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Selecting Roadway Design Treatments to Accommodate Bicycles

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FOREWORD

There is a need for guidance on which type of on-road bicycle facility (wide curb lane, shoulder, shared lane, or marked bicycle lane) to provide under particular roadway design and traffic operational conditions. To date, engineering judgment and trial and error have been used to make these decisions.

This report, FHWA-RD-92-073, presents a set of tables that can be used to determine the recommended type of bicycle facility to be provided in particular roadway situations. In addition, the report presents a brief discussion of the "design user" for bicycle facilities, and presents a planning process for bicycle facilities.

Five criteria were used to determine recommended bicycle facilities: traffic volume; average motor vehicle operating speed; traffic mix of automobiles, trucks, buses, and/or recreational vehicles; on-street parking; and sight distance. Values for these criteria were determined and tables were developed for urban and rural roadway sections for two groups of design users.

Sufficient copies of this report are being distributed to provide a minimum of one copy to each Region and Division office and State highway agency. Additional copies for the public are available from the National Technical Information Service (NTIS), Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. A small charge will be imposed by NTIS.

Lyle Saxton
Director, Office of Safety and Traffic
Operations Research and Development

NOTICE

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16. Abstract

This manual is designed to assist transportation planners and engineers in selecting roadway design treatments to accommodate bicycles. This is the first attempt to provide comprehensive guidelines for this process. The recommendations are based on assumptions regarding policy goals and the types of bicyclists to be accommodated, the state of the practice, and professional judgment. More research, testing, and evaluation are needed to assess and refine these recommendations. A more detailed final report on this study is available.

This manual is not intended to serve as a comprehensive guide to the design of bicycle facilities. The user is referred to the current edition of the American Association of State Highway and Transportation Officials' *Guide to the Development of Bicycle Facilities* for detailed specifications.

The manual describes the assumptions, principles, and approaches used to develop the recommendations; provides a model planning process for identifying a network of routes on which designated bicycle facilities should be provided to accommodate bicyclists of moderate ability (casual adult riders and children); and recommends design treatments and specifications for roadways to serve different types of bicyclists under various sets of traffic operational factors. The appendix contains a detailed discussion of the various types of bicycle facilities.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 l shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

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1. INTRODUCTION

This manual is based on the answers to two key questions:

1. What is the Federal policy goal for bicycle use?

2. Who is the "design bicyclist?"

POLICY GOAL FOR BICYCLE USE

The two basic policy alternatives are: (1) to accommodate current bicycle use and/or (2) to increase the level of use. A review of recent policy statements by Congress, the U.S. Department of Transportation, and the Federal Highway Administration makes it clear that the Federal policy goal for bicycling is to accommodate current use and to encourage increased use, while enhancing safety.[2-4] Therefore, the recommendations in this manual are oriented toward meeting the needs of current and potential bicyclists using the highway system.

THE "DESIGN BICYCLIST"

Nearly 100 million people in the United States own bicycles.[5] The Bicycle Federation of America estimates that fewer than 5 percent would qualify as experienced or highly skilled bicyclists. Since the policy goal is to accommodate existing bicyclists and encourage increased bicycle use, there will be more novice riders than advanced bicyclists using the highway system. Therefore, any roadway treatments intended to accommodate bicycle use must address the needs of both experienced and less experienced riders. One solution to this challenge is to develop the concept of a "design cyclist" and adopt a classification system for bicycle users such as the following:

- Group A—Advanced Bicyclists: These are experienced riders who can operate under most traffic conditions. They comprise the majority of the current users of collector and arterial streets and are best served by the following:

  - Direct access to destinations usually via the existing street and highway system.

  - The opportunity to operate at maximum speed with minimum delays.

  - Sufficient operating space on the roadway or shoulder to reduce the need for either the bicyclist or the motor vehicle operator to change position when passing.

- Group B—Basic Bicyclists: These are casual or new adult and teenage riders who are less confident of their ability to operate in traffic without special provisions for bicycles. Some will develop greater skills and progress to the advanced level, but there will always be many millions of basic bicyclists. They prefer:

- Comfortable access to destinations, preferably by a direct route, using either low-speed, low traffic-volume streets or designated bicycle facilities.

- Well-defined separation of bicycles and motor vehicles on arterial and collector streets (bike lanes or shoulders) or separate bike paths.

- Group C—Children: These are pre-teen riders whose roadway use is initially monitored by parents. Eventually they are accorded independent access to the system. They and their parents prefer the following:

  - Access to key destinations surrounding residential areas, including schools, recreation facilities, shopping, or other residential areas.

  - Residential streets with low motor vehicle speed limits and volumes.

  - Well-defined separation of bicycles and motor vehicles on arterial and collector streets or separate bike paths.

