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The Bicycle as a Transportation Mode

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BICYCLES AND LEGISLATION

Edward I. Koch, U. S. Representative, New York City

Several approaches to the problem of bicyclists are discussed on the state and federal levels. Examples of state and federal legislation to make bicycling safer and more appealing are presented.

•REQUESTS to turn down thermostats, awaken when it is still dark, and decrease use of the automobile contradict the statement made by Presidential Assistant Peter M. Flanigan in 1973: "The United States is not going back to the cold, the dark and the bicycle."

These measures, coupled with the fact that there are now more than 80 million bicyclists, indicate that Flanigan's statement has come full cycle.

A study conducted by the Ford Foundation estimated that 14 to 23 percent of the energy consumed in this country is used by the automobile and at least 50 percent of this automobile travel is trips less than 5 miles (8 km) long. The U. S. Department of Transportation (DOT) has estimated that, if 5 percent of the motorists using cars for 2.5 to 3.5-mile (4 to 5.6-km) trips would convert to bicycles, 12.5 billion gal (47 hm^3) of gas would be saved during the next 16 years.

The energy crisis combined with foul air and congested city streets makes the bicycle an appealing remedy.

We are all in agreement that the bicycle is the most energy-efficient mode of transportation. However, as any urban or suburban cyclist knows, the automobile and the bicycle are not compatible roadfellows.

Citizen groups have familiarized people with the positive qualities of the bike: It is quiet, clean, and healthful. And they have lobbied, often quite effectively, for legislative changes. However, they have only begun to gain widespread acceptance of the bike as a commuting vehicle as well as a recreational resource.

Many states have begun to address some of the problems facing bicyclists. Washington and Oregon have laws mandating the use of a small percentage of state Highway Trust Fund money to promote bicycling. In New York, the 1972 legislature passed a law that includes bike safety guidelines for the first time. California, however, has made the most dramatic advances. In 1973, the legislature passed a bill mandating a minimum annual state expenditure of $360,000 for bike facilities and provided an additional $360,000 to local agencies for the same purpose. Bicycle path systems are springing up all over the state; the largest is planned to run 444 miles (714 km) from north of San Francisco to south of Los Angeles along an abandoned aqueduct.

Cities such as New York, Cleveland, Atlanta, Boston, Denver, and Washington, D. C., either have in operation or have planned bikeway systems.

What additional legislation is needed on the state level? Moneys from state departments of transportation must be made available for bikeways. Abandoned railroad rights-of-way provide a superb foundation for bicycle roadbeds. Ohio recently passed a law requiring the return to state jurisdiction of these rights-of-way for conversion to bikeways. In addition, the Bay Area Rapid Transit System in San Francisco has provided bicycle racks at stations, and they have been a success. Many of these monthly rental lock-ups have 100 percent occupancy.

On the local level, building developers should be required to construct space for racks in both residential and commercial buildings. Police departments should be encouraged to launch annual registration drives.

On the federal level, Congress overwhelmingly accepted as part of the Federal-Aid Highway Act of 1973 provisions to make available $40 million per year from the Highway Trust Fund (for fiscal years 1973 through 1975) for the development and construction of bicycle lanes and paths, traffic control devices, and parking shelters. DOT issued new regulations allowing these moneys to be used apart from primary and secondary road systems. In addition, the Secretary of Transportation authorized a $2 million study to be conducted on bicycle and pedestrian safety.

According to a 1972 study by the California Department of Highways, it costs $4 million to construct 1 mile (1.6 km) of freeway and $500,000/mile ($312,000/km) of secondary road. When compared with the Ann Arbor bicycle study estimate of $24,000/bikeway mile, the difference is significant.

Incentives such as safe routes and ample parking facilities are needed. In addition, use of the car must be discouraged through higher parking taxes, negatively graduated tolls on bridges and turnpikes, and less construction of new highways.

As a result of these and other glaring needs, I drafted legislation entitled the Urban Bikeway Transportation Act of 1975. This bill includes provisions for $20 million, half from the Highway Trust Fund and half from general revenues, in a bicycle transportation fund to be administered by the Secretary of Transportation. This money would be available for planning and construction of bikeways, traffic control devices, and parking shelters within urbanized areas (at least 50,000 population) and would be granted on an 80-20 basis to states or local municipalities within urbanized areas.

In addition, letters have been sent to DOT requesting inclusion of bicycle provisions for driver education programs and a change in existing parallel designs for sewer grates, which represent a hazard for the cyclist and possible liability suits against the state.

Finally, I have drafted a letter to request the Secretary of Transportation to form an office of bicycle transportation to coordinate the approximately 92 federal programs that have jurisdiction over bicycle transportation.

All this and much more can spur expansion of bike use and in so doing make life a little safer and healthier for us all. But the key to it all lies in the need for massive letter writing campaigns and lobbying legislators on all levels of government.

This is a process of psychological conditioning. Many of us, particularly city dwellers, recognize the practical and pleasurable aspects of cycling. However, too many of us have become accustomed to an unhealthy dependence on the automobile not only as a form of transportation but also as a symbol of prestige. We also have correctly recognized the danger of cycling unprotected from the automobile.

The future of the bike is now, especially in American cities. To ensure this future, we must act on legislation needed to pave the way for more bikes with separate bike lanes, not more cars.

PLANNING AND DESIGN OF BICYCLE FACILITIES: PITFALLS AND NEW DIRECTIONS

Daniel T. Smith, Jr., De Leuw, Cather and Company

This paper focuses on several recent failures in bikeway design in the hope that similar mistakes can be avoided in the future. Pros and cons of independent bicycle paths are listed, and the major deficiency is shown to be problems in design, inasmuch as they are usually designed for pedestrians rather than for bicyclists. This paper gives several questions that planners must answer when considering an independent right-of-way opportunity. These relate to safety, utility and linkage, and proximity to population centers. The use of sidewalks as bikeways is discussed, and unsatisfactory experience with such paths is presented. Some of the more obvious problems are poor sight distance, hazards from shrubs and signs, driveways, pedestrians, poor-quality surface, and curbs. Various attempts at curb cuts and ramps are mentioned. Signed bike routes are rarely used by cyclists because they usually do not serve desired activity centers and offer few if any safety advantages. Bike lanes, created from roadway space left over by motor vehicles, are shown to be basically unsatisfactory, though some negative behavior patterns have been modified by the provision of such lanes. The need to acquire accurate before and after data is discussed, as is the need for planners and designers to develop knowledge of good bikeway design. The way to acquire a sensitivity to bicyclists' needs and behaviors is to ride a bike.

•DRAMATIC INCREASES in bicycle activity during the last few years have spurred a considerable effort to develop facilities for utility and recreational bicycle travel. To date, a significant number of bicycle facilities have been constructed and placed in use. Although these facilities generally have been greeted by the public and in technical literature with adulation, the actual usage experience has been one of mixed success and failure.

The roots of the problem lie in the incomplete state of current technical knowledge in the field of bikeway planning and design and the facts that most work to date has been dependent on the intuitive judgment and sensitivity of the individual planners and designers responsible and that each undertaking has been an independent trial-and-error experience.

This paper critically focuses on some recent failures in bikeway design not for the sake of criticism but in the hope of identifying pitfalls to be avoided and sensitizing planners and designers to the subtle factors that affect the functionality and acceptance of bicycle facilities.

BICYCLE FACILITIES

Independent Bicycle Path

An independent bicycle path is a cycle facility in its own right-of-way, entirely separate from (except for inevitable crossings) streets and highways. It includes facilities specially provided for bicycling in parks and forest preserves or along greenbelts, abandoned (and possibly operational) railroad rights-of-way, service roadways in utility rights-of-way, drainage and irrigation canals, and flood control levees.

Independent paths can be particularly attractive and effective for both recreational and utility riding. Independent paths are especially effective for utility riding when greenbelt paths are designed to penetrate neighborhood areas and provide accessibility independent of the motor vehicle roadways as has been done in new town and planned community developments. A frequent problem with the design of independent paths is that they are deficient in meeting bicyclist needs. Historically, the design of trails in parks and greenbelts has focused on pedestrian considerations and the trail as a feature of the landscape. Unfortunately, this has led to facilities with grade profiles, curvatures, sight distances, pavement widths, and pavement surfacing inappropriate for use by bicyclists. Fortunately, this problem is being resolved as literature on functional bikeway planning becomes available.

A more serious concern relates to the use of corridors of opportunity as rights-of-way for independent pathways. In many cases, corridors such as levees, utility line maintenance paths, abandoned rights-of-way, and the like afford unique opportunities for the creation of independent pathways. A number of bikeway facilities have been constructed in such corridors simply because the right-of-way was available, but there has been little regard for the potential usefulness of the ultimate facility. The cost of independent path facilities is generally of such magnitude that, if the funds were devoted instead to the construction of bypasses to bike travel barriers or links providing bikeway system continuity, significant results could be achieved. When considering an independent right-of-way opportunity, planners must answer the key questions that they have too often failed to address.

1. Does this corridor constitute an attractive place to ride a bicycle as a specific activity, or does it provide a useful transportation linkage for utility bicycling?
2. Is the corridor located in sufficient proximity to population centers that a level of facility use can be anticipated that reasonably justifies resources devoted to its provision?
3. Does the corridor offer sufficient benefits to safety or the bicycling environment to justify incremental cost over that of placing a facility in a parallel roadway corridor?

If these questions can be answered affirmatively, then an independent bike path is a reasonable choice for providing a recreational opportunity or a transportation linkage. Independent bike paths when properly sited are valid treatments and not wasteful extravagances, but the following questions of priority must still be addressed.

1. How do the needs for and potential benefits of this project compare with those associated with other potential projects within the jurisdiction?
2. Is this opportunity perishable, or will it remain a future possibility if currently available funds are used for other bikeway projects?

Too many planners are not asking themselves questions like these but are blindly attempting to seize available independent path opportunities. Until we begin to appraise opportunities with a critical eye, we will continue to build white-elephant bike paths and to divert funds from potentially more needed or useful facilities.

Sidewalk Bikeway

A sidewalk bikeway is a bike path that is within the road right-of-way but off the motor vehicle traveled way and that may or may not be used by pedestrians as well as bicyclists. Considerable unsatisfactory experience with sidewalk bikeways is now being reported. The reasons for this are quite evident.

1. At driveways the sight distances and visibility relationships are often poor. Landscaping, shrubbery, and fences tend to impair sight distances at driveways. Compounding the problem are the poor visual relationships that result when motor vehicles

back out of and turn into driveways.

2. Poor visual relationships between cyclists and motorists also occur at intersections. The emergence of a high-speed bicycle (as opposed to pedestrian speed) into the crosswalk area is often unanticipated by motorists, particularly those completing turns.

3. Sidewalk bikeways tend to be used bidirectionally despite signs and markings to the contrary. Bidirectional operations compound the sight distance-visual relationship problems at driveways and intersections noted above.

4. Sharing space with pedestrians creates a number of problems. Pedestrians are extremely mobile directionally and often change direction unpredictably. This factor, coupled with the difference in travel speed (average travel speed for a bicycle is 3 to 4 times the average walking speed), leads to a high conflict potential. Small children often use sidewalks as play areas, and they, together with their toys, can constitute an obstacle course. Older pedestrians and blind persons are particularly uneasy at meetings with cyclists along sidewalks.

Besides these safety considerations are convenience factors, which of themselves are enough to lead cyclists to eschew sidewalk bikeways in favor of the street. Sidewalk surfaces are often cracked or broken and offer a poorer quality ride than the pavement of streets they parallel. Encounters with pedestrians are inhibiting even when hazardous conflict is not evident. At times, existing sidewalks, which are too narrow to function effectively when shared with pedestrians and are uninviting even when no pedestrians are present, have been pressed into service as bikeways. Up and down curb designs are extremely inconvenient.

For these reasons sidewalk bikeways should be used only under special circumstances. One such circumstance is the opportunity for or the existence of a sidewalk path along a roadway that is uninterrupted by cross streets or driveways for long stretches. Another is when the bikeway must be placed in a high-volume roadway corridor where all available street space must continue to be devoted to motor vehicle traffic (no possibility for elimination of parking or a traffic lane or no possibility for narrowing traffic lanes) and motor vehicle speeds along the street are significantly higher than the bike speed range. In each of these cases, great care must be taken in marking intersection crossings and ensuring good sight clearances.

The subject of ramps or curb cuts merits attention. If sidewalk bikeways are to be used, curb cuts at intersections are essential because the low-profile tires and rims standard on lightweight bikes now in predominant use cannot jump curbs as could the older balloon-tired bicycles. A number of jurisdictions concerned with the accident hazard posed at intersections by rapid emergence of bicyclists from the sidewalk into the crosswalk area have attempted to provide sidewalk bikeways and to retard bicyclist entry to intersection crossings by maintaining unbroken curbs. It should be no surprise that this contrivance generally does not have the desired effect. Bicyclists, like most human beings, normally follow the path of least resistance, and, when they encounter barriers such as this, they do the natural thing: avoid the sidewalk facility completely and use the street.

