveness—The bicycle is a means of transportation and of recreation and enjoyment; for this reason environmentally pleasant routes are much more important in bicycle planning than in planning for the more utilitarian and higher speed motor vehicles.
3. System continuity—Bikeways should be a continuous system with a minimum of interruptions. Although some types of facilities may be safer or more attractive than others, there are situations in which the most desirable solution is impractical. In those cases, the goal of system continuity should take precedence.
4. Cost—The costs of bicycle facilities must be weighed against the estimated benefits of safety, environmental attractiveness, and system continuity.

Given the criteria for evaluating bicycle facilities, discussion turns to the alternatives. While a wide variety of specific applications are possible, bikeways can be classified into the following five categories (Fig. 1):

1. Bike route—a road signed for bicycling but with bicyclists sharing the road surface with other vehicles.
2. Unprotected bike lane—a lane on street pavement separated from motor vehicle traffic only by a stripe marking the lane.
3. Protected bike lane—a lane on street pavement separated from motor vehicle traffic by a physical barrier.
4. Bike track—a path within a transportation right-of-way separated from the street by an intervening strip of land.
5. Bike path—a bicycle facility completely separated from a street or highway right-of-way.

The cost of these facilities varies considerably; bike routes and unprotected lanes cost far less than the other alternatives (Table 5). Therefore, it is not surprising that bike routes and unprotected bike lanes constitute the dominant proportion of all bikeways within urban areas.

Although it would be desirable to build systems that provide bicyclists with a maximum amount of physical protection from motorists, this desire must be balanced against the amount of funds that might become available for biking facilities. One way of measuring the effect of this restriction is to estimate the number of system-miles that would be desirable in an urban area and then to assess the potential cost of such a system for each of the five types of biking facilities. Such an analysis was undertaken for Atlanta. Hypothetical bikeways laid out in grids with ½-, 1-, 2-, and 4-mile (0.8-, 1.6-, 3.2-, and 6.4-km) spacings were evaluated within the 500-square-mile (1300-km^2) urban area. The costs varied dramatically (Table 6) from $200,000 for signed routes on a 4-mile spacing to a conservatively estimated $20 million for bicycle tracks or bike paths on a ½-mile spacing (8).

In regard to facility spacing, generally bicycle facilities should be spaced no more than ¼ to ½ mile (0.4 to 0.8 km) apart if a useful bicycle system is to be provided in all parts of an urban area. This rather close spacing is required since most bicycle trips are no longer than 2 miles (3.2 km) (Fig. 2).

Given this spacing, the smallest bike route system for the Atlanta area was estimated to cost $900,000. Although this cost is considerable, higher level treatments on a systemwide basis appear to be unattainable in the short run even with currently proposed financing. For example, even if 1 percent of all federal and state highway and street funds were diverted for biking facilities, it would take at least 20 years to finance a system of bike tracks or bike paths in the Atlanta metropolitan area on the desired ½-

Figure 1. Bicycle facility alternatives.