While other distinctions can be added, these lists support combining groups B and C bicyclists in most situations. Therefore, a "design cyclist" concept is proposed that recognizes two broad classes of bicyclists: group A riders and group B/C riders.

Generally, group A bicyclists will be best served by designing all roadways to accommodate shared use by bicycles and motor vehicles. This can be accomplished by:

- Establishing and enforcing speed limits to minimize speed differentials between bicycles and motor vehicles on neighborhood streets and/or by implementing "traffic-calming" strategies.

- Providing wide outside lanes on collector and arterial streets built with an "urban section" (i.e., with curb and gutter).

- Providing usable shoulders on highways built with a "rural section" (i.e., no curb and gutter).

Generally, group B/C bicyclists will be best served by a network of neighborhood streets and designated bicycle facilities, which can be provided by:

- Ensuring neighborhood streets have low speed limits through effective speed enforcement or controls and/or by implementing "traffic calming" strategies.

- Providing a network of designated bicycle facilities (e.g., bike lanes, separate bike paths, or side-street bicycle routes) through the key travel corridors typically served by arterial and collector streets.

- Providing usable roadway shoulders on rural highways.

DESIGN APPROACH

Given these two types of design bicyclists, a two-tiered approach to meeting their needs is proposed.

- Group A riders will be best served by making every street "bicycle-friendly." This may be accomplished by adopting highway design standards that include wide curb lanes and paved shoulders to accommodate shared use by bicycles and motor vehicles. This approach will provide adequate space for bicycles and motor vehicles to share the roadway with minimum need for changing lanes or lane position. The desired outcome is to have sufficient space to accommodate shared use by bicycles and motor vehicles with minimum delays and maximum safety for all users.

- Group B/C riders will be best served by identifying key travel corridors (typically served by arterial and collector streets) and by providing designated bicycle facilities on selected routes through these corridors. These key travel corridors can be identified through the type of planning process described in section 2 of this manual.

Full implementation of this approach will result in a condition where every street on which bicycles are permitted to operate will incorporate at least the design treatments recommended for group A bicyclists. In addition, a network of routes will be enhanced by incorporating the designated bicycle facilities recommended for group B/C bicyclists.

RELATED ISSUES

The approach to selecting and designing roadway treatments to accommodate bicycles and motor vehicles proposed in this manual relates to other bicycle facility and program issues.

Signing and Marking Bicycle Facilities

Signs and pavement markings for bicycle facilities will encourage increased use. In addition to obvious traffic operations benefits, signs and pavement markings have the effect of "advertising" bicycle use. (See part IX of the *Manual of Uniform Traffic Control Devices* for specific details.[6]) This helps legitimize the presence of bicycles in the eyes of motorists and potential bicyclists. Also, while not discussed specifically in this manual, use of bike route signs in combination with destination information or a map can contribute to development of a network of designated bicycle routes to provide community access for group B/C bicyclists.

Education/Training and Law Enforcement

As with motor vehicle use, bicycle program specialists have long advocated including education/training and law enforcement activities as an integral part of encouraging and managing bicycle use. Communities must develop regular programs to educate and train adults and children on the proper use of bicycles in traffic and make bicycle-related law enforcement activities—for motorists as well as bicyclists—a routine, ongoing element of the local police department's duties.

Bicycles, Motor Vehicles, and Pedestrians

The highway transportation system is characterized by the interaction of three basic modes of transportation: motor vehicles (including transit services), bicycles, and walking. All decisions related to the planning, design, and implementation of highway-based transportation facilities should address the potential impact on each of these modes. Regardless of the source of funding for transportation improvements, all members of the public are entitled to use public thoroughfares by their choice of mode. Therefore, it is incumbent on transportation agencies to plan and design facilities accordingly.

SUMMARY

Four principles define the basic approach used for this manual:

1. Two types of design bicyclists are recognized: group A (advanced) and group B/C (basic adult and child).

2. To paraphrase the *AASHTO Guide*, every street and highway on which bicycles are permitted to operate is a "bicycle street" and should be designed and maintained to accommodate shared use by bicycles and motor vehicles. Thus, at a minimum, all streets should include the design treatments recommended for group A bicyclists.

3. Given the stated policy goal, a supply-driven approach of providing designated bicycle facilities to encourage increased use by group B/C riders (i.e., "if you build them they will come") is warranted.

4. Selecting design treatments to meet the needs of group B/C bicyclists involves two steps:

   - A planning process to identify key travel corridors and/or routes along which access is important (section 2).

   - A design decision to identify the most appropriate facility treatment for a given route or corridor (section 3).