Some jurisdictions have attempted to create makeshift ramps by placing small wedges of asphaltic materials in the gutter against the curb. The problem with this type of approach is that such ramps frequently still provide too abrupt a transition and still lead to potential tire and rim damage and pedal scrape, which may cause nasty spills. There are also problems with more formally constructed ramps. Some jurisdictions have attempted to retard cyclist entry to the crossing area in a more subtle way by offsetting the ramp a few feet from the direct line of the sidewalk. Unfortunately, this causes the cyclist to be involved in a turning movement while on the ramp, which can also lead to pedal scrape and spills. Moreover, for some cyclists the slight inconvenience involved in using the offset ramp is sufficient cause for them to forgo use of the sidewalk facility. One jurisdiction's well-intended effort in this vein is worthy of note. To reinforce the retarding effect of the offset, the ramp provided was made extremely narrow (about 1 ft, 0.3 m) and framed by vertical sides. Contrary to what the designer anticipated, cyclists who continued to use the sidewalk facility became so preoccupied with negotiating the narrow curb ramps that they became oblivious to the hazards of crossing motor vehicle traffic.

Inadequate width is a common deficiency in many types of sidewalk bikeway ramps. If all such curb breaks were constructed to at least the 4-ft (1.2-m) minimum operating space for bicycles, they would have the added value of being useful for wheelchairs, baby carriages, and shopping carts.

Signed Routes and Bike Lanes

Signed routes are streets or sequences of streets marked by signs denoting them as a bike route but with no other facility provisions for bicyclists. Typically, many jurisdictions have used the signed bike route as the first step in attempting to deal with the bicycle activity boom. Bike route signs may be the product of earnest efforts to indicate to cyclists utility routes with continuity to activity centers and low traffic volume or desirable grade profile. Or they may indicate recreational routes having scenic views and continuity to points of touring interest and recreational facilities. Although a limited measure of safety may be afforded when motorists see bike route signs and are alerted to anticipate cyclists, signed routes do little to ensure bicyclist safety. Moreover, signed routes have been used as a temporizing device that creates an illusion of positive action by public officials who are unconvinced of bicycle facility needs, uncertain how to implement more advanced facility treatments, or simply anti-bike.

Signed bike routes do have some utility in providing guidance to touring cyclists. However, their limited overall usefulness in urban and suburban system contexts is illustrated by the experience of Palo Alto, California, in the late 1960s. In 1967 Palo Alto implemented a 27-mile (43-km) signed bike route system (15 percent of the city's street miles) as a 1-year test demonstration. Results of this demonstration program were indicative of the inadequacies of the signed route system. In a survey of Palo Alto cyclists, more than 65 percent of respondents reported that they seldom or never used the signed routes and, where usage was reported, it was most frequently incidental and coincidental rather than intentional. One reason that cyclists gave for not using the routes was that in many cases the routes did not serve desired activity center destination points. But, more important, cyclists simply were unwilling to ride out of their way to use a signed bike route that appeared to offer no obvious travel or safety advantages.

A bike lane is an on-street treatment in which separate motor vehicle and bicycle travel lanes are designated by signs and street markings. A significant amount of criticism of bike lanes is now being heard because of experiences with the bad facilities that have been provided in many areas. This often happens when the planning process consists of designating as a bike lane whatever roadway space is left over after motor vehicle needs have been met. The result may be lanes too narrow for satisfactory riding because of either inadequate basic width, unridable quality of the surface in the lane area due to broken pavement or a poorly matched pavement-gutter pan joint, or site obstructions such as gaping drainage grates that narrow the effective width. A more serious situation caused by thoughtless planning results when a seemingly adequate bike lane suddenly terminates or leads the bicyclist into a point of hazardous conflict. Poor maintenance is another problem. When sand, gravel, bits of broken glass, weeds, other debris, or puddles or standing water are allowed to accumulate in bike lanes, the facilities become useless. These are not basic faults of the bike lane concept; they are the result of bad planning and poor follow-through on the part of individuals. But they have a tremendous impact on bikers who not only experience the hazards due to deficient facilities but also encounter hostility of motorists and occasional harassment of enforcement personnel when they quite reasonably choose to avoid the facilities. The problem here is a lack of sensitivity on the part of the planners and designers to the subtleties that are so critical to the success or failure of the bicycle facility. Probably more harm than good is done when a traffic engineer decides that bike lanes are a cure-all and that the way to build them is to stripe the portion of the roadway not required for motor vehicle travel or parking as a bike lane.

Are bike lanes effective treatments? Recent technical literature and some bicycle spokespeople have posed this question. It is true that the forms of midblock accidents, particularly sideswipe and rear-end bike-motor vehicle collisions, which appear to be the principal types of accidents bike lanes would minimize, compose a very small percentage of total bike-motor vehicle accidents. However, the argument that, because these types of accidents are such a small portion of the problem, bike lanes have little safety value does not logically follow. For this ignores the fact that bike lanes may have positive effects on behavior patterns that have been identified as causal factors in other types of accidents. For instance, riding against traffic has been identified as a significant causal factor in midblock and intersection bike-motor vehicle accidents. And provision of properly marked bike lanes has been demonstrated to have significant effect in decreasing wrong-way riding. In Santa Clara County, California, before and after observations on three bike lane facilities showed a 21 percent decrease in wrong-way riding during a period in which total bike traffic increased by 50 percent. In other words, against-traffic riding dropped from 25 to 13 percent of total bike activity when well-marked bike lanes were provided. This is only one example of how provision of bike lanes can induce behavior pattern modification to reduce behavior that causes accidents. Behavior modification must be viewed as a benefit of bike lanes; the limited view that bike lanes only affect sideswipe and rear-end collision incidence is not correct.

A real problem in evaluating the performance of bike lanes is the lack of convincing before and after accident experience data. One part of the problem lies in obtaining statistically significant data on accident incidence and causal factors in true before and after situations. A second stumbling block is the growth in bicycle activity. Some studies have attempted to account for the increased accident exposure rate resulting from increased bicycle and motor vehicle traffic, but this is done purely on the basis of the changes in traffic volume. What is not accounted for is the fact that the composition of the bicyclist population has changed as a result of its growth; a higher percentage of less experienced and presumably more accident-prone bicyclists are now on the road than before.

A third problem in assessing before and after data relates to the particular circumstances under which they were generated. If the data indicate a failure of the bike lane to improve accident experience, is this indicative of failure of bike lanes in concept or does it reflect specific deficiencies in the design or maintenance of the facility under consideration? Are the individual facilities simply bad bikeways suffering the types of faults discussed earlier? Too often cold statistics are used to condemn a concept without consideration of whether the test facilities constitute a good representation of that concept.

BIKEWAY PLANNING

The most obvious faults of bikeway planning and implementation activities to date are (a) design and construction of individual bikeway segments where opportunities are available rather than in a systematic framework, (b) leaving gaps in what should be continuous facilities, and (c) placement of facilities on tortuous routings and avoidance of areas where solutions are difficult or involve high (relative to other bicycle facilities) capital costs. Without question, more effort must be devoted to developing means for safe and convenient bicycle passage through the bottlenecks and barriers to bike travel that are a feature of urban areas. Planners and designers have been guilty of devoting a vast portion of their attention to providing linear segments of bikeways that have low costs, pose minimal implementation problems, and have high visibility, all of which have maximum public relations value. There has been considerable reluctance to deal with problem spots where construction costs are substantial or where other impediments to implementation are encountered. The results are fragmented bikeway systems that fail to provide areawide accessibility or even linear continuity and a failure to deal with locations where bike travel is most hazardous or is completely obstructed. This does not imply, as some have contended, that linear bike facilities are unnecessary and that efforts to provide them should cease. It is simply an indication that more effort and a willingness to bridge the bikeway gaps where solutions are costly and there are obstacles to functional design and implementation are needed.

The most critical need is for planners and designers to develop a solid working knowledge of the principles of good bikeway design, a sensitivity to the subtle factors that affect bicyclist behavior, and a commitment to dealing with bikeways as part of the total transportation picture, not as an afterthought, a nuisance, or a public relations gimmick. Public demand for good bicycle facilities and increasing availability of technical literature are helping to resolve the problem. However, professionals working in the field tend to have a perspective shaped by training and experience dealing with motor vehicles and pedestrians. Although there are many parallels, bikes and bicyclists are quite different from motorists, motor vehicles, and pedestrians, and the designer is not likely to develop a sensitivity to the implications of these differences and to the often subtle factors affecting bicyclist behavior and the functional effectiveness of bicycle facilities without experiencing them from a bicyclist's perspective. Riding a proposed route on a bicycle brings details important to the cyclist to the designer's immediate attention—details that might be overlooked in a windshield tour and not even contained on a plan map.

The bikeway planner must be conscious of typical cyclist behavior patterns, particularly the tendency to rationalize and trade off safety for convenience and maintenance of momentum and the tendency to be less scrupulous in observing certain traffic ordinances and to avoid unnecessary grade climbing and out of direction travel. Cyclists will not go wherever the planner might find it convenient to place bicycle facilities unless these facilities offer obvious advantages over travel in mixed traffic. Cyclists consider themselves legitimate roadway users and reject facilities that provide inferior treatment.

PLANNING AND DESIGNING A DEMONSTRATION BIKEWAY

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Rather than install an entire network of bikeway corridors, which would be costly and time-consuming, the Seattle bikeway committee developed a demonstration bikeway program that designated three bikeways. The purpose of the program was to test known design techniques and to devise methods unique to the constraints in Seattle. This paper discusses the first of the three demonstration bikeways and describes the incremental approach used to solve individual design problems.

•WITH the enactment of a law in 1972 Washington became the second state in the nation to provide funds for the development of bicycle paths. This legislation, very similar to the landmark bicycle bill of Oregon, requires all governmental entities to spend a minimum of ½ percent of their motor vehicle funds each year for the establishment of facilities for pedestrians, equestrians, or bicycles. A comprehensive plan dealing with one or more of these areas of community interest must be approved before the funds are available for that purpose. The intended facility must be within the highway right-of-way or meet a highway purpose and satisfy the needs of public safety, be part of the approved comprehensive plan, and be cost effective.

Shortly after the enactment of the state law, the city of Seattle began a study of the feasibility of developing commuter bikeways. The study report, Preliminary Commuter Bicycle Study, recommended that the city develop a comprehensive plan for a citywide bikeway network with strong emphasis on the needs of the commuting bicyclist. A committee of bicycling city employees was formed to use the community interest generated by the study as a base for developing a comprehensive bikeway plan.

The comprehensive bikeway plan, approved by the mayor and city council early in 1973, designated the entire network of bikeway corridors within the city and established priorities for implementation. It also covered, in a very general fashion, the method of establishing priorities for bikeway installations; tentative design standards; potential local, state, and federal funding sources; legal aspects of developing bikeways in Seattle; and some thoughts on bicycle registration, licensing, safety, and education.

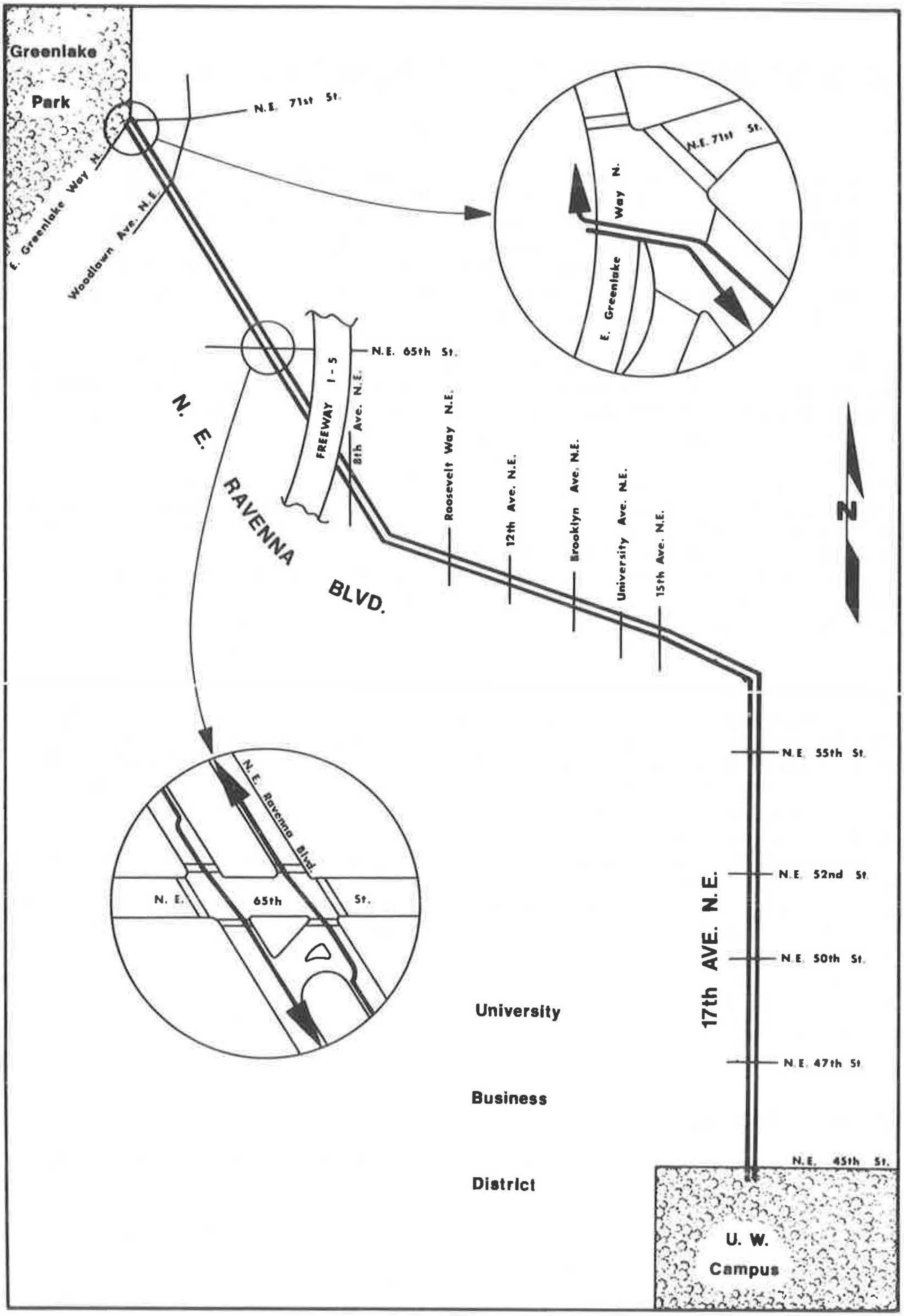
It became apparent even before the committee's work was complete that to install the first bikeway as envisioned in the plan would delay its opening until 1974. In addition, the limited design knowledge gathered from other communities needed to be tested to determine its applicability in Seattle. The bikeway committee developed a demonstration bikeway program that allowed work to begin immediately on three bikeways to test known design techniques and to devise unique methods to satisfy the conditions in Seattle. The first of these bikeways along Ravenna Boulevard and 17th Avenue N. E. from Green Lake Park to the University of Washington campus opened in the middle of August 1973 (Figure 1).