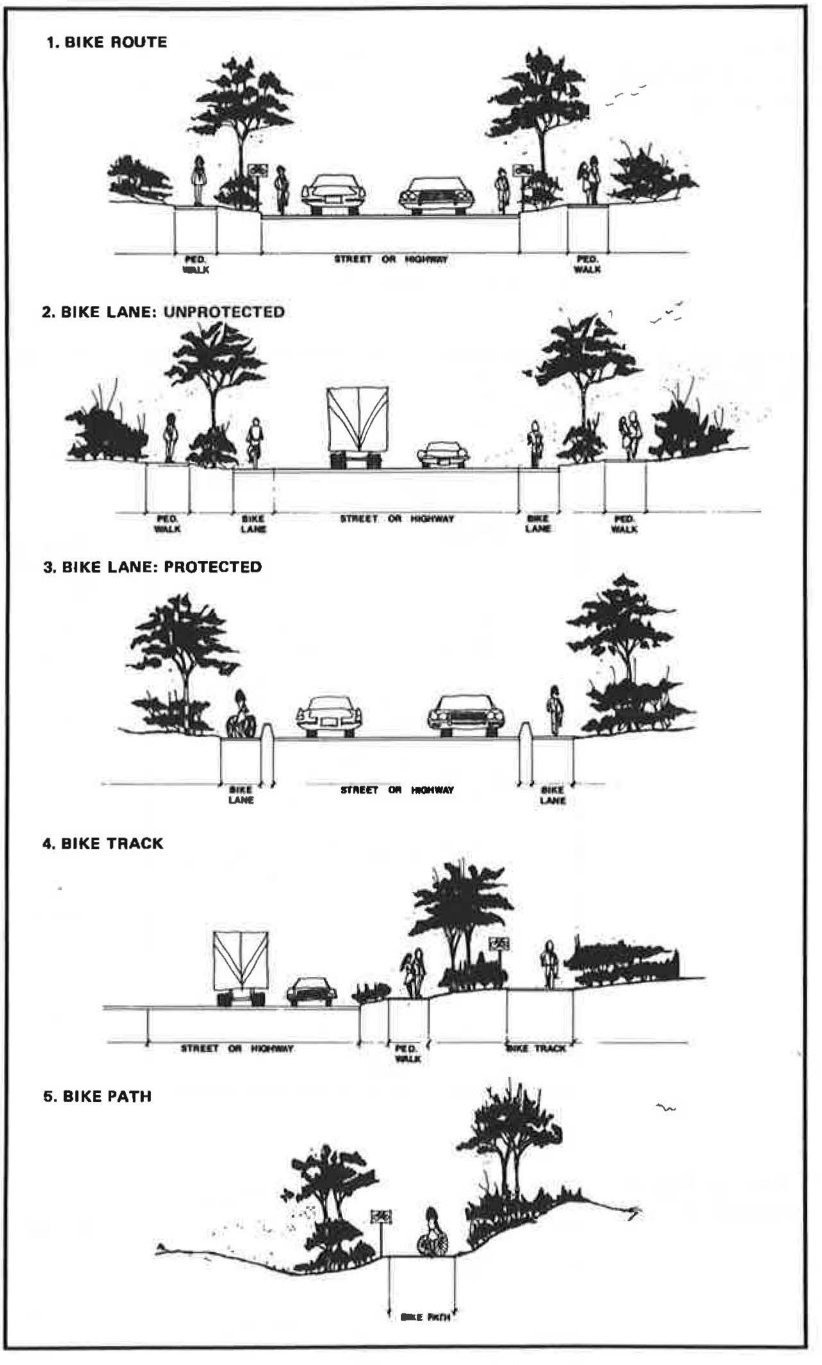

Table 5. Sample costs (in dollars) of alternative bicycle facilities.

Bicycle Facility	Signing	Striping	Barrier	Pavement and Base	Right-of-Way	Total
Signed route	500	0	0	0	0	500
Unprotected bicycle lane	500	500	0	0	0	1,000
Protected bicycle lane	400	0	2,650	0	0	3,050
Bicycle track	400	0	0	10,560	-*	10,960
Bike path	200	0	0	10,560	-*	10,760

*Right-of-way cost for a 10-ft-wide (3-m) strip at a land value of $10,000 per acre (4.05 km^2) would be $12,100 per mile (1.6 km).

Table 6. Costs of hypothetical biking systems within Atlanta area.

Type	Cost of Bicycle Facilities (millions of dollars) ½-Mile	1-Mile	2-Mile	4-Mile
Signed route	0.9	0.5	0.3	0.2
Unprotected bicycle lane	1.8	1.0	0.6	0.4
Protected bicycle lane	5.6	3.1	1.8	1.2
Bicycle track[a]	19.6	10.9	6.6	4.4
Bike path[a]	19.4	10.8	6.4	4.3

Note: Costs in this table were based on system component estimates as established in Table 3.

[a]These estimates do not include land costs.

Figure 2. Hypothetical bicycle facility grid.