2. THE BICYCLE PLANNING PROCESS

Transportation planning is a process for making decisions about the development of transportation facilities. This includes providing accurate information about the effects proposed transportation projects will have on the community and projected users.[7] Bicycle planning is no exception. However, because much of the information necessary to reach sound decisions about providing for safe, efficient bicycle use is already available as a byproduct of the normal operation of the road system, the bicycle planning process is a specific application of the overall transportation planning process.

This is especially true in the case of group A bicyclists, the more experienced and proficient bicyclists that comprise about 5 percent of bicycle users in the United States. These bicyclists are able to operate on the roadway in most traffic conditions and favor the directness and right-of-way preference given to roads with a high functional classification. The planning process used to develop or improve roadways for motorists is equally valid for this type of bicyclist.

There are, however, some important design features to be taken into account to best accommodate group A bicyclists, and for this reason, planners and engineers should refer to the *AASHTO Guide* during the planning process for streets and highways. Group A riders should be anticipated and provided for on all roadways where bicycles are not excluded by statute or regulation, regardless of functional classification.

The situation is very different for group B/C bicyclists (bicyclists of average skill and experience, and children). While these bicyclists value many of the same roadway features as group A bicyclists (i.e., accessibility and directness), they also value other characteristics such as designated bicycle facilities and lower traffic volumes.

Group B/C bicyclists typically prefer to ride on neighborhood streets and/or designated bicycle facilities. The location of these facilities is best determined through a planning process that seeks to determine where designated facilities are needed and the type of bicycle facilities that should be provided to accommodate and encourage group B/C bicyclists.

DEVELOPING A BICYCLE NETWORK PLAN

The following discussion details a planning process intended to identify a network of routes where special bicycle facility treatments should be employed to meet the needs of group B/C bicyclists.

Many model planning processes could be used to select routes and design facility treatments to accommodate group B/C bicyclists. Chapter 1 of the *AASHTO Guide* contains several suggestions for establishing a bicycle planning program. The following process is but one example. It consists of six steps:

1. Establish performance criteria for the bicycle network.

2. Inventory the existing bicycle facility and roadway system.

3. Identify bicycle travel desire lines and corridors.

4. Evaluate and select specific route alternatives.

5. Select appropriate design treatments.

6. Evaluate the finished plan against the established performance criteria.

Establish Performance Criteria for the Bicycle Network

Performance criteria define the important qualitative and quantitative variables to be considered in determining the desirability and effectiveness of a bicycle facility network. These can include:

- Accessibility: This is measured by the distance a bicycle facility is from a specified trip origin or destination, the ease by which this distance can be traveled by bicycle, and the extent to which all likely origins and destinations are served. Some communities (e.g., Arlington, VA) have adopted a criterion of having a bicycle facility within 1 mi (1.61 km) of every residence. More importantly, no residential area or high priority destination (school, shopping center, business center, or park) should be denied reasonable access by bicycle.

- Directness: Studies have shown that most bicyclists will not use even the best bicycle facility if it greatly increases the travel distance or trip time over that provided by less desirable alternatives.[8,9] Therefore, even for group B/C bicyclists, routes should still be reasonably direct. The ratio of directness to comfort/ perceived safety involved in this tradeoff will vary depending on the characteristics of the bicycle facility (how desirable is it?), its more direct alternatives (how unpleasant are they?), and the typical user's needs (in a hurry?, business or pleasure trip?).

- Continuity: The proposed network should have as few missing links as possible. If gaps exist, they should not include traffic environments that are unpleasant or threatening to group B/C riders, such as high-volume or high-speed motor vehicle traffic with narrow outside lanes.

- Route Attractiveness: This can encompass such factors as separation from motor traffic, visual aesthetics, and the real or perceived threat to personal safety along the facility.

- Low Conflict: The route should present few conflicts between bicyclists and motor vehicle operators.

- Cost: This would include the cost to both establish and maintain the system.

- Ease of Implementation: The ease or difficulty in implementating proposed changes depends on available space and existing traffic operations and patterns.

Inventory Existing System

Both the existing roadway system and any existing bicycle facilities should be inventoried and evaluated. The condition, location, and level of use of existing bicycle facilities should be recorded to determine if they warrant incorporation into the proposed new network or if they should be removed. If existing bicycle facilities are to be used as the nucleus of a new or expanded network, the inventory should note which improvements to the existing portions of the network may be required to bring the entire new network up to uniform design and operations standards.

A simple inventory of the roadway system could be based on a map of the annual average daily traffic (AADT) counts on each road segment within a community or region. A more complex inventory could include factors such as the number of traffic lanes, the width of the outside lane, the posted speed limit or actual average operating speed, the pavement condition, and certain geometric and other factors (e.g., the frequency of commercial driveways, grades, and railroad crossings).