PLANNING PROCESS

The committee chose the first route because of its known high bicycle usage. A survey of 320 persons conducted at the University of Washington in October 1972 indicated that about 16 percent of the bicycle commuters used this route to and from school. A 12-hour cordon count held the following May refined this figure to almost 20 percent of the 7,000 total bicycle trips entering and leaving the campus area.

Although no similar counts of recreational bicycle volumes were taken, a video tape and visual observation were made of recreational activities along this route. Impres-

Figure 1. Demonstration bikeway one.



sions were gathered on the breakdown of users by sex and age and riding maneuvers at various locations. The route survey and observations, although limited in scope and detail, pointed out one significant item: The number of commuter bicycles traveling west along Ravenna Boulevard increased substantially until the underpass at Interstate 5. From there, until the flow turned south at 17th Avenue N. E., many riders left the mainstream of bicycles only to reenter it on 17th Avenue N. E. before arriving at the campus. It was hoped that the establishment of a designated bikeway would encourage many more bicyclists to remain with the majority of bicyclists and thereby decrease the accident potential in the surrounding neighborhood.

Establishing a demonstration bikeway along this route gave the city an opportunity to study various ways of designing a bikeway to fit within a parkway. Although Seattle does not have an abundance of parkways, the knowledge gained through this design effort will be applicable to other roadways or in analogous situations, e. g., using available open space versus placing a facility on the existing pavement. This route selection also provided a major commuter and recreational link between two important activity centers.

During the initial phases of planning the bikeway, a method evolved that can best be described as an incremental approach. Each specific design element was viewed in isolation from all others. All possible solutions were developed for that element, and the advantages and disadvantages of the solutions were identified. A recommendation was made for each solution based on its advantages and disadvantages and established planning and design criteria. A matrix of all feasible design solutions, disregarding the recommendations, was created that tied all possible solutions together in a continuous fashion along the route. An analysis of this matrix and the sketches depicting geometric design solutions quickly eliminated many combinations because they were unsafe, costly, or unfeasible from a traffic operation standpoint or did not meet the planning or design criteria.

DESIGN APPROACH

An example of the approach used to solve a specific design problem and the interaction of route elements can best be presented by discussing the bikeway crossing at N. E. 65th Street. Possible bikeway crossings of this intersection included the following:

1. Bikeway against median curb throughout intersection (Figure 2),
2. Median curb bikeway crossing to median grass (Figure 3),
3. Median curb bikeway moved to center lane approaching intersection and crossing to median curb (Figure 4),
4. Right curb bikeway crossing to right curb or sidewalk (Figure 5), and
5. Right curb bikeway moved to center lane of roadway approaching intersection and crossing to right curb (Figure 6).

To accept one of the first three solutions required a determination that a median lane bikeway was acceptable at this point on the roadway. A study of the traffic flow at the intersection and to the southeast at the on-ramp to I-5 showed that this was the most acceptable conclusion. Placing the bikeway at the right curb or on the sidewalk would necessitate an interaction between bicycles and motor vehicles at a point where the motor vehicles were moving at a high speed and the motorist was concentrating on entry to the freeway ramp. Placing the bikeway in the median lane moved the point of conflict closer to the intersection where the motorist's attention normally was in the direction of the approaching bicycle and where the motor vehicle was moving more slowly.

A study of motor vehicle traffic flow and volume characteristics at this intersection highlighted the need to place the bikeway so that bicyclists will not impede left-turning motorists. Bicyclists in Seattle tend to move along the right side of a string of stopped cars at a traffic signal. Not only can this irritate some motorists, but also it places

Figure 2. Bikeway against median.

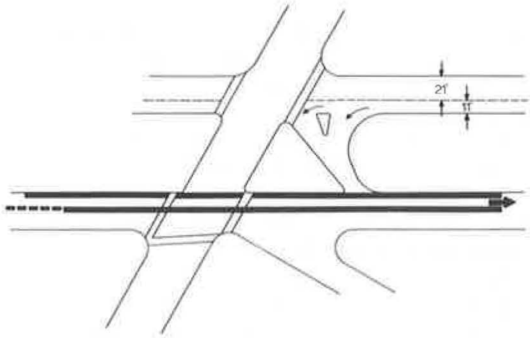


Figure 3. Bikeway located from median curb to median grass.

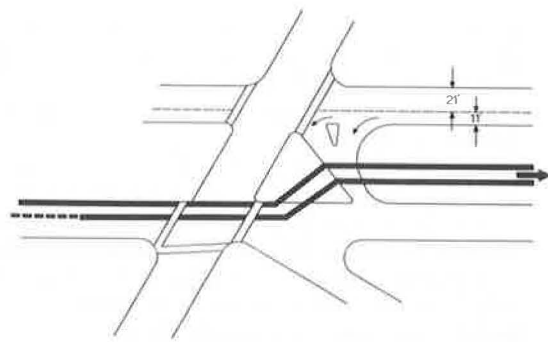


Figure 4. Bikeway located between left-turn bay and through and right-turning motor vehicle traffic and crossing to median curb.

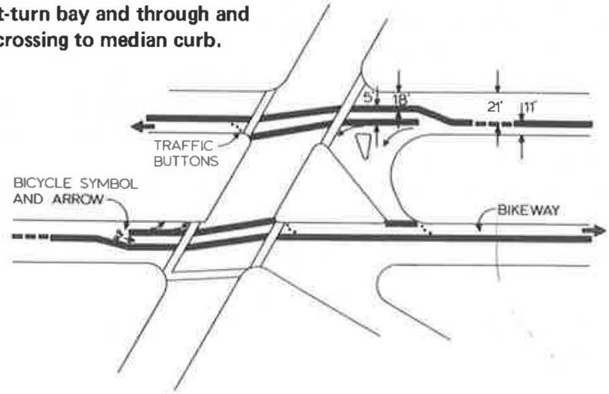


Figure 5. Bikeway located along right curb and crossing to right curb or sidewalk.

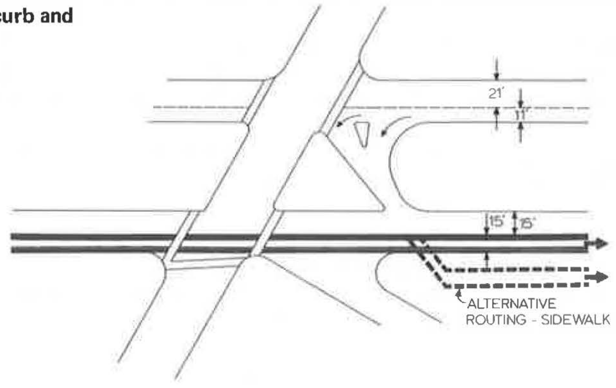
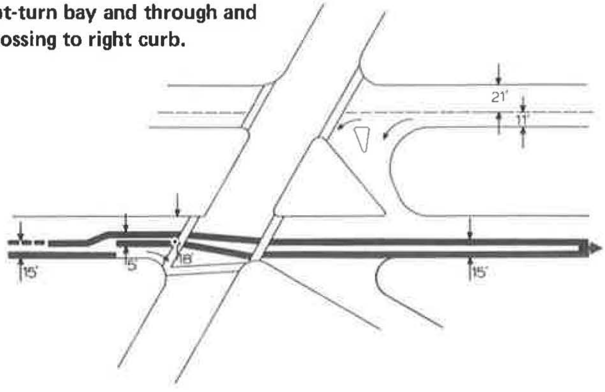


Figure 6. Bikeway located between right-turn bay and through and left- turning motor vehicle traffic and crossing to right curb.



the bicyclist in a narrow, unsafe position if accomplished from the median lane bikeway shown in Figure 2.

Therefore, the decision to use the median lane bikeway and to provide sufficient left-turn capacity for motor vehicles depended on motor vehicle traffic flow characteristics in and beyond the intersection and knowledge of motorist and bicyclist behavior. The incremental approach identified the acceptable solutions for one small area. But it was not until the solutions for each element were linked together that decisions were knowledgeably made. The selected intersection design is shown in Figure 4. The design shown in Figure 3 was rejected because it did not meet the cost criteria and also required the elimination of some of the median grass, a negative aesthetic impact.

Some of the other bikeway design decisions that were made and the basic thought that led to their acceptance follow.

1. Strong yellow green boundary line paint was chosen because it is a unique roadway color. This unusual color draws the attention of passing motorists to this new facility and emphasizes the messages of the special bikeway signs. The choice was made from the unassigned colors in the Manual on Uniform Traffic Control Devices.
2. Left-turning vehicles are allowed to enter the bikeway before reaching an intersection. This maneuver is permitted by mandatory signs, but the motorist must yield the right-of-way to bicycles. This arrangement causes less conflict than allowing left turns across the bikeway from the adjacent traveled lane.
3. At one point along the route a short section of path was constructed within the median. Although this was counter to the cost and aesthetic criteria, it was necessary for bicycle safety. Without this path, bicyclists would have been required to remain exposed to the arterial traffic they were crossing for a substantially longer time.
4. Where the roadway width narrowed and eliminated the possibility of a designated bicycle lane, signing was used to alert motor vehicle drivers to the fact that bicycles have preference on the entire roadway. Regulatory signing requiring motor vehicles to to yield to bicycles was used. Low traffic volumes and vehicular speeds, high parking density, and a low parking turnover rate supported this decision.
5. At all intersections where motor vehicles may enter the traffic lane adjacent to the bicycle lane, traffic control buttons were placed across the bikeway. Although these constitute a potential hazard to bicyclists, a much greater danger would be created by motor vehicles that might inadvertently enter the bicycle lane.

CONCLUSION

Since the completion of this bikeway in 1973, it has been visited by many observers from across the country. Some of the design decisions remain controversial, but in general its performance has exceeded the goals of those who worked to make it a reality. More bicyclists use the designated path now than used the same route before the green lines were painted and signs appeared. Its existence encourages bicycle use throughout the year even during the wet dark days of winter.

PREDICTING THE TYPE AND VOLUME OF PURPOSEFUL BICYCLE TRIPS

Carl E. Ohrn, Barton-Aschman Associates, Inc.

If an adequate system of bicycle facilities is to be built, who should it accommodate? What types of trips will it be used for? This paper assumes that (a) a comprehensive system of bicycle facilities will exist in the Minneapolis-St. Paul area and (b) the maximum distance of a bicycle trip is 2 miles (3.2 km). By using these assumptions, this paper determines the percentage of trip makers by trip type who could make their trips by bicycle. The factors affecting bicycle use are discussed. Because trips whose schedule is flexible have a greater probability of being made by bicycle, bicycle systems should not be designed to accommodate trips whose schedule is rigid, such as work and school trips.

•AS IS the case with all public investments, the agencies appropriating funds for bicycle facilities want to receive the greatest benefit from the dollars spent. Some procedure is needed that will assure government officials that the type and location of bicycle facilities will exhibit a reasonable return on the investment. This return may be measured by factors such as increased safety of the bicyclist and volume of usage. This paper determines which trips are most likely to be made by the bicycle if facilities are provided and estimates the volume of those trips.

Two assumptions were necessary to produce meaningful results based on the limited factual data currently available on bicycle use. The first assumption is that a comprehensive system of bicycle facilities will exist in the Minneapolis-St. Paul study area. (This area was chosen because recent travel data were readily available.) The number of bicycle trips being made today is not a valid indication of the number of trips that can be expected. Bicycle facilities generate trips just as roads generate trips. The existing facilities in the study area are limited in number, have little continuity, and are designed and located for recreational use. The present number of purposeful bicycle trips is, therefore, far below what is possible. A comprehensive system of bicycling facilities is necessary if a substantial number of trips are to be generated. Without a continuous system connecting origins and destinations, the utility of the bicycle is severely limited. Competing with the automobile for street space is the greatest cause of bicycle accidents. Fear plus the foul air and noise makes bicycling in busy streets far from pleasant.

The definition of an adequate system is open to debate. The spacing of paths and the type of facilities are two important factors. For this analysis a grid system of routes spaced no more than ½ mile (0.8 km) apart was assumed within the beltway that encircles the St. Paul-Minneapolis area. In the remainder of the metropolitan area, a grid spacing of 1 mile (1.6 km) was assumed. No specific types of facilities were contemplated other than paths that are relatively safe. Because its safety is debatable, the signed bike route would only be used to provide access to the system of bicycle facilities.