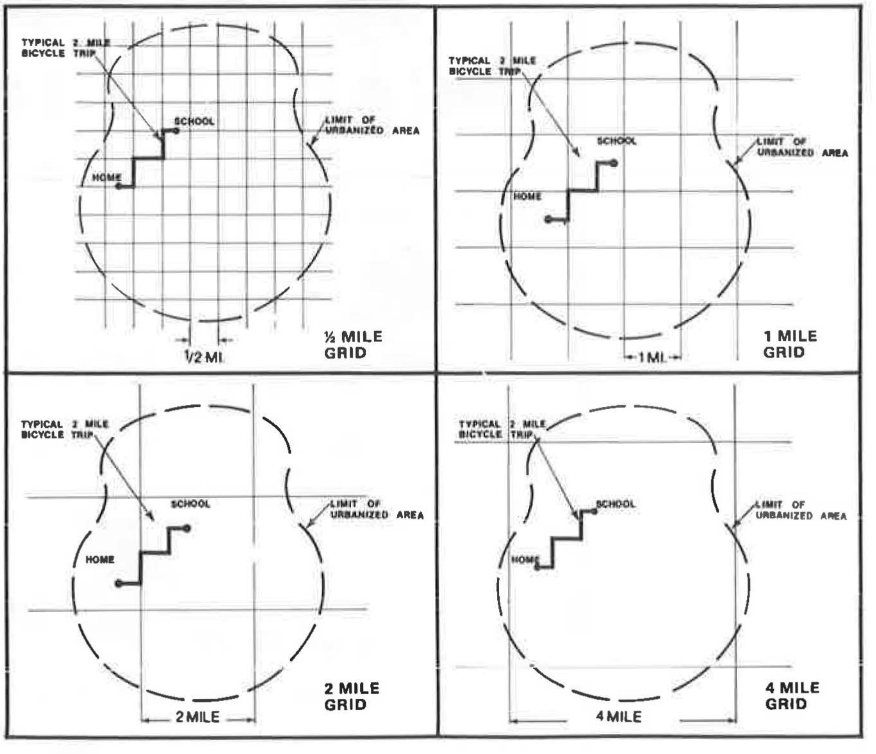

Table 7. Potential locations for urban bicycle facilities.

General Category	Best Location Opportunities
Barrier removal	Freeways and major arterials, rail lines, gorges or rough topography
Storage facilities	All high-use areas
Penetrator systems	Schools (especially universities), central business districts, large employment concentrations, shopping centers, transit stations and express bus stops, heavily used parks
Internal systems	Colleges and universities, large city parks
Environmental corridors	Stream valleys, utility rights-of-way, ridge lines
Transportation linear corridors	Street and highway rights-of-way, adjacent to public transit lines, adjacent to operational rail lines
New land developments	Residential subdivisions, large-scale planned unit developments

mile (0.8-km) grid spacing. (This is based on the assumption that current expenditures for streets and highways will remain constant.)

At this stage of bicycle facility development within urban areas it is risky to advocate one type of bicycle facility over the others. Too little is known about the safety and performance characteristics of the alternatives under operating conditions. Nevertheless, the following tentative recommendations on the selection of alternative bicycle facilities are presented for consideration.

1. Bike route signing should be used primarily as a route identification technique. Although statistical evidence is not available, there is enough preliminary evidence from operational bike routes to seriously question the degree of safety gained by merely signing streets. Whereas signing warns the motorist, there is a danger that it may create a false sense of security on the part of the bicyclist. The principal advantage of signing appears to be its usefulness in directing the bicyclist to the safest roads in a given area. However, signing in conjunction with other related actions such as reducing traffic volumes and speeds on streets designated for priority bicycle treatment may have a significant impact.

2. The unprotected bike lane is a marked improvement over the signed bike route. When traffic volumes and speeds are low, these lanes substantially protect the bicyclist from passing motor vehicles. When traffic volumes become heavy, the motorist is especially prone to encroach into a bike lane. Under normal operating conditions, right-turning vehicles and the opening of parked car doors present the greatest dangers.

3. Protected bike lanes and bike tracks have similar performance characteristics. Both bike lanes and bike tracks offer considerable protection from the automobile. Of the two, the bike track generally is preferred for two reasons. First, the bicyclist is protected to a greater degree from noise and exhaust fumes by being separated by a greater distance from motor vehicles. Second, a slightly greater degree of protection is provided at intersections, especially with regard to right-turning vehicles.