Identify Bicycle Travel Corridors

Predicting bicycle travel corridors for a community is not the same as identifying the routes that bicyclists currently use. Instead, travel corridors can be thought of as "desire lines" connecting neighborhoods that generate bicycling trips with other zones that attract a significant number of bicycling trips.

For motor vehicle traffic, most peak morning trips are made between residential neighborhoods and employment centers. In the evening peak, the opposite is true. In the evening or on weekends, the pattern of trip generation is much more dispersed as people travel to shopping centers, parks, and the homes of friends or relatives.

Estimating these trip flows for an entire city can be a complex, time-consuming effort requiring significant amounts of raw data and sophisticated computer models. Fortunately, transportation planning for bicycles is much simpler. Unlike traditional transportation planning that attempts to predict travel demands between future zones on as-yet-unbuilt streets and highways, bicycle planning attempts to provide for bicycle use based on existing land uses assuming that the present impediments to bicycle use are removed. These desire lines are, in fact, well represented by the traffic flow on the existing system of streets and highways.

The underlying assumption is that people on bikes want to go to the same places as do people in cars (within the constraints imposed by distance), and the existing system of streets and highways reflects the existing travel demands of the community. Furthermore, most adults have a mental map of their community based on their experience as motor vehicle operators. Thus, they tend to orient themselves by the location of major streets and highways.

Therefore, a good way to estimate desire lines for bicyclists and to project bicycle trips is based on the existing pattern of motor vehicle flows. The simplest way to do this is to multiply the AADT of each segment of the road system by the bicycle mode split (the percentage of all trips that are made by bicycle) for the community or region. For the first time, the 1990 census will provide bicycle mode splits for census tracts and entire communities. Mode split estimates of total trips by bicycle in American cities have ranged between 3 and 11 percent.[10-12]

Again, it is important to note that the resulting map may not be a representation of where cyclists are now, but is instead a reflection of where bicyclists wish to go. The actual travel patterns of group B/C cyclists are heavily influenced by their perception of the bicycling environment they face. Uncomfortable or threatening bicycling conditions will cause these bicyclists to alter route choice from their most preferred alignment, choose a different travel mode, or not make the trip at all. Thus, the task of the transportation planner for bicycling is to ask, "Where are the bicyclists now?" and "Where would they be if they could go where they preferred?"

Although this use of existing traffic flows is a useful overall predictor of bicyclists' desire lines, a few special situations may require adjustments to the corridor map:

- Schools—especially colleges and universities—and military bases can generate a disproportionately large share of bicycle trips. This is especially true for campuses where motor vehicle parking is limited.

- Parks, beaches, libraries, greenways, rivers and lakesides, scenic roads, and other recreational facilities attract a proportionately higher percentage of bicycle trips.

Evaluate and Select Specific Route Alternatives

The corridor identification procedure identifies desire lines for bicycle travel between various locations. The next step is to select specific routes within these corridors that can be designed or adapted to accommodate group B/C bicyclists and provide access to and from these locations. The aim is to identify the routes that best meet the performance criteria established in the first step of this planning process.

Typically, this step and the selection of appropriate design treatments are highly interactive processes. The practicality of adapting a particular route to accommodate group B/C bicyclists may vary widely depending upon the type of design treatment selected. For example, a less direct route may become the best option if comparatively few, inexpensive, and easily implemented design improvements are required.

Therefore, steps 4 and 5 should be approached as an iterative loop in which both route selection and design treatment are considered together to achieve a network that is highly advantageous to the user, is affordable, has few negative impacts on neighbors and other nonusers, and can be readily implemented.

In summary, the selection of a specific route alternative is a function of several factors, including:

- The degree to which a specific route meets the needs of the anticipated users as opposed to other route options.
- The possible cost and extent of construction required to implement the proposed bicycle facility treatment.
- The comparative ease of implementing the proposed design treatment. For example, one option may entail the often unpopular decision to alter or eliminate on-street parking while another does not.
- The opportunity to implement the proposed design treatment in conjunction with a planned highway construction or reconstruction project.

A more inclusive list of factors to be considered in the selection of a specific route is presented in the *AASHTO Guide.*[1]

Select Appropriate Design Treatments

Guidelines for selecting an appropriate design treatment are presented in section 3 of this manual. In overview, the principal variables affecting the applicability of a design treatment are:

- The design bicyclist. Is the proposed route projected to be used primarily by group A bicyclists, or is it intended to also serve as part of a network of routes for group B/C bicyclists?
- The type of roadway project involved on the selected route. Is the roadway scheduled for construction or reconstruction, or will the incorporation of design improvements be retrofitted into existing geometrics or right-of-way widths?
- Traffic operations factors. The most significant traffic operations factors for determining the appropriateness of various design treatments are:
    - Traffic volume.
    - Average motor vehicle operating speeds.
    - Traffic mix.
    - On-street parking.
    - Sight distance.
    - Number of intersections and entrances.