The second assumption was that a maximum distance for a bicycle trip is 2 miles (3.2 km). A report based on bicycle use in England found that most purposeful trip makers do not travel more than 2 miles on a regular basis. Closely corresponding to this is the fact that in Rotterdam, where 43 percent of all trips are made on bicycles, the average trip time is 10 min. Based on an average bicycle speed of 12 mph (19 km/h), 10 min equals a 2-mile trip. This is an arbitrary figure, for in both England and the Netherlands, the 10-min or 2-mile measure is an average. Arguments might be presented that this distance is too short; nevertheless, because the existing data are from countries having high bicycle use, this figure will be used as the upper bound of purposeful bicycle trips.

FACTORS AFFECTING BICYCLE USE

Obviously certain trip characteristics influence which mode a trip maker will use. Table 1 gives typical conditions that increase or decrease the probability that a particular purposeful trip will be made by bicycle. This list is limited to the most important factors influencing use. The evaluation of the effect of each factor is subjective, and the assigned evaluations can be disputed. The purpose of the analysis was to determine those trips most likely to be made by the bicycle. Therefore, no one item would determine whether a trip would be made by bicycle.

The factors used to evaluate the possibility of bicycle travel were the typical conditions that existed in the study area and in most U. S. urban areas. The level of street congestion, for example, was evaluated for the various trip purposes. For the work trip a high degree of street congestion due to peak-hour movement and the concentration of trip ends was assumed to exist. This tends to encourage bicycle use inasmuch as both automobile and transit service are slowed during this period. The personal business trip, which in many instances can be accomplished at a local shopping center or other neighborhood facility in off-peak periods, was assumed to function at a free flow level of service; thus, congestion would discourage bicycle use.

The evaluation is largely self-explanatory. Two items that deserve further explanation are trip length and flexibility. The assumption is that only those trips of 2 miles (3.2 km) or less were considered possible by a bicycle. Data collected in a travel behavior inventory for the study area provided trip time in 6-min intervals, which was used as an indicator of trip length. The trip times are all for home-based vehicular trips. Because the automobile was used for more than 90 percent of all trips, the speed of the automobile was used as the measure of distance. The automobile speed was assumed to be 20 mph (32 km/h) (a high speed for door-to-door automobile use); thus, a 6-min trip would be the equivalent of 2 miles in distance. Therefore, only those trips 0 to 6 min in duration were eligible for bicycle use based on the second assumption.

Table 2 gives the cumulative percentage of trips made in Minneapolis and St. Paul during a 24-hour period in 1970 by trip purpose and trip time. Obviously, there are substantial differences in trip lengths for various trip purposes. More than 48 percent of shopping trips are made in 6 min or less, and less than 20 percent of work trips fall in this category. Because distance is an important factor in bicycle use, it should be given considerable thought when purposeful bicycle trips are provided for.

If the automobile speed is set lower, for example, 10 mph (16 km/h) for door-to-door trips, which is more likely than 20 mph, the bicycle can be used for all trips of 12 min or less. This greatly increases the percentage of trips possible by bicycle.

The other factor deserving special attention is the degree of flexibility in scheduling of a particular trip. The trips that are most likely to be made by bicycle are those whose schedule is flexible from hour to hour and day to day. The more flexible the schedule is, the greater the probability is that the trip can or will be made by bicycle. Weather is always cited as one of the greatest deterrents to bicycle use. Rain, snow, or wind along with high or low temperatures can most assuredly discourage a trip maker from using a bicycle. If a trip cannot be delayed for even a few minutes, the traveler may choose another mode over the bicycle to avoid the inclement weather. But, if the trip can be delayed an hour to let a shower pass or a day until the temperature becomes more comfortable, the probability that the trip will be made by bicycle increases. Thus, those trips made on a rigid schedule such as work and school discourage the use of the bicycle. Trips that can be made at the convenience of the trip maker (personal business, shopping) encourage bicycle use.

Table 1. Effect of selected factors on the probability of bicycle use by trip purpose.

Factors	Work	Shopping	School		Personal Business	Recreation[a]	
			Grade	College		Outdoor	Indoor
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 storage	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	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
Transit availability	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.

Table 2. Cumulative percentage of home-based trips by time and purpose.

Trip Time (min)	Trip Purpose					
	Shopping	Personal Business	Recreation	School	Work	Medical
0 to 6	48.6	40.5	35.8	20.1	18.9	14.0
6 to 12	73.1	64.4	57.7	45.2	38.2	34.8
12 to 18	86.5	80.1	73.5	65.7	58.6	58.9
18 to 24	89.7	85.4	78.3	74.2	68.0	69.5
24 to 30	96.5	94.5	91.9	88.9	86.9	86.6
30 to 36	97.3	95.6	93.6	91.7	90.8	90.1
36 to 42	98.0	97.1	95.7	94.1	94.6	93.9

Table 3. Vehicular trips that can be attracted to the bicycle in the Minneapolis-St. Paul Metropolitan Area.

Trip Purpose	Total Daily Home-Based Vehicular Trips	Percentage of Vehicular Trips Less Than 6 Min Long[a]	Percentage of Trips Less Than 6 Min Long That Can Be Made by Bicycle	Trips Attracted to Bicycle if Proper Facilities Were Provided	
				Percent	Number
School	160,000	20.1	50.0	10.0	16,000
Recreation	817,000	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
Total	3,086,000			8.7	268,000

[a]Based on an automobile operating speed of 20 mph (32 km/h) and equivalent to a 2-mile (3.2-km) bicycle trip.

Table 4. Home-based vehicular trips in 1970 in Minneapolis-St. Paul by purpose and mode.

Trip Purpose	Assumed Percentage of Bicycle Trips	Percentage of Trips by Present Mode				Impact on Present Modes
		Automobile Driver	Automobile Passenger	Transit	Miscellaneous	
Personal business	12.0	71.3	22.9	1.9	3.9	Reduce automobile passengers and drivers
Recreation	12.0	39.1	57.1	0.9	2.9	Reduce automobile passengers
School	10.0	15.7	20.5	4.6	59.2[a]	Reduce school bus trips and automobile passengers
Shopping	9.7	64.6	31.3	1.2	2.9	Reduce automobile drivers
Work	2.0	75.7	14.3	5.4	4.6	Reduce automobile passengers and transit users
Medical	—	47.7	40.8	8.8	2.7	—

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

BICYCLE ACCESS TO TRANSIT STATIONS

The typical conditions given in Table 1 for each trip purpose can, of course, change. As these typical conditions change, the probability of bicycle use fluctuates. An investigation of all the variations cannot be undertaken in a paper of this length, but an analysis of one change affecting the work trip is valuable. This change is a rapid transit system (rail or bus) within a metropolitan region and the resulting effect on bicycle use. Our concern is with the method of access to the transit stations and not the entire work trip made by transit.

There are four typical methods of access to transit stations: (a) walking, (b) feeder bus service, (c) park-and-ride, and (d) kiss-and-ride. The problem with kiss-and-ride is that it requires a driver to deliver the passenger to the transit station. Park-and-ride demands that an automobile be left at the station for the entire day. This can prove to be inconvenient or unacceptable if the family has only one automobile. Access by feeder bus can be time-consuming depending on the routing and schedules. Walking is limited to a distance of ½ mile (0.8 km).

In each of these situations, the bicycle has advantages over the other methods. It may be faster and more convenient than the feeder bus because it provides door-to-door service. If the bicycle is used instead of the park-and-ride mode, the family car is free for other uses. By using the bicycle, the transit patron who usually depends on the kiss-and-ride procedure is independent of the driver. Those who walk to transit stations are not expected to traverse a distance greater than ½ mile (0.8 km). The bicycle is an ideal access mode up to a distance of 2 miles (3.2 km). The ½-mile radius results in an area of 0.8 $mile^2$ (2 km^2) accessible to the pedestrian. The use of the bicycle for a trip up to 2 miles increases this area to 12.6 $mile^2$ (32.6 km^2), an area approximately 16 times as great. Those individuals within this area not having access to a car would find the bicycle ideally suited for a trip of this length.

Evaluation of the number of access trips that might be made by the bicycle should take into consideration many existing conditions, such as residential density within the 2-mile service areas of the bicycle. In conjunction with these elements, the other typical conditions given in Table 1 should be reviewed. The degree of encouragement or discouragement can have similar effects on the probability that the access trip will be made by bicycle.

ESTIMATING TRIP VOLUME

Based on trip length, flexibility, and other factors (Table 1), an estimation was made of the percentage of trips by purpose that could be made by bicycle. These estimates are given in Table 3. Of the 3,000,000 daily home-based vehicular trips made in the study area, the bicycle has a strong probability of attracting 268,000 trips. To put this into perspective, the transit system in Minneapolis and St. Paul attracted only 163,000 passengers daily in 1970. Bicycle trips would account for 8.7 percent of total home-based vehicular trips. The volume would be increased if those trips being made from non-home-based origins and recreational bicycle trips were also included.

There are substantial differences in the percentages of trips attracted to the bicycle for varying trip purposes. Fifty percent of school trips currently made by motorized vehicles can be made by bicycle, but only 10 percent of the work trips are less than 2 miles long. The majority of trips that can be made by bicycle are recreational and personal business trips.

IMPACT OF MODAL SPLIT

Using the bicycle for purposeful trips may generate new trips, but it is more likely that certain trips now made by automobile or transit will be made by bicycle. Thus, a change in the modal split will result. A breakdown of the 1970 modal split in the study area is given in Table 4, including the assumed percentage of trips made by bicycle by trip purpose. The conclusions stated in that table summarize the present form of transportation from which bicycle trips are likely to be attracted.

The greatest number of bicycle trips will be drawn from the present automobile passenger trips. The automobile passenger in many ways must be considered a captive rider. Currently, numerous trips are made just to accommodate the passenger. This number, in many instances, is as high as 10 percent of total automobile trips in a metropolitan area. If an alternative is available to the passenger, the driver might insist the passenger take advantage of this mode. Since, in many cases, the scheduling of these trips is based on the schedule of the driver the passenger may find it more convenient to use a bicycle.

A much smaller number of trips will be derived from present transit patrons. The door-to-door service of the bicycle is a distinct advantage over transit, which may require walking, waiting, and transferring to complete a trip. Due to the rather meager volume of transit patrons at present (2.7 percent of home-based trips) and the inclusion within this group of a large number of elderly people and commuters, the change of mode will not be very substantial. The transit riders who would be attracted to the bicycle are students and individuals who cannot afford an automobile but are physically able to use a bicycle.

The probability of drawing trips from the school bus is high if bicycle facilities are available. This would not be true for cross-town busing, but would affect the number of children being bused because they live beyond a reasonable walking distance.

Thus, it can be expected that, if a comprehensive system of bicycle facilities were built in the study area, a substantial number of purposeful trips would be made by bicycle. The majority of these trips would be made for recreational, personal business, school, and shopping purposes. The present modes that would show a reduction in use would be the automobile when used to serve the passenger, school bus when the trip is less than two miles in length, and transit.

CONCLUSIONS

1. The best candidates for purposeful bicycle trips are probably those who do not have ready access to an automobile. There are numerous instances during the course of a day when members of the family may not have ready access to the family car (or cars). In those and similar cases, the option of a short bicycle trip might be more attractive than either delaying the trip until an automobile is available or using public transit whose schedules and routes may not be convenient. This may have the side effect of reducing the significant number of automobile trips that are taken solely for the convenience of the automobile passenger.

2. The benefits of investing in commuter biking facilities may not be so significant as the benefits of investing 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 option. These factors pose a serious question of whether first-priority bicycle facility investments should be directed toward accommodating the commuter. A considerably larger number of convenience trips such as shopping and personal business trips might be more readily accommodated at less expense. However, the potential of bicycle commuting shows enough promise to give it a much better chance than currently exists in any major city. A pilot study of a high-quality system in a selected city would be beneficial. Development of a system focusing on a transit station would provide valuable information on the use of the bicycle as an access mode.

3. Bicycle ridership for purposeful trip making could exceed public transit ridership in most U.S. cities. If a safe and convenient bicycle system were provided, bicycle usage could outstrip public transit usage, in most cities, even if all purposeful bicycle trips were restricted to a distance of less than 2 miles (3.2 km). Consequently, as transportation funding for modes other than the automobile increases, the bicycle should receive serious consideration. Although the bicycle and public transit modes are primarily middle distance forms of urban transportation, they are largely complementary. Public transit is most useful in carrying large numbers of people to concentrated points, but the bicycle is better suited to moving smaller numbers of people to dispersed points.

DEVELOPMENT OF A PLANNING PROCESS FOR A FUNCTIONAL AND RECREATIONAL BICYCLE SYSTEM

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ABRIDGMENT

•THE PURPOSE of this investigation was to develop a planning process to serve both functional and recreational travel demands in a community. This process involves determining the demands for bicycle travel and developing a bike transportation system to satisfy the demands at an acceptable level of service. An assessment of the desired level of service was obtained through an opinion survey on bicycle travel in the community.

The planning process consists of the following five phases:

1. Organization,
2. Study design,
3. Data collection,
4. System development, and
5. Route design.

The demands for bicycle travel are developed through the study design and data collection phases, and development of a feasible bicycle system is accomplished through the system development and route design phases.