4. The bike path is preferred to all solutions. A bike path system totally divorced from roads carrying motorized traffic offers a more pleasing environment for the bicyclist and reduces the potential number of bicycle-automobile conflicts. A bike path system can also be effectively combined with pedestrian and equestrian routes as evidenced in many of the American and British new town developments (3). This preference, of course, must be weighed against costs. There is a great potential for constructing such systems on the fringes of urbanized areas as new land developments are undertaken. By aggressive public action supported by good development ordinances, these facilities could be largely provided by private developers at a minimum of public expense.

WHERE SHOULD BICYCLE FACILITIES BE PLACED?

Determining where investments in bicycle facilities should be directed must be based on an investigation into the potential purposes of bicycling. Because the bicycle is being used for a variety of recreational and purposeful trips, investments in bicycle facilities should reflect these diverse interests. Currently not enough is known about the specific interests of bicyclists to make this determination.

Use of the bicycle will be strongly influenced by the type and location of systems constructed. For example, if safe and direct commuter routes are provided into areas of high employment, probably commuter biking would increase substantially. The same, of course, would probably be true for bicycle touring, if pleasant environmental corridors of some continuity are provided. Based on this observation, it is recommended that investments in bicycle facilities in urban areas be initially directed toward serving a wide variety of trip purposes.

So that public investments will be channeled into opportunities having the greatest potential payoff, the following specific opportunities (Table 7) are offered for consideration.

Barrier Removal

Opportunities for bicycling within urban areas will be maximized if selected barriers to continuous travel are removed. In particular, construction of underpasses and bridges will accommodate movement across obstacles such as freeways and principal railway lines. Although these may appear costly, a few such improvements might significantly increase the use of the biking system.

Storage Facilities

The provision of adequate numbers of well-placed and relatively inexpensive storage facilities might increase bicycle travel more than any other type of immediate biking improvement. Placing these facilities close to points of origins and destinations will enhance a major potential advantage of the bicycle—portal to portal service. Bicycle storage facilities should be required at most major trip attractors such as shopping centers, schools, selected public buildings, and office and employment locations. Many of these facilities could be provided by building owners. Inasmuch as mandatory inclusion at the time of construction is the most effective means of ensuring that such facilities are provided, such a requirement might be part of local zoning ordinances.

Penetrator Systems

If the bicycle is to be used to make purposeful trips, bikeways that lead into concentrations of high employment or other high-use areas such as shopping centers and universities must be provided. Unfortunately, intense motor vehicle traffic in and around these high-activity areas often precludes safe bicycling. Bicycle facilities penetrating into these areas are bound to be costly or unfeasible in many situations. Nevertheless, where opportunities do occur, expenditures higher than the average might be justified when high usage can be anticipated.

Internal Systems

In portions of urban areas an appropriately designed bicycle system could result in the bicycle becoming a primary means of transportation. This opportunity appears to be particularly good on college campuses where a well-developed bicycle system could provide an efficient, low-cost transportation alternative with low storage-area requirements.

Environmental and Aesthetic Corridors

Although the rush has been to provide bicycle facilities adjacent to streets and highways, providing environmentally pleasing routes totally separated from motorized transportation facilities is getting less attention than is deserved. Particularly appealing are stream valleys with flat gradients that are highly conducive to bicycle riding.

Transportation Linear Corridors

There is a great opportunity to provide bike tracks adjacent to major transportation corridors such as freeways, toll roads, major arterials, and public transit lines at the time of construction or reconstruction. Once construction is completed, the cost of bike tracks escalates sharply because of the number of structures that must be removed or redesigned.

New Land Development

To a certain extent, the battle for high-quality bicycle facilities has already been lost in developed portions of urbanized areas. Particular attention should be paid to the possibility of providing bicycle facilities separated from transportation corridors within new land developments. Development incentives could be included in local ordinances to encourage developers to provide bike paths as part of their subdivisions.

CONCLUSIONS AND RECOMMENDATIONS

The following principal conclusions are offered to serve as guidelines for future bicycle facility development in urban areas:

1. Considerably more expenditures for bicycle facilities are justified. Although traditional transportation economics cannot be used to justify greater expenditures for bicycle facilities, there is ample evidence through other evaluation measures. Without substantially greater investments to provide safe and convenient facilities for the bicyclist, it is very possible that the true potential of the bicycle may never be realized in the United States, especially for purposeful trip-making.