Evaluate the Finished Network Plan Using the Established Performance Criteria

Will the proposed network meet the criteria established at the start of the planning process? If it does not meet most of these criteria, or inadequately meets a few critical goals, either the proposal will require further work, or the performance criteria must be modified. In the latter case, the planning process as a whole should be reviewed to determine if previously discarded routes should be reconsidered. They may now be more preferred options in light of the newly modified criteria.

This reality check is important. Many well-considered proposals fail when it is determined that the finished product no longer meets its established objectives.

3. DESIGN SELECTION AND SPECIFICATIONS

This section provides recommendations for selecting roadway design treatments to accommodate bicycles. Specific dimensions are suggested for the width of the recommended facility type. These recommendations reflect the current state of the practice in the design of bicycle-friendly roadways. Users of this manual are encouraged to treat these recommendations as "guidelines" rather than absolute standards.

TYPES OF FACILITIES

Five basic types of facilities are used to accommodate bicyclists:

- Shared lane: shared motor vehicle/bicycle use of a "standard"-width travel lane.
- Wide outside lane: an outside travel lane with a width of at least 14 ft (4.2 m).
- Bike lane: a portion of the roadway designated by striping, signing, and/or pavement markings for preferential or exclusive use of bicycles.
- Shoulder: a paved portion of the roadway to the right of the edge stripe designed to serve bicyclists.
- Separate bike path: a facility physically separated from the roadway and intended for bicycle use.

Each of these facilities is discussed in detail in the appendix.

DESIGNATING BICYCLE FACILITIES

An important consideration regarding the five types of facilities designs is whether or not they should be designated, by pavement markings and/or signs, as bicycle facilities. As discussed in section 1, group B/C bicyclists prefer designated facilities for bicycle use. Therefore, when bike lanes or shoulders are provided to serve group B/C riders, some designation should be included.

However, the legality of bicycle use on highway shoulders may not be well defined in every State. This is due, in part, to the current language in the Uniform Vehicle Code regarding where vehicles are permitted to operate. Users of this manual are encouraged to contact their State Attorney General's office to determine the current situation regarding bicycle use on selected highway shoulders. Consideration should be given to amending some State vehicle codes to explicitly permit this widespread practice.

When design treatments are provided primarily to serve group A riders, designation is optional. In some cases, it may be more desirable not to designate the facility for bicycle use. For instance, if bicycle use is permitted on the shoulder of a controlled access freeway, it is usually not appropriate to designate this roadway as a bicycle facility unless this route serves as the only link between two points.

Another consideration involves minor or marginal roadway improvements for bicyclists, such as providing a narrow (less than 4-ft [1.2-m]) shoulder. This can significantly improve riding conditions for group A bicyclists and should be considered if no better treatment is possible. However, this width is less than the minimum called for in virtually all design specifications and therefore should not be designated as a bicycle facility. Where a facility is intended to be designated as a "bicycle facility" it is essential the design conform to the State standard or AASHTO guidelines.

PREPARING TO SELECT A FACILITY TREATMENT

To determine the appropriate highway design treatment to accommodate bicyclists, several factors associated with the specific route or project must be assessed:

- What types of bicyclists is the route most likely to serve?
- What type of roadway project is involved (new construction, reconstruction, or retrofit)?
- What are the current and anticipated traffic operations and design characteristics of the route that will affect the choice of a bicycle design treatment?

What Types of Bicyclists is the Route Most Likely to Serve?

This manual takes its lead from the *AASHTO Guide*, which states:

> To varying extents, bicycles will be ridden on all highways where they are permitted. All new highways, except those where bicyclists will be legally prohibited, should be designed and constructed under the assumption that they will be used as a bicycle street.(1)

Using the concept of two broad types of design bicyclists—group A and group B/C—the recommendations included in tables 1 through 6 are keyed to the most likely type of user. All streets and highways where bicycles are permitted to operate should, *at a minimum*, incorporate the design treatments recommended in the tables for group A bicyclists. Where it is determined that use by group B/C bicyclists is likely, the tables recommending design treatments for group B/C should be used. The group B/C design treatments will also accommodate group A bicyclists.

At a minimum, all streets and highways open to bicycle use should have roadways incorporating the design treatments recommended for group A bicyclists. Where a planning process has determined a given route is the best choice to form part of a network of routes to provide access to the community for group B/C bicyclists, the recommended design treatment appropriate to B/C riders should be implemented.

New Construction and Reconstruction vs. Retrofitting

The recommended design treatments in the tables are most easily implemented when new construction or reconstruction is planned. It is a relatively straightforward process to adopt the specified design treatment for bicycles at the project planning stage.