The first four phases of the bike planning process were conducted by the technical staff with volunteer assistance from a community service group for home interviews. The final phase of route design involves decisions by local officials on the precise locations of the bikeways within the bicycle corridors that were defined in the system development phase. In addition, the technical staff provided details on geometric design, signing, marking, and pavement design of the various bikeways after the final location and the degree of traffic separation had been determined for each segment of the bicycle system.

The development of a bicycle system was based on the selection of bicycle corridors to satisfy varying degrees of demand for bicycle travel. Therefore, a functional classification system was adopted to develop a system of different classes of bikeways that reflect the variations in user demands. Geometric design criteria were selected in accordance with the functional classifications of the bikeways.

The bicycle planning process was applied to the development of a functional system for a university campus and a functional-recreational system for a contiguous community of 10,000 persons. Although these two bike studies were conducted separately, regional and intercommunity considerations of bicycle travel resulted in the integration of these two bicycle systems.

ESTABLISHING WARRANTS FOR CONTROL OF A BICYCLE CROSSING THROUGH SIMULATION

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ABRIDGMENT

A simulation model calibrated from data collected where bicycles cross a two-lane, two-way street was developed for a crossing controlled by a yield sign to bicycles. Experimentation was done with the model to determine delay and queue formation of bicycle traffic. Various levels of motor vehicle and bicycle demands were tested with the model. Situations in which a yield sign to bicycle traffic are ineffective at a crossing are discussed, and warrants for signalization are suggested based on these situations.

•EXCLUSIVE bicycle paths are becoming more and more popular as recreational and transportation facilities. A significant problem arises when such a path crosses a busy urban street. Several control options are available to the traffic engineer who wishes to operate the crossing in a safe and efficient manner. The options include stop and yield signs for bicycles or motor vehicles, traffic signals, and complete grade separation. The appropriate control strategy is a function of both the motor vehicle volume and bicycle volume wishing to use the crossing. Unfortunately, no warrants or guidelines exist to aid the traffic engineer in developing an appropriate control strategy. Simulation modeling was chosen as a method to determine appropriate warrants.

THE MODEL

A model to simulate operation of a bicycle crossing was developed. The crossing is at mid-block on a two-way, two-lane street. Bicycles arriving to cross are controlled by a yield sign. The practice of simulating intersection operation is not new (1, 2, 3, 4, 5). Some researchers have used simulation for suggesting warrants for control of motor vehicle traffic (1, 2, 5). There has been no work reported on the simulation of bicycle traffic.

The basic structure of the model developed for this study is shown in Figure 1. Motor vehicle and bicycle arrivals are generated randomly. When a bicycle arrives to make the crossing, the operator must decide to accept or reject gaps in the motor vehicle traffic. The modeling of this gap acceptance decision has been shown to be critical to delay measurements with a simulation model (5). The gap acceptance criteria used in this model are shown in Figure 2. A random number drawn from a uniform distribution is generated by the model. This number is then used in the relationships of Figure 2 to select the minimum gaps the cyclist is willing to accept. Simple straight-line relations were used because available data were insufficient to warrant a more complex treatment.

Motor vehicle traffic flow on the roadway and the rate at which bicycles attempt to cross are model inputs. Output of the model includes delay and queue formation data of the bicycle traffic for each 15-min period simulated.

The model was validated by collecting delay measurements at a crossing on the University of California, Davis, campus. For three 15-min periods, bicycle flows, motor vehicle flows, and cyclist delay time were recorded. Two model simulations were made for comparison to each set of field data. The second computer model run used random numbers equal to one minus the random numbers in the first run. Average bicycle delay was selected as one variable for use in validating the computer model. In all but one of the six comparisons there is general agreement between observed and predicted average bicycle delay. However, for the one case where the difference in mean delay was greatest, the motor vehicle flow rate between field and model differed by 12 percent. Because bicycle and motor vehicle flows are generated by a stochastic process in the model, observed field flow rates could not be duplicated exactly. In the other tests, motor vehicle flows varied by less than 4 percent.

Paired comparisons were also made on the same data by using the χ^2 contingency table test. In this test the proportion of bicycles delayed in the model and in the field were compared. The hypothesis that the model and field data are the same could not be rejected at the 5 percent level of significance in five of the six tests. Again the worst comparison occurred in the case where model and field motor vehicle flows differed by 12 percent.

APPLICATIONS TO ESTABLISH WARRANTS

Three output variables of the model were used to begin to establish warrants for signal installation: percentage of bicycles delayed, total delay to bicycles, and maximum queue length occurring in 15 min.

Adequate Gaps

The percentage of bicycles delayed was the model output analyzed to determine whether the gaps in the motor vehicle stream are adequate to permit bicycles to cross. Groth suggested that, when 75 percent of bicycle traffic is delayed, cyclists might begin to take chances by accepting inadequate gaps (6). The author feels that assumption is reasonable. This 75 percent figure of bicycles delayed is predicted by the model to occur at a motor vehicle flow rate of approximately 1,000 vehicles per hour. Levels of 800 and 600 motor vehicles per hour for four- and six-lane crossings were determined to be safe limits for bicycle crossings based on field observations in Holland and Denmark (6). The conclusions here for two-lane crossings are not in disagreement with those findings. More bicycles are delayed by multilane streets because longer gaps are required for safe crossings.

Total Delay

Total delay to bicycles was measured with the model. No conclusions can be drawn regarding the flow levels at which signals produce less delay than the yield sign. Operations with signal control were not investigated because adequate saturation flow rates for bicycle facilities were not available.

Normally, total delay under signalized operation is greater when motor vehicle delay is included. Thus, it is expected that the other criteria presented here based on safety considerations will warrant a signal at lower traffic demands than the minimization of delay objective will.

Impedance of Traffic

When bicycle queues become sufficiently long, motorists will often freely yield the right-of-way and allow cyclists to pass. This has been observed when queue lengths reach four to eight bicycles. The crossing is then operating in a mode for which it was not designed. In addition to causing delay to motor vehicles, it causes behavior of bicyclists and motor vehicle operators to become unpredictable and unsafe. At com-

Figure 1. Simulation model.

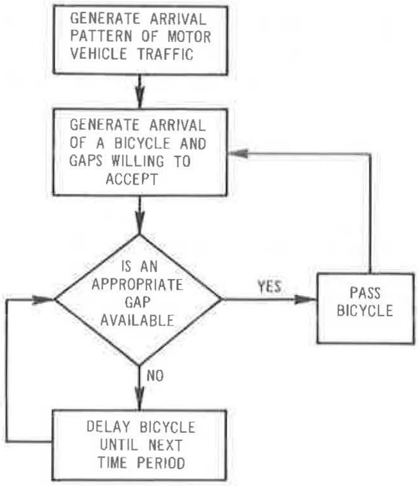


Figure 2. Gap acceptance criteria used in simulation model.

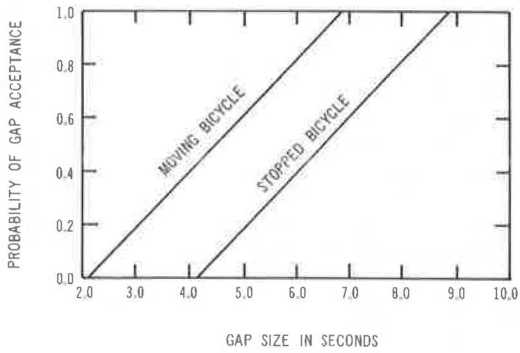
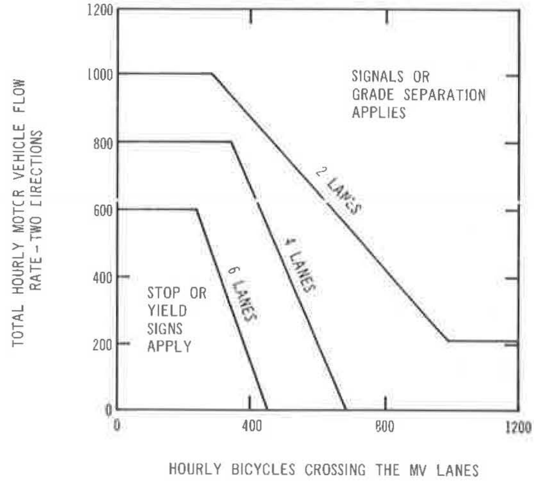


Figure 3. Warrants for controls at bicycle crossings.



binations of motor vehicle and bicycle flows where a queue length of six may be expected to occur each 15 min, it is suggested that signals be installed.

Warrants

The report by Groth drew some conclusions on what might be appropriate warrants for control of a bicycle crossing based on previous work done by Grabe and Raff (6). However, Groth's work was for four- and six-lane crossings. Warrants for installation of signals at bicycle crossings are shown in Figure 3. Specific recommendations for control are not presented inasmuch as more experience with control of bicycle crossings is necessary. Consideration must also be given to factors such as available sight distances, motor vehicle speeds, and the duration of flow. This author feels that flows during the two peak periods should be used in establishing warrants for control.

The four- and six-lane lines in Figure 3 were developed from information in the

Groth report (6). The horizontal limits between signalized and nonsignalized controls were drawn from reported experiences in Holland and Denmark. The remainder of these limits are representations of work done by Grabe.

The two-lane limits are based on results from the model described here. The horizontal portion of the curve at 1,000 motor vehicles per hour represents a level of motor vehicle demand that does not provide adequate gaps in the traffic stream. At this level, 75 percent of the bicycles are delayed. The remainder of the two-lane curve is based on the requirement that the maximum queue should be no more than six bicycles in a 15-min period. It is at this level that motorists have been observed to yield their right-of-way.

CONCLUSIONS

The following comments are offered as aid in selection of crossing controls. The nonsignalized domain in Figure 3 represents an area where a yield sign to control bicycle traffic is appropriate. In the area of low motor vehicle flow (less than 200 per hour), it may be more appropriate to use stop sign controls for the motor vehicle traffic. In general, use of stop signs to control bicycle traffic exclusively is not recommended because observance and enforcement are usually lacking.

The signalized domain represents an area where signals or grade separations are required based on the criteria. Signals may be warranted at lower combinations of demands if such controls produce fewer overall delays. However, this is unlikely. Grade separations are expensive, but they essentially eliminate all delay at the crossing. They do not completely eliminate accidents, for the grades increase bicycle speeds. Bicycles go out of control more often, and the structure provides a fixed object for collision.

The author is eager to hear of other experiences in controlling bicycle crossings. The addition of experience with control of crossings to warrants such as these based on predicted traffic performance is the only way that warrants may be developed that can be applied with confidence. It may take years to develop that experience.

ACKNOWLEDGMENTS

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PROBLEMS IN INTEGRATING BICYCLE TRAVEL INTO THE URBAN TRANSPORTATION PLANNING PROCESS

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With bicycle sales increasing rapidly and with attitudes that regard the bicycle as a toy declining, bicycle travel must be integrated into the urban transportation planning process. The bicycle is being recognized more and more as a viable means of urban transportation, but rational planning for the bicycle requires detailed information concerning the nature of intraurban bicycle travel, information that currently does not exist for U. S. cities. This paper uses detailed travel data gathered recently in Sweden to demonstrate that bicycle travel closely resembles motor vehicle travel. The data show that, when bicycle ownership is high and when planners treat the bicycle as a viable means of transportation, the bike is used extensively in daily travel for a variety of trip purposes. In planning for bicycle facilities in U. S. cities, transportation planners must recognize that viewing the bicycle primarily as a recreational vehicle will not meet the needs of most cyclists. The bicycle must be integrated into the urban transportation planning process like any other urban transportation mode.

•MUCH has been said about America's love affair with the automobile, but evidence indicates that the car will soon have a new rival to contend with as Americans rediscover the bicycle. In 1973 bicycles outsold cars in this country for the first time since reliance on the automobile became a way of life; furthermore, most of those bikes were sold to adults (9). Both urban residents and transportation planners are recognizing the bicycle as a potentially viable means of urban transportation. The purpose of this paper is to review the potential of the bicycle as a means of transportation and, by using detailed travel data from a medium-sized Swedish city, to demonstrate how the bicycle is used in comparison with other modes of transportation and why the bicycle should be viewed as an integral part of any urban transportation system.

THE NEED FOR RATIONAL BIKEWAY PLANNING

The list of advantages to be gained by using the bicycle in urban transportation is impressive. Besides benefits to the health of the bicyclist, the urban transportation system itself stands to gain from increased use of the bicycle. Reduced levels of air and noise pollution, fewer serious traffic accidents, lower levels of fuel consumption, less urban space consumed by parked vehicles, and lower levels of traffic congestion are some of the advantages that substitution of bicycle trips for motor vehicle trips would bring to urban areas.

In addition, the bicycle offers a cheap and efficient means of transportation for those who are either too young, too old, or too poor to own or operate a car. Currently this carless portion of the population has little choice in matters of transportation, and for this reason the transportation disadvantaged have been referred to as captive public transit riders (2). If they do not use public transportation, they must either walk or rely on the use of a friend's, neighbor's, or relative's car. Therefore, another factor (13) in support of safe bicycling facilities is the increased freedom of choice that it affords many urban residents in matters of transportation.