2. Investment in commuter biking facilities may not produce benefits so significant as similar investments in "convenience" biking. The commuter trip is typically the longest of all urban trips, must be performed on a rigid schedule, and has the best transit options. All of these factors, in combination, pose a serious question on whether first priority bicycle facility investments should be directed toward accommodating the commuter. It appears that considerably more convenience trips such as shopping and personal business trips might be readily accommodated at less expense. However, bicycle commuting shows promise.

3. Bicycle ridership for purposeful trip-making could exceed public transit ridership in many U.S. cities. Given a safe and convenient bicycle system, the use of the bicycle could outstrip public transit use even if all purposeful bicycle trips are restricted to a distance of less than 2 miles. Consequently, as transportation funding for modes other than the automobile increases, the bicycle should receive serious consideration. Whereas the bicycle and public transit modes are primarily "middle distance" forms of urban transportation, they are largely complimentary. Public transit is most useful in carrying large numbers of people to concentrated points, whereas the bicycle is better suited to moving smaller numbers of people to dispersed points.

4. Proportionately more should be spent on bicycle facilities other than signed bike routes. The principal advantage of signing routes appears to be to direct bicyclists to safer streets rather than to provide protection on these streets. As more funds become available for bicycle facility development, it is recommended that a much greater proportion be spent on those facilities that separate the bicycle from motor vehicles.

5. Greater emphasis should be placed on developing bike paths within environmental areas. To date, the majority of attention on biking facilities has been directed toward locations within or adjacent to street and highway rights-of-way. At this formative stage of accommodating the bicycle within urban areas, it should be recognized that the "ideal" solution is not adjacent to corridors accommodating motor vehicles but rather in the interior of developed blocks.

6. Barriers to safe bicycle travel should be removed. Instead of building long stretches of expensive bicycle facilities, it may be more useful to concentrate on removing barriers to travel (such as a bridge over a freeway) where the greatest dangers to bicyclists occur. The number of miles of bicycle facilities provided is not an accurate indicator of the adequacy of the system; the amount of safety provided is.

7. Warrants for alternative bicycle facilities should be developed. There is considerable uncertainty surrounding the selection of an appropriate type of bikeway for each type of traffic, parking, and pavement width condition. Much more data regarding accident propensities must be gathered before the decision among bicycle facility alternatives can be made with authority. An important first step would be the systematic reporting of bicycle accidents and the routine inclusion of bicycle traffic volumes in traffic surveys.

8. Local bicycle facility plans should be a prerequisite for governmental grants. If substantial funds become available from state and federal sources for the purpose of constructing bicycle facilities, it seems only natural that guarantees should be made that these funds are spent wisely. Investigations of existing bicycle facilities indicate that many of the solutions are piecemeal and not suited to long-term development. In many cases, this situation could be corrected by advance system planning.

9. Municipal ordinances should encourage or require provision of bicycle facilities. It is a common practice to require provision of streets, open spaces, and automobile parking spaces as a precondition for zoning and subdivision approvals. The same type of requirement should be adopted where the provision of bicycle facilities would be in the public interest.

REFERENCES

1. Atlanta Areawide Regional Highway Improvements Program. Atlanta Regional Commission, 1972.
2. Before the Traffic Grinds to a Halt.... The British Cycling Bureau, undated.
3. Perraton, J. K. Planning for the Cyclist in Urban Areas. The Town Planning Review, Vol. 39, No. 2, July 1968, pp. 149-162.
4. Smith, R. A. A Social History of the Bicycle. American Heritage Press, 1972.
5. Some Facts About the Current Bike Explosion. Bicycle Institute of America, New York, unpublished, 1973.
6. Special Survey on Bicycle Safety. American Automobile Association, Nov. 1972.
7. Statistical Abstract of the United States. U.S. Department of Commerce, 1972.
8. The Bicycle: A Plan and Program for Its Use as a Mode of Transportation and Recreation: Atlanta Metropolitan Region. Barton-Aschman Associates, Inc., July 1973.
9. A Summary Report of Travel in the Twin Cities Metropolitan Area. Twin Cities Metropolitan Council, draft rept., 1970.