When implementation involves retrofitting an existing roadway to accommodate bicycle use, the project can be more complex. Existing streets built with a curb and gutter section will often be viewed as having a fixed width and improvements will likely be limited to "moving paint," that is, restriping the existing lanes.

When working with existing streets and highways, planners should investigate the opportunity to make at least minor or marginal improvements. However, where the need is to serve group B/C bicyclists, it is essential to commit the resources necessary to provide facilities that meet the recommended design treatments. Only then can routes and facilities be designated for bicyclists and provide the desired access to the community.[13]

Which Traffic Operations and Design Factors Help Determine the Appropriate Design Treatment?

A general consensus has emerged among transportation planners and engineers working with bicycle facilities on the traffic operations and design factors having the greatest effect on bicycle use.[12] Six factors are most often cited; five are used to define the recommendations contained in the tables.

Each of these factors is discussed below along with the ranges of values used to differentiate levels of needs. Determining these ranges was difficult; there is little in the state of the practice to go by, and there is tremendous regional variation in prevailing conditions. Therefore, it is again suggested that the tables be used as a guide and that adjustments be considered to reflect, for instance, different values for the ranges for annual average daily traffic (AADT) volume.

The six major factors are as follows:

- Traffic volume. Higher motor vehicle traffic volumes represent greater potential risk for bicyclists and the more frequent overtaking situations are less comfortable for group B/C bicyclists unless special design treatments are provided. The recommendations contained in the tables are based on three ranges of AADT:

  - Under 2,000 AADT.
  - 2,000 to 10,000 AADT.
  - Over 10,000 AADT.

- Average motor vehicle operating speed. The average operating speed is more important than the posted speed limit, and better reflects local conditions. Again, motor vehicle speed can have a negative impact on risk and comfort unless mitigated by special design treatments. Four ranges of average speeds are used:

- Less than 30 mi/h (less than 48.3 km/h).
- 30 to 40 mi/h (48.3 to 64.4 km/h).
- 41 to 50 mi/h (66 to 80.5 km/h).
- Over 50 mi/h (over 80.5 km/h).

- Traffic mix. The regular presence of trucks, buses, and/or recreation vehicles (i.e., approximately 30 per hour or more) can increase risk and have a negative impact on comfort for bicyclists. At high speeds, the wind blast from such vehicles can create a serious risk of falls. Even at lower operating speeds, shared lane use is less compatible. All types of bicyclists prefer extra roadway width to accommodate greater separation from such vehicles. Many bicyclists will choose a different route or not ride at all where there is a regular presence of such traffic unless they are able to remove themselves several feet from these motor vehicles.(1) The recommendations contained in the tables suggest different design treatments and widths depending on whether or not the volume of truck, bus, and/or recreational vehicles is likely to have a negative impact on bicycle use.

- On-street parking. The presence of on-street parking increases the width needed in the adjacent travel lane or bike lane to accommodate bicycles. This is primarily a concern associated with streets and highways built with an urban section. It is addressed in the recommendations by including a separate set of tables for urban sections with on-street parking.

- Sight distance. "Inadequate sight distance" relates to situations where bicycles are being overtaken by motor vehicles and where the sight distance is likely less than that needed for a motor vehicle operator to either change lane positions or slow to the bicyclist's speed. This problem is primarily associated with rural highways, although some urban streets have sight distance problems due to poor design and/or sight obstructions.

  The most effective response to the problem is to correct it. Providing for bicycle operation to the right of the designated motor vehicle lane (i.e., on a bike lane or shoulder) or, at speeds less than 41 mi/h (66 km/h), by adding extra width to a wide outside lane, are viable options.

- Number of intersections. Intersections pose special challenges to bicycle and motor vehicle operators, especially when bike lanes or separate bike paths are introduced. The *AASHTO Guide* and various State design manuals include general guidelines for intersection treatments.(1,14,15)

  While not included as a selection factor in the tables, the number and/or frequency of intersections should be considered when assessing the use of bike lanes. There is some evidence to suggest that the disruption in traffic operations associated with bike lanes is temporary. Over time, both bicyclists and motorists adapt to the new traffic patterns, learning to look for each other and effect merges prior to intersections.[16]

How to Use the Tables to Determine the Recommended Treatment

Recommended roadway design treatments and widths to accommodate bicycles are presented in tables 1 through 6. There are separate tables for group A and group B/C bicyclists. The design treatments for group A bicyclists should be used as a guide to the minimum design for any roadway on which bicycle use is permitted. The recommended design treatments for group B/C bicyclists should be considered the desirable design for any route on which this type of bicyclist is likely to ride.

There are separate tables for the two basic types of roadway sections: urban (with curb and gutter) and rural (without curb and gutter). Separate tables are provided for highways with urban sections with on-street parking and with no on-street parking.