However, transportation facilities in most urban areas today do not encourage use of the bicycle; in fact riding a bicycle in motor traffic is usually so hazardous that it discourages anyone from frequent bicycle use, let alone from substituting bicycle trips for automobile trips. As many have already recognized (1, 4, 11, 18), if the bicycle is to become a viable, safe, and frequently used means of transportation, proper facilities must be provided. This means primarily constructing separate bicycle paths or delimiting bicycle lanes on existing streets to separate bicycles from motor traffic. In addition, a number of secondary support facilities, such as showers in places of employment and secure parking places at destinations, are necessary to encourage increased bicycle use. The critical point is that the number of bicycles on the road is growing so rapidly that the number of accidents involving bicycles and motor vehicles will continue to skyrocket unless appropriate steps are taken to provide bikeways that are separate from motorized traffic. For safety, environmental quality, and increased options for the carless, therefore, transportation planners can no longer afford to ignore the bicycle.

If it is accepted that providing bicycle facilities in U. S. cities is a necessity or perhaps even an inevitability, then attention must be paid to the careful planning of bikeways and to the integration of bikeways into the urban transportation system. Although constructing facilities will not be so costly as providing highways for automobiles, the cost of building a comprehensive bikeway system for one city can amount to many millions of dollars (1). This means that in most cases provision of bicycle facilities will need to be analyzed within a cost-benefit framework so that facilities are installed where the demand is greatest. It will be necessary, therefore, to assess variations in the level of demand for bicycle transportation throughout the city.

The alternatives to trying to predict bicycle demand so as to allocate resources efficiently are either to do nothing, which is unacceptable, or to provide a comprehensive system of bicycle paths throughout the urban area, which may be, for reasons of cost, impossible. Any scheme that provides bicycle paths on a selective basis must, if it is to be rational, forecast demand so that bike facilities are located where they will be most heavily used. Citizens and city officials who have begun to plan for bikeways recognize the necessity of predicting levels of demand and the difficulty in doing so (3, 4, 5, 7, 12).

LACK OF ADEQUATE DATA ON BICYCLE TRAVEL

Bicycle demand is currently very difficult if not impossible to predict because so little is known about the nature of bicycle travel, especially how bicycle trips compare with those made on other modes of transportation (4, 11, 14, 16). This lack of knowledge about bicycle travel reflects the dearth of appropriate data sources in this country. Urban transportation studies (8) have consistently overlooked nonmotorized transportation, and so it is not surprising that the needs of the pedestrian and the cyclist remain poorly understood.

To overcome the lack of information on bicycle travel in this country, a number of surveys have been undertaken. Some have identified potential bicycle trip generation or destination areas (6, 7, 20), some have studied levels and types of bicycle use (6, 7, 16, 17, 20) or have identified the characteristics of bicycle users (6, 17, 19), but none of the data collected contains detailed and comprehensive information on bicycle travel, and only one study permits comparison of bicycle trips and trips made by other modes of urban transportation. The one study that does compare bicycle use with other modes (16) deals only with commuting; information on bicycle trips for other purposes was not collected.

Major drawbacks to the data gathered in these studies relate to the sampling procedures, the method of data collection, and the scope of the studies. The sampling procedures used do not permit inferences to be drawn to the general population because the respondents either are selected nonrandomly (4, 7, 20, 16) or are taken from a particular segment of the population such as those with registered bicycles or members of bicycle clubs (4, 6, 17). The method of data collection also presents a problem because (a) the questionnaires were mailed and (b) respondents were asked to recall in general terms how often they used their bicycles for each of a small number of trip purposes such as shopping or going to work. The problems associated with data gathered in this way have been documented, and ways of circumventing the problems have been outlined (10). The most critical problem with the data obtained in these studies, however, is that the information pertains only to bicycle use and does not permit evaluation of the role of the bicycle in the total intraurban travel of the household. There is no way to view bicycle use in perspective or to compare bicycle trips with trips made by other modes. Because no suitable U. S. data source was found, this study uses data gathered recently in Sweden to investigate questions regarding the place of the bicycle in urban transportation.

UPPSALA HOUSEHOLD TRAVEL SURVEY

The best data currently available for assessing the use of the bicycle in urban transportation were collected in the Uppsala, Sweden, household travel survey. In spring 1971 a unique, disaggregate, longitudinal data set was collected in Uppsala, a medium-sized city with a population of 120,000 located about 50 miles (80 km) northwest of Stockholm. Marble, Hanson, and Hanson (15) give a detailed description of the survey design and procedures. The survey collected detailed data on the intraurban travel behavior of a panel of about 300 sample households selected randomly from six predefined life-cycle groups.

A self-administered travel diary was kept by every household member older than 16. For 5 consecutive weeks, members of the panel recorded the details of all trips made outside the residence. A trip is defined as a series of movements that begin and terminate at the home. One or more locations may be visited in the course of the journey, and these interruptions on the trip are referred to as stops. For each stop on each trip, the panel members recorded the times of arrival at and the departure from the stop, detailed information on the reason for making the stop, amount of expenditure (if any) made at that stop, and the mode of transportation used on that leg of the journey. The following seven modes were explicitly recognized: walk, bus, bike, car driver, car passenger, taxi, and motor scooter. An eighth category, designated other, was used for all other modes including motorcycle, horse, and even elevator.

When the study was undertaken, Uppsala had no special provisions for bicycle transportation although about 70 percent of the households owned one or more adult bicycles, and the bicycle was considered a means of transportation rather than a toy. Therefore, these data should be of particular interest to planners in this country because they show how the bicycle can be used in urban transportation when bicycle ownership is relatively high but when the bikeways and attendant facilities are lacking, as is the case in most U. S. cities. The Swedish data, therefore, give some idea of what the situation could be like in the United States shortly if bicycle ownership among adults continues to rise and no special bicycle facilities are installed.

EXTENT OF BICYCLE USE

The first question to be addressed in analysis of the travel data deals with the extent of bicycle use in comparison with other modes. That is, How often is the bicycle used, and how does bicycle use vary with stages in the life cycle? The data show that, although as in the United States the car is frequently used, walking, biking, and riding the bus are important modes. Bicycle movements accounted for 11.6 percent of the total number of movements made by the 296 households during the 5-week recording period. Because the study was conducted in early spring (March 31 to May 6), this figure represents serious bicyclists who are not deterred by cold and often wintry weather.

Bicycle use appears to remain fairly stable throughout the various stages in the life cycle until retirement, when, as might be expected, bicycle use is less frequent.

The elderly are also the only group who do not use a bicycle more often than the bus. The predominance of the bike over the bus was unexpected inasmuch as bus system operation in Uppsala at the time of the survey was efficient and extensive. The remainder of the analysis examines the nature of bicycle use for the sample as a whole.

CHARACTERISTICS OF BICYCLE USE

To estimate the nature of the demand for bicycle transportation requires that a number of bicycle travel characteristics be examined. Among those considered here are the distribution of bicycle trips throughout the week, the trip purposes accomplished by bicycle, the length of bike trips, and patterns of expenditure on bicycle trips.

When the distribution of bicycle movements throughout the week is examined in comparison with other modes, it is clear that the bicycle is used primarily on weekdays. Only a small proportion of bicycle movements are made on the weekend: 6.5 percent on Saturday and only 4.2 percent on Sunday. Although the overall level of travel activity declines on the weekend and especially on Sunday, the weekend proportions of movements on other modes are not so low as they are for the bicycle. This temporal pattern of movement frequencies suggests that the bicycle in particular might be closely associated with the journey to work. Also, the fact that bicycle use does not increase during the leisure time provided on the weekend indicates that the bicycle is being used primarily as a means of urban transportation rather than for recreation. To determine whether the bicycle is frequently used for the journey to work and whether recreation is, in fact, of relatively little importance in bicycle travel, the next portion of the analysis examines the specific purposes for which bicycle trips were made.

The data show that in Uppsala the bicycle plays an especially important role in the journey to work; 21.6 percent of all stops made at the workplace were made by bike. Just how important the bicycle is on the work trip is clear in the light of the fact, mentioned earlier, that about 11 percent of all movements are made by bike; for travel to the workplace, the proportion nearly doubles. This high incidence of bike use on the work trip could in part account for the relatively low level of bicycle usage among the elderly who, by definition, no longer make the journey to work.

Analysis of trip purpose indicates, further, that the bicycle is used relatively often to run errands or to carry out business within the neighborhood. For instance, at least one-tenth of all stops at supermarkets, kiosks, flower shops, libraries, banks, and post offices were made by bicycle. However, although bicycle stops at these local retail and service establishments are well-represented, the bicycle does not appear to be used frequently to make social visits, nor is its use for recreational activity outstanding. One interesting point is the frequency with which the bicycle is used to travel to a stop where the purpose is to change mode. These are most likely trips wherein cyclists ride to the train station, park their bikes, and take the train.

The fact that the bicycle seems to be used primarily for the journey to work and for local trips raises the question of whether the bicycle is used primarily for single-purpose trips or whether longer, multistop trips are made by bicycle as well. The analysis shows that about 40 percent of all movements by bike are associated with traveling to the first stop on a trip; similar percentages are found for bus (43 percent) and automobile (37 percent). The bicycle is also comparable to the other modes in terms of the proportion of stops that occur on trips of greater duration. Thus, although the majority of bicycle movements occur on one- or two-stop trips, the bicycle, like other modes, is occasionally used for longer, multistop journeys.

The final question about the nature of bicycle use concerns patterns of expenditure related to bicycle travel. If the bicycle is used like any other mode of urban transportation, expenditures at locations visited by bicycle should be comparable to those made when other modes are used. In Uppsala, 80 percent of all stops involved no expenditure at all, and 11.8 percent of the no-expenditure stops were made by bike. Inasmuch as 11.6 percent of all stops are made by bicycle, it is clear that the bicycle is being used as often as other modes for travel that involves making an expenditure. Furthermore, in regard to the amount of the expenditure, the bicycle is not used only for making minor purchases.

SUMMARY

This paper has examined the rationale for gaining greater understanding of bicycle travel in urban areas and has described how the use of the bicycle compares with the use of other modes of urban transportation. If concern for the safety of cyclists is genuine, facilities appropriate for bicycling must be provided. If these facilities are to be provided on a rational basis, we need to know more about the characteristics of bicycle travel and the nature of the demand for bicycle travel in urban areas. Information enabling the rational planning of urban bikeways does not currently exist in this country.

The primary purpose of this paper has been not to review bicycle use in Uppsala, Sweden, but to demonstrate that when detailed data like these are examined it is evident that the bicycle is used as a viable means of urban transportation, not as a means of recreation. Integration of bicycle travel into the urban transportation planning process requires recognition of the fact that the bicycle must be planned for like any other mode of urban transportation. Scenic bikeways along abandoned railroad rights-of-way will not suffice.

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DISCUSSION

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The paper by Hanson and Hanson is a positive step toward integrating the bicycle mode into the urban transportation planning process. I would question whether the survey done in Uppsala, Sweden, has applicability in the United States. The authors make an analogy between travel in the United States and travel in Sweden, and it is difficult for me to resolve whether the factors governing travel in the United States are the same as those in Sweden. If they are, then the bicycle is a viable mode of transportation for U. S. urban areas. However, engineers lack the criteria or the know-how to determine the bicycles per hour or per time interval needed to justify an exclusive lane or partial use of an ordinary transportation lane for bicyclists.

I advocate incorporating bicycles into the urban transportation planning process and would suggest that all bicycle advocates in urban areas include bicycle planning as a line item in all of the unified work programs they deal with. It was through this process that an adequate bicycle plan was developed for Boise, Idaho, when I was the transportation planner there.

If the bicycle is to be planned for like any other mode of transportation, then a bicycle or pedestrian capacity manual, similar to the Highway Capacity Manual developed by the Highway Research Board in 1965, must be developed. This bicycle capacity manual should have speed, volume, and density curves similar to those in the Highway Capacity Manual. Bicycle lane widths should be specified, and methods of predicting bicycle person trips per typical household should also be included. The type of signing and signaling for bicycle lanes, equestrian trails, and pedestrian walkways should be included in this manual and in the Manual of Uniform Traffic Control Devices.

We must not forget the objectives of urban transportation planning. In too many cases advocating a specific mode has left that mode in a framework that cannot be incorporated because of its merits as a people-moving facility into the total transportation picture.

Again let me state that I advocate including bicycle planning in the urban transportation planning process, but, until clear-cut objectives and clear-cut information on the characteristics of bicycles, pedestrians, and all nonmotorized vehicles have been thoroughly examined and documented, it will be very difficult for engineers to justify bicycle lanes for urban areas.

AUTHORS' CLOSURE

We wholeheartedly agree with Markve's point that we need clear-cut objectives and clear-cut information on the nature of bicycle and pedestrian travel before we can plan wisely for bicycle or pedestrian transportation systems. Our paper was offered as one step toward providing the kind of information needed. The intent was not to draw analogies between bicycle travel in Sweden and that in the United States but to show the extent to which bicycles can be used as a mode of transportation in a medium-sized city when people view the bicycle as a transport vehicle rather than as a recreational one. The other major purpose of the paper was to illustrate the kinds of insights into bicycle travel that can be gained from detailed travel data such as those contained in the Uppsala household travel survey. At present there are, unfortunately, no such data available for an American city. U. S. studies of bicycle trip generation and distribution are an essential prerequisite to the planning process.

CITIZEN PARTICIPATION IN BICYCLE PLANNING FROM THE PUBLIC AGENCY'S VIEWPOINT: WHY AND IS IT WORTH THE EFFORT?