[Note: Controlled-access freeways are considered a special case and are not addressed by the tables. Several States now permit bicyclists to operate on the shoulder of some or all of their controlled-access freeways.[13] Controlled-access freeway rights of way also have been used for separate bike paths.]

The tables indicate the appropriate design treatment given various sets of traffic operations and design factors. The tables do not include any specific recommendations for separate bike paths. The use of separate bike paths depends on specific right-of-way conditions (e.g., very few intersections, adequate set-back) that do not exist along most highways. These conditions are most often found along parkways, river and lake shores, in park and recreation areas, on abandoned railroad rights of way, and on the right of way of some controlled-access freeways. Where such suitable conditions exist, separate bike paths can be pleasant additions to the facilities available to bicyclists. However, they cannot take the place of access to the roadway of the street and highway system.

Recommendations are provided for the width of the various recommended design treatments. These recommended dimensions are considered to be "desirable widths." They should be treated as "minimum widths" unless special circumstances preclude such development. Any treatment specifically designated for bicycle use must meet the minimum design standards called for in the *AASHTO Guide* or the appropriate State standard.

Finally, these recommendations are preliminary and should be tested and refined over time. It is anticipated that this manual will be revised to reflect the continuing evolution of the state of the practice in selecting design treatments for roadways to accommodate shared use by bicycles and motor vehicles.

Table 1. Group A bicyclists, urban section, no parking.

average motor vehicle operating speed	average annual daily traffic (AADT) volume											
	less than 2,000				2,000-10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv				truck, bus, rv				truck, bus, rv		
less than 30 mi/h	**sl 12**	**sl 12**	**wc 14**	**wc 14**	**sl 12**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**
30-40 mi/h	**wc 14**	**wc 14**	**wc 15**	**wc 15**	**wc 14**	**wc 15**	**wc 15**	**wc 15**	**wc 14**	**wc 14**	**wc 15**	**wc 15**
41-50 mi/h	**wc 15**	**wc 15**	**wc 15**	**wc 15**	**wc 15**	**wc 15**	**wc 6**	**wc 6**	**wc 15**	**wc 15**	**wc 6**	**wc 6**
over 50 mi/h	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane** **sh** = shoulder **sl** = shared lane** **bl** = bike lane **na** = not applicable

* See page 11 for definitions.

** **WC** and **SL** numbers represent "usable widths" of outer lanes, measured from lane stripe to the edge of gutter pan, rather than to the face of the curb. If no gutter pan is provided, add 1 ft (0.3 m) mininum for shy distance from the face of the curb.

Table 2. Group A bicyclists, urban section, with parking.

average motor vehicle operating speed	average annual daily traffic (AADT) volume											
	less than 2,000				2,000-10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv				truck, bus, rv				truck, bus, rv		
less than 30 mi/h	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 15**	**wc 15**	**wc 14**
30-40 mi/h	**wc 14**	**wc 14**	**wc 15**	**wc 15**	**wc 14**	**wc 15**	**wc 15**	**wc 15**	**wc 14**	**wc 15**	**wc 15**	**wc 15**
41-50 mi/h	**wc 15**	**wc 15**	**wc 15**	**wc 15**	**wc 15**	**wc 16**	**wc 16**	**wc 16**	**wc 15**	**wc 15**	**wc 16**	**wc 16**
over 50 mi/h	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane** **sh** = shoulder **sl** = shared lane **bl** = bike lane **na** = not applicable

* See page 11 for definitions.

** **WC** numbers represent "usable widths" of outer travel lanes, measured from the left edge of the parking space (8 to 10 ft [2.4 to 3.0 m] minimum from the curb face) to the left stripe of the travel lane.

Table 3. Group A bicyclists, rural section.

average motor vehicle operating speed	average annual daily traffic (AADT) volume											
	less than 2,000				2,000-10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv				truck, bus, rv				truck, bus, rv		
less than 30 mi/h	**sl 12**	**sl 12**	**wc 14**	**wc 14**	**sl 12**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**sh 4**	**sh 4**
30-40 mi/h	**wc 14**	**wc 14**	**sh 4**	**sh 4**	**wc 14**	**wc 15**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**
41-50 mi/h	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**
over 50 mi/h	**sh 4**	**sh 6**	**sh 6**	**sh 4**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane** **sh** = shoulder **sl** = shared lane** **bl** = bike lane **na** = not applicable

* See page 11 for definitions.

** **WC** and **SL** numbers represent "usable widths" of outer lanes, measured from the lane stripe to the edge of the pavement if a smooth, firm, level shoulder is adjacent. If rough or dropped pavement edges or a soft shoulder exists, add 1 ft (0.3 m) minimum for shy distance from the edge of the pavement.