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Citizen participation is critical to the development of a sound traffic system plan that serves all segments of the public. Cyclists are a segment with unmet needs who can greatly assist in developing and consequently supporting such a plan. This paper examines the reasons that many highway departments lack good bicycle-related knowledge. The characteristics of today's bicyclists and their needs are presented, along with a discussion and evaluation of bikeway design criteria. The following courses of action are recommended to attract broad public support and increase traffic safety: (a) initiate a program to reduce the serious hit and run problem, (b) enforce regulations controlling motor vehicle emissions, (c) make pedestrian and bicyclist access part of new traffic system improvements, (d) provide safe, attractive bicycle paths, and (e) assign agency personnel and resources to the bicycle field and include them in decision making. The circumstances of Chief Justice Warren E. Burger's bicycle accident are examined, and it is revealed that the causal factors were the responsibility of public agencies. The methods for eliminating these factors have been well-documented.

•IS CITIZEN PARTICIPATION worth the effort? Are state highway departments biased against bicycles? Who are today's bicyclists, and what do they desire? What positive actions can state and local governments initiate quickly and ensure broad support? Those are the questions that seem especially relevant to the topic of citizen participation.

ARE STATE HIGHWAY DEPARTMENTS BIASED AGAINST BICYCLES?

Are state highway or transportation departments biased against bicycles? Yes, of course. First, look at training. Although there is a very large body of knowledge on bicycle planning in Europe and a rapidly emerging one in the United States, traffic engineers and allied professionals receive almost no training in this area. For example, Paquette, Ashford, and Wright's 760-page text, Transportation Engineering, devotes one paragraph to bicycling, and that paragraph merely points out that the bicycle craze of the latter nineteenth century contributed to pressure for improved road construction. Matson, Smith, and Hurd's 647-page Traffic Engineering notes that "2 percent of automobile fatalities involve bicycle collision," and spends about a page documenting the problem of children on bicycles. The Highway Capacity Manual and Pignataro's Traffic Engineering do not discuss bicycles at all. This is entirely consistent with the short shrift given buses and pedestrians and is only partly attributable to the recentness of America's bicycle boom. The effect of ignorance is to make the traffic planner wary of bicycle-related facilities.

Next, look at the personal transportation modes of highway department employees. Typically, most ride cars and few ride bicycles. This is unfortunate because of the well-documented correlation between lack of exercise and coronary heart disease (19, 20).

Naturally, the personal experiences, frustrations, and thinking are from the nonbiker standpoint. Despite traffic laws that give bicycles equal rights, the automobile-commuting traffic planner is tempted to view the bicycle as an obstacle rather than as a vehicle with which to share the roadway.

Another point is that decision makers in a highway department are older than the general population and live farther away from work than the general population. Although bicycle commuting is prevalent among all age groups, its incidence is higher among people in their twenties and thirties than among those in their forties or fifties. The question of distance to work is an important one. For planning purposes, I use a radius of comfort of 5 miles (8 km), varying with terrain, weather, and physical ability. Of course, many bikers commute longer distances. The office of the Mayor of the District of Columbia has estimated that 30,000 automobiles are used for commuting distances of less than 3.5 miles (5.6 km). Conversion to bicycles has the obvious potential for reducing traffic congestion. In 1974, the decision makers in the D.C. Department of Highways and Traffic, however, lived in the far suburbs: the director in Potomac, Maryland; the head of traffic engineering in Lanham, Maryland; and the head of planning in Beltsville, Maryland.

The circumstances of the Maryland Department of Transportation are different, and even less representative of the state population. The Maryland DOT is located at Baltimore-Washington International Airport and is accessible by bicycle only from airline departure stations and hangars. All surface approach is via a limited-access superhighway. No wonder no state transportation employee bikes to work; it is impossible. How can Maryland DOT personnel possibly appreciate the commuting experiences of the people they serve when over half of all Marylanders live in a single metropolitan area far away from the airport?

WHO ARE TODAY'S BICYCLISTS, AND WHAT DO THEY DESIRE?

In general, bicycle commuters are not much different from the working population as a whole, except that they tend to be healthier, to some extent, because of their bike riding.

In 1971 the Metropolitan Washington Council of Governments (COG) did a survey of bicycle ridership. Of biking respondents, 61 percent were male and 39 percent were female. The percentage of persons who ride bicycles for transportation purposes (defined as work, shop, or school) is as follows:

Age	Percentage	Age	Percentage
<21	21	31 to 35	16
21 to 25	26	36 to 40	10
26 to 30	21	>40	6

The City Council of the District of Columbia also did a preliminary survey from which it estimated that 6,000 persons commuted by bicycle.

In Washington, people with higher incomes are more apt to ride bicycles than people with lower incomes. I think, however, that it is possible to carry the categorization of bicycle riders too far. A survey in Prince George's County, Maryland, for example, found desire for better biking facilities in all occupational groups. During a research trip in Europe in 1973 (15, 16), I found that biking is not the province of any particular group. Local statistics in the United States may change as biking becomes more broadly based.

What do bikers want? According to COG, "Traffic conflicts, bike storage at destination, and theft were the three overwhelming obstacles facing the respondents in using their bicycles.... Somebody must provide a place to store his bike at the destination,

Table 1. Problem areas identified by bikers.

Problem Area	Percentage of Comments
Necessity of bike paths	32
Need for bike racks	16
Heavy traffic	12
Inconsiderate automobile drivers	11
Inconsiderate bus drivers	5
Smoke and exhaust fumes	7
Hazardous road (bumps and storm drains)	7
Need for education of motorists	6
Other	4
Total	100

Table 2. Reasons for choice of streets for bicycling.

Reason	Percentage of Responses			Weighted Average
	1	2	3	
Least motor vehicle conflict	66.4	19.6	14.0	2.52
Most direct route	59.8	29.2	11.0	2.49
Best road surface	22.1	58.4	19.5	2.03
Least cross traffic	32.1	38.1	29.8	2.02
Most scenic route	30.2	34.9	34.9	1.95
Fewest stop signs	13.5	45.6	40.9	1.73
Least hilly route	13.0	30.2	56.8	1.56

and there must be provided for the cyclist a right-of-way or other means of recognizing bikeways for his use."

According to the D.C. City Council survey, the problem areas most frequently cited by bicyclists are those given in Table 1.

Other similar American surveys have shown similar results, except that the need for bike racks is really a need for a storage area secure from theft. Bike racks are secure only under certain circumstances.

These results do not contain the type of data needed to develop locational criteria for bikeways. To help fill that gap, the Washington Area Bicycle Association conducted a survey in 1973 that asked Washington area bicyclists their reasons for bicycling where they indicated they did. Seven possible reasons were listed, and bicyclists were asked to rank them from 3 (very important) to 1 (not important). The results are given in Table 2.

The rationale ranking highest was least motor vehicle conflict, suggesting that streets with low traffic volumes are chosen where practicable. A very close second, however, was most direct route, which is often an arterial with high traffic volume. Bicycles are attracted to arterials for numerous reasons including direct routes, smooth grades, few stops, presence of commercial areas, and high likelihood that the origin or destination is on or near an arterial. Cars are attracted to arterials for similar reasons. With respect to bikeway location, those alternative criteria may counter or reinforce each other, depending on local traffic networks and topography. As a result, bikers choosing arterials for one or more of the reasons enumerated above will necessarily be increasing the chance of motor vehicle conflict. One method of serving all those needs at once would be to use lower volume side streets near and parallel to arterials as biking streets. That would require a level, parallel grid network, which is lacking in many areas because the side streets do not parallel the arterials or are not continuous. Some level side streets could be made good biking streets by the addition of appropriate linkages such as bridges or connecting paths. Even so, however, they would frequently fail to fulfill the functions for which experienced bicyclists prefer arterials. Research sponsored by the Federal Highway Administration (11) shows, for instance, that bikeways at the sides of arterials would increase bicycle traffic more than bikeways at the sides of collector streets. Respondents were asked whether providing bikeways at the sides of arterials or collectors would increase their use of bicycles. The responses in percentages were as follows:

Street	Yes	No
Major arterial	87.9	12.1
Residential (collector)	67.7	32.3

In other words, the utility of bikeways on arterial streets (as distinguished from collector streets) reflects a preference for the advantages arterials offer all traffic, and the need of bikers is not so much for an alternative to arterials as for a safe means of sharing their use.

IS CITIZEN PARTICIPATION WORTH THE EFFORT?

Citizen participation today bears the relationship to planning that motherhood and apple pie used to bear to politics. Everyone is willing to be quoted in favor. Not only is it impolitic to be against citizen participation, but also seeking public views is a legal or administrative requirement in many projects.

Nevertheless, agencies frequently deter citizen participation through their actions or inactions: failure to connect the public with responsible agency representatives or slow response. Even the public hearing process suffers when notice is little or late, hearings are held in the daytime when most working people cannot attend, and follow-up with participants after the hearing is nonexistent.

Some administrators are perhaps unwilling to become involved in citizen participation because they are unaware of its potential benefits and, instead, view it only as a cumbersome if not abrasive give and take. It is, therefore, necessary, despite the rhetoric in favor of citizen participation, to review its value to transportation agencies and not simply its obvious value to the public.

First, direct contact with and utilization of citizens is far cheaper than use of private consulting services, and is more productive than blind efforts of agency personnel without citizen participation. The typical consultant's proposal for work in the bicycle field involves two elements—(a) a survey or polling of local bicycle riders, and (b) a background information search. Effectively, you are paying the consultant to obtain from citizens information that they have and are willing to transmit directly. Usually, the citizens know firsthand and in specific detail what they desire and are willing, if not eager, to engage in direct communication with representatives of public agencies. Unfortunately, citizens and citizen organizations do not have the financial resources to devote to major, lengthy, time-consuming efforts. However, what is often overlooked is that their financial requirements for such work are much less than the financial demands of traditional consulting organizations.

Many bicycle commuters have high professional qualifications but may be subject to unfair stereotyping by transportation department personnel. Lawyers, scientists, engineers, college professors, and economists are among those who commute to work by bicycle. For example, one avid bicycle commuter, who has a doctorate in nuclear engineering, was informed by a Maryland DOT official that he could not look at bikeway plans because he was technically unqualified to understand them. He has been recognized by his county with an appointment as a transportation advisor, but I do not know whether the Maryland DOT official's bias has been rectified.

Furthermore, active citizens have an enormous amount of the initiative and enthusiasm that are important ingredients in any undertaking. Coupled with that initiative is a desire to participate and communicate cooperatively. But it is the agencies that must establish the necessary channels.

Another very important function for citizen participation is to help ensure the political acceptability of results. On some occasions, bikers have testified against faulty bikeway proposals that might have been corrected had there been direct communication with potential users. In contrast, Arlington County, Virginia, established a working citizen advisory committee. The plans resulting from the effort were widely supported.

Highway departments today are increasingly under public scrutiny. There is much handwringing about the institutionalized, historic commitment to the private automobile and some of the unfortunate side effects in pollution, energy consumption, and traffic fatalities. Some departments appear to alienate the critics by denying the role of other transportation modes. Where it occurs, this is a tragic mistake.

Bikers are a constituency, composed of real people with real needs. As these needs are met, they become avid supporters of the agency that meets them. They are road users to be sure and, aside from their legitimate needs, have no a priori view on the transportation mode debate. Their antagonism or support (and recall that one of every three Americans has a bicycle) is dependent on whether they are thwarted or accommodated.

Among the results achieved by bike-riding citizens in Washington, D.C., are a legal decision to require the removal of abandoned trolley tracks, increased bikeway appropriations (the local budget process involves federal approval and passage), Zoning Commission decisions in favor of bike facilities (4, 5, 6), and a mandate from the Environmental Protection Agency. The EPA decision (1, 2, 3) includes a number of provisions concerning bikeway planning, including technical requirements, mileages, and dates of completion for bikeways.

WHAT POSITIVE ACTIONS CAN STATE AND LOCAL GOVERNMENTS INITIATE QUICKLY?

Initiate a Program to Reduce the Serious Hit-and-Run Problem

It is, of course, illegal to hit and run, but there are documented cases of bicycle riders being left unconscious by hit-and-run motorists. Unfortunately, concern with accident liability is sometimes stronger than moral responsibility on the road today.

The case of the Supreme Court Chief Justice Warren Burger is only an example. The Justice was riding after dark on a well-lighted bicycle. The average speed of motor traffic in the area in which he was riding is well above the speed limit, and enforcement of speed laws has not been effective. When headlights bore down on him quickly, Burger pedaled faster and veered toward the curb. There was no bicycle lane for the Justice to take shelter in. Instead, a sewer grating of the type that traps bicycle tires reduced his room for maneuver. The sewer grating problem is well-documented, and safe, hydraulically efficient alternatives are available (7), but corrective action had not been taken in his area. The Justice was suddenly slammed against the pavement and knocked temporarily unconscious. It happened so quickly that he thought he fell, and initial newspaper reports carried the story that way. X-rays and medical examination revealed that he had been hit twice, once on each side. According to the medical report, he was hit not only by the pavement but also by the automobile. The motorist never returned to the scene of the accident, despite the possibility that a man's life might be at stake.

What can we learn from this? Those who attempt to assign blame to either motorists or bicyclists as a class completely miss the boat. All road users stand to benefit from improvements that allow them to travel safely together, and a very small minority of motorists can be an enormous traffic hazard far beyond their numbers. This minority can be divided into two groups—the bad driver and the attitudinally misguided. The traffic threat posed by the bad driver can be reduced by better education and enforcement of existing traffic laws. Then there are drivers, and even police officers, who believe the bicycle does not belong on the road. Whether it is frustration in traffic, jealousy of the biker's good health and esteem, unthinking desire for amusement, or even desire to harass a woman on a bicycle, the result can be a traffic casualty. Virginia, where the Burger incident occurred, is like most states; the bicycle has equal rights to the road under law, but that fact does not appear on the motorist's licensing exam. For the motorist who does not instinctively believe it, there is no mechanism for him to learn it. Great Britain, by comparison, includes an extensive section on cycling in its official national driving manual (13).

The posting by the D.C. Department of Motor Vehicles of traffic signs reading BIKES HAVE EQUAL RIGHTS was an extremely important step toward increasing traffic safety in the District of Columbia. Another medium that reaches motorists is the radio. Public service safety announcements during evening rush hour (when fatigue, tension, and listenership are at a peak) would help in reestablishing courtesy for all road users.

Enforce Regulations Controlling Motor Vehicle Emissions

The pedestrian, the bicycle rider, the passenger waiting at a bus stop, the commercial (and taxi) driver, and to a much lesser extent the casual motorist are human victims of motor vehicle exhaust. Recent findings published in the Journal of the American Medical Association on levels of carbon monoxide in urban drivers' blood are extremely disturbing. All states should have laws such as the District of Columbia's to forbid exhaust that is visible and to forbid idling longer than 3 min. The exhaust problem can often be ameliorated by proper engine tuning. The law needs to be enforced through ticketing and vehicle inspection.

Make Pedestrian and Bicyclist Access Part of New Traffic System Plans

There once was a time when you could walk from the Pentagon and nearby areas of Arlington into the District of Columbia. Today the maze of redundant highways in that area (called the mixing bowl) makes it impossible. Highways in particular sever communities, sometimes making it necessary for all members of a family to be driven places by car. Bridges are also structures that, when improperly designed, hinder or stop nonmotorized transport. It is not necessary. In Holland and Sweden, spacious pathways along highways, across bridges, and through cloverleafs are common (15, 16).

Provide Safe, Attractive Bicycle Paths to Enable People to Safely Develop Their Skills

Picture the following circumstances. A new owner of a bicycle takes it into traffic. He weaves somewhat, is afraid of traffic, does not trust himself near the curb, and is frightened of the honking his behavior arouses. The prime cure is the development of bike riding skill, which will occur almost automatically when there is an attractive, automobile-free area in which to learn.

Bicycle paths are the obvious answer, and, once built, they are a permanent resource for the community. One major bicycle path in the Washington, D.C., area—from Memorial Bridge to Mount Vernon (8)—has done more for traffic safety than all the area's lectures and safety demonstrations combined. It is not necessary, however, to await new path construction to begin provision of facilities, if a policy of street closings is followed. National Capital Parks closed portions of the George Washington and Rock Creek Parkways to motor vehicles on a regular, well-publicized basis, and the program was enormously successful.

Assign Agency Personnel and Resources to the Bicycle Field, and Include Them in Decision Making

An agency works only through people, and unless staff is assigned to a problem, no solution or even correct information bearing on it will emerge. Despite traffic department bias against bicycles, particularly in the upper, older ranks, young, bright, ambitious traffic engineers and other professionals are often very interested in the new bicycle field, but they need the go-ahead of their departments.

I even recommend that the agency buy such a person a well-equipped bicycle so that he may become better informed about the relation between biking and the local traffic network through first-hand experience. The D.C. Department of Transportation bought a 10-speed bicycle for its personnel, painted it departmental orange, and attached a large emblem with the department's name on it. It was an immediate public relations success.

It is only through the designation of real people with real time and an ear within an agency that an effective link with citizens can be forged.

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A HIGHWAY SAFETY STANDARD FOR BICYCLE FACILITIES

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ABRIDGMENT

More than 1,100 pedal cycle deaths each year for the last 2 years have focused national attention on the growing bicycle safety problem. The Highway Safety Act of 1973 requires that bicycle safety provisions be incorporated into highway safety standards. The Federal Highway Administration is the agency responsible for developing a standard that will encourage safe operation of bicycles in the highway environment through improved traffic engineering practices and physical facilities. In many instances, no physical improvements will be needed. In others, the widening of the outside travel lane or paving of the shoulder may be required. Some situations may justify a bicycle roadway separate from high-speed motor vehicle traffic. The standard will provide guidance to appropriate officials so that safe and usable bicycle facilities will be planned and constructed where needed. Discussion among educators, enforcement officials, and engineering experts has shown that there is agreement that improving bicycle safety will require a combination of all three areas of specialization. Providing a safe facility is only a partial solution to the bicycle-motor vehicle conflict.

•THE OFFICE of Highway Safety, Federal Highway Administration, develops, publishes, and administers highway safety program standards relating to the highway environment of states and local governments. In the past, this office has been very much involved with highway safety features for the motor vehicle operator and protection of the pedestrian. However, much still remains to be done in this field.

Everyone at one time or another is a pedestrian. This cannot be said about bicycling. Although Americans now own an estimated 85,000,000 bicycles, many of them are used infrequently. Still, more than 1,100 pedal cycle deaths have been reported each year in this country for the last 2 years, and estimates for 1974 surpass that figure. A few facts must be noted, however, before methods to reduce the number of bicycle deaths can be considered.

The Consumer Product Safety Commission, which monitors hospital emergency rooms, estimated that 372,000 adults and children were treated for bicycle-associated injuries during the year ending June 30, 1973. Almost 90 percent of these injuries, though, were from accidents that did not involve a motor vehicle, for example, a child catching his or her foot in the bicycle chain or an adult going too fast around a corner and skidding on gravel. The 40,000 crashes that do involve a motor vehicle account for the overwhelming majority of all bicycle deaths.

The fact that most of the bicyclists killed or injured in accidents are under 15 years of age is also important in consideration of safety programs. These youngsters have not driven an automobile on public roads and, therefore, may not fully understand the behavioral requirements of operating a vehicle in heavy urban traffic. Because of highway hazards facing bicyclists, the Highway Safety Act of 1973 requires that bicycle safety provisions be incorporated into highway safety standards. The National Highway Traffic Safety Administration is currently working on a standard relating to education of bicyclists and the enforcement and legislative aspects of bicycle safety. Further information on the safety administration's proposed standard is available from them.

The Federal Highway Administration's responsibility centers on developing a standard for a safe highway environment in which to operate bicycles by improving traffic engineering practices and physical facilities. Implementation of the proposed standard will become part of the states' highway safety program and may be funded with federal highway safety money. Coverage of the standard extends to each state with the cooperation of its political subdivisions, and each federal agency that controls highways open to public travel or supervises design, construction, and maintenance of these highways.

The standard will recognize that providing adequate and safe facilities for bicyclists is an integral element of planning and of the community highway transportation system. Promulgation of the new standard does not mean that every road in America will be required to have a parallel 8-ft-wide (2.4-m) paved bicycle lane. This undertaking could cost $25,000 to $35,000 per mile ($16,000 to $22,000 per km) or even more.

It will require that existing and potential bicycle use and safety needs be determined for all types of bicycle users—school children, recreational riders, and commuters. In many instances, no physical improvement will be necessary. In others, outside travel lanes may need to be widened, lanes exclusively for bicycles may be required, or facilities separate from high-speed motor vehicle traffic may be justified.

Research into locational criteria and bikeway design is under way in the Office of Research, Federal Highway Administration. The Office of Highway Safety is using the results of these studies in drafting the standard. Also, the Office of Research has recently expanded its interest and budget to look into the concept of citizen acceptance of alternative modes of transportation. The hope is to find answers to questions like the following: What are the economic and environmental trade-offs among walking, bicycling, taking a bus or train, or driving a private automobile? What incentives make people choose the mode they do? What makes a man or woman choose to ride a bicycle or walk to work? The concept of a bicycle boulevard and redesign of intersections may be a product of these efforts.

States and communities across the country are in different stages of bikeway development. Examples of good-quality separate paths are shown in Figures 1, 2, 3, and 4. Figures 5, 6, 7, and 8, however, show bike paths that are unpaved, have poor sight distance, or are unprotected. Providing bike routes on busy streets is effective only if there is strict enforcement of parking regulations. Well-marked sidewalk bike paths (Figure 9) are adequate only if they are maintained and provide necessary clearance (Figure 10). When bike routes must be placed on the street, consideration should be given to details such as grate configuration. Figure 11 shows a grate that is safe for bicycle travel.

Attempts at channelizing bicycle traffic in on-street paths often lead to conflicts between bicyclist and motorist (Figure 12). Figure 13 shows a damaged barrier where conflicts have resulted. The boxed-in bicycle lane shown in Figure 14 can be dangerous and is only necessary if street traffic travels at high speeds. Factors such as traffic volume, speed, and movement determine whether the treatments shown in Figures 15, 16, 17, and 18 are necessary or adequate. Figures 19, 20, 21, and 22 show signs and devices that have been used for the benefit of bicyclists and bike facility planners. The University of California, Davis campus, is a bicyclist's dream (Figure 23).

In regard to state legislation, Oregon has appropriated, as a minimum, 1 percent of its state highway fund to its cities and counties for nonmotorized highway use since 1971. In 1974, California issued a new section of its Highway Design Manual entitled Bike Routes, which was developed with the input and cooperation of many citizens of the state, including expert bicyclists.

California's positive attitude toward accommodation of bicycle traffic on state highways is illustrated by a section entitled General Design Philosophy. In part, it reads as follows (1):

> The standards in this section provide guidance as to how the existing road system may be supplemented with facilities or measures specifically designed to enhance the safety and feasibility of bicycle travel. The standards represent an attempt at a consensus as to what is required to provide a good level of service for cyclists. Since experience and research in this area are relatively limited, the standards are based on a combination of theory, empirical analysis, and the subjective judgment of cyclists.

Figure 1. Wood-planked hiker-biker trail near Mt. Vernon, Virginia.

Figure 2. Bike trail on creek right-of-way in Denver.

Figure 3. Trail on abandoned railroad right-of-way in Tiburon, California.

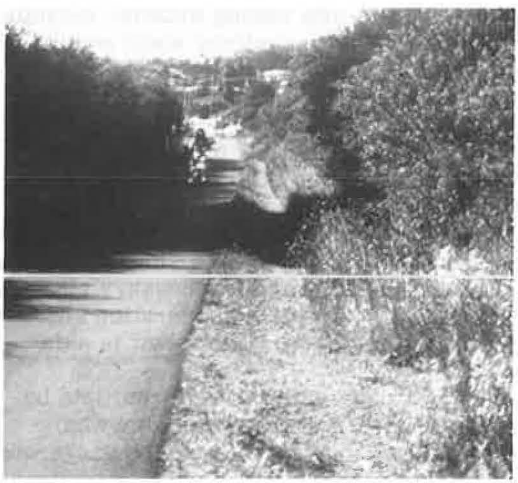

Figure 4. Bicycle path separated from pedestrians on Santa Barbara campus of University of California.

Figure 5. Unpaved, poorly maintained trail in Mt. Vernon, Virginia.

Figure 6. Bikeway that crosses busy highway and that provides poor sight distance for bicyclist and motorist near Mt. Vernon, Virginia.

Figure 7. Well-marked but poorly protected bike lane in Berkeley, California.

Figure 8. Well-marked but blocked bike lane in San Francisco.

Figure 9. Sign marking sidewalk bikeway in Palo Alto, California.

Figure 10. Sidewalk bikeway with inadequate clearance.

Figure 11. Street grate that is safe for bicycling.

Figure 12. Channelized bikeway in Davis, California.

Figure 13. Channelized bikeway marked by barrier damaged through conflicts in Lafayette, California.

Figure 14. High planter boxes and curbs enclosing bike path in Sausalito, California.

Figure 15. On-street bikeway in Davis, California.

Figure 16. Exclusive bike lane on high-speed Danville Highway in California.

Figure 17. Bike lane in each direction in Denver.

Figure 18. Placement of bicycle through lane between left and right automobile turning lanes in Seattle.

Figure 19. Explicit sign warning motorists of bicycle's presence in Seattle.

Figure 20. Inductive loop detector in bicycle lane in Eugene, Oregon.

Figure 21. Push-button signal for bicyclists that activates traffic signal.

Figure 22. Bicycle signal in Europe that turns from red to green for cycle-only movement.

Figure 23. Biker's heaven in Davis, California.

> It is recognized that much of the existing street and highway system is suitable for general cycling.
>
> In planning any highway improvement, consideration should be given to the bicycle as a potential part of the traffic mix....

The California manual also mentions the need for separate facilities when they will be used extensively by young children, but the adequacy of the highway shoulder for use by mature riders is discussed frequently in the publication. It cites a few facts that an inexperienced bikeway planner may sometimes overlook. One is the bike rider's urge to maintain momentum; therefore, the number of required stops should be minimized. Another is the cyclist's tendency to select the most direct route that, in his judgment, is acceptable, whether or not it is designated as a bicycle facility. This is where the importance of having the user's input surfaces.

The new federal highway safety standard and accompanying manual will address these points and other similar ones. They will provide guidance to the appropriate officials so that safe and usable bicycle facilities will be planned and instituted when needed.

CONCLUSION

Education, enforcement, and engineering experts agree that improving bicycle safety will require a combination of all their areas of specialization.

It must be realized that providing a safe facility, no matter what form it takes, is only a partial solution to the bicycle-motor vehicle conflict and resulting deaths. Further education of the motoring public regarding bicycle use and potential for conflict will be necessary as will training bicyclists to ride in a reasonable and predictable way. Both of these elements of a safety program are as important as the facility.

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