Table 4. Group B/C bicyclists, urban section, no parking.

average motor vehicle operating speed	average annual daily traffic (AADT) volume											
	less than 2,000				2,000-10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv	truck, bus, rv			truck, bus, rv	truck, bus, rv			truck, bus, rv	truck, bus, rv	
less than 30 mi/h	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**wc 14**	**bl 5**	**bl 5**	**bl 5**	**bl 5**
30-40 mi/h	**bl 5**	**bl 5**	**bl 5**	**bl 5**	**bl 5**	**bl 6**	**bl 6**	**bl 5**	**bl 5**	**bl 6**	**bl 6**	**bl 5**
41-50 mi/h	**bl 5**	**bl 5**	**bl 5**	**bl 5**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**
over 50 mi/h	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**	**bl 6**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane** **sh** = shoulder **sl** = shared lane **bl** = bike lane** **na** = not applicable

* See page 11 for definitions.

** **WC** numbers represent "usable widths" of outer lanes, measured from lane stripe to edge of gutter pan, rather than to face of curb. If no gutter pan is provided, add 1 ft (0.3 m) mininum for shy distance from face of curb. **BL** numbers indicate minimum width from the curb face. The bike lane stripe should lie at least 4 ft (1.2 m) from the edge of the gutter pan, unless the gutter pan is built with adequate width to serve as a bike lane by itself.

Table 5. Group B/C bicyclists, urban section, with parking.

average motor vehicle operating speed	average annual daily traffic (AADT) volume											
	less than 2,000				2,000-10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv	truck, bus, rv			truck, bus, rv	truck, bus, rv			truck, bus, rv	truck, bus, rv	
less than 30 mi/h	**wc** **14**	**wc** **14**	**wc** **14**	**wc** **14**	**wc** **14**	**wc** **14**	**wc** **14**	**wc** **14**	**bl** **5**	**bl** **5**	**bl** **5**	**bl** **5**
30-40 mi/h	**bl** **5**	**bl** **5**	**bl** **5**	**bl** **5**	**bl** **5**	**bl** **6**	**bl** **6**	**bl** **5**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**
41-50 mi/h	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**	**bl** **6**
over 50 mi/h	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane** **sh** = shoulder **sl** = shared lane **bl** = bike lane **na** = not applicable

* See page 11 for definitions.

** **WC** numbers represent "usable widths" of outer lanes, measured from left edge of the parking space (8 to 10 ft [2.4 to 3.0 m] minimum from the curb face) to the left stripe of the travel lane.

Table 6. Group B/C bicyclists, rural section.

average motor vehicle operating speed	average annual daily traffic (AADT) volume											
	less than 2,000				2,000-10,000				over 10,000			
	adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance		adequate sight distance		inadequate sight distance	
		truck, bus, rv				truck, bus, rv				truck, bus, rv		
less than 30 mi/h	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**
30-40 mi/h	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 4**	**sh 6**	**sh 6**	**sh 4**	**sh 6**	**sh 6**	**sh 6**	**sh 6**
41-50 mi/h	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 6**
over 50 mi/h	**sh 6**	**sh 6**	**sh 6**	**sh 6**	**sh 8**	**sh 8**	**sh 8**	**sh 8**	**sh 8**	**sh 8**	**sh 8**	**sh 8**

1 mi/h = 1.61 km/h

Key:* **wc** = wide curb lane **sh** = shoulder **sl** = shared lane **bl** = bike lane **na** = not applicable

* See page 11 for definitions.

APPENDIX:

TYPES OF BICYCLE FACILITIES

There are many ways in which bicycles can be accommodated on roadways and other rights of way. This section provides an overview of shared lanes, special design treatments, and other possible improvements, including European traffic-calming techniques.

SHARED LANES

Shared lanes are streets and highways with no special provision for bicyclists. Shared lanes typically feature 12-ft (3.6-m) lane widths or less with no shoulders, allowing cars to safely pass bicyclists only by crossing the center line or moving into another traffic lane.[17]

In residential areas with low motor vehicle traffic volumes and average motor vehicle speeds of less than 30 mi/h (48.3 km/h), this should present no problem for group A riders, and will normally be adequate for group B/C bicyclists to use as well if the lane width is at least 12 ft (3.6 m). Where existing lane width is less than 12 ft (3.6 m), additional lane width or lower operating speed is called for.

With higher speeds and traffic volumes, shared lanes become less attractive routes, especially to group B/C riders. As the *AASHTO Guide* notes, however:

> *To varying extents bicycles will be ridden on all highways where they are permitted. All new highways, except those where bicyclists will be legally prohibited, should be designed and constructed under the assumption that they will be used by bicyclists. Bicycle safe design practices should be followed to avoid the necessity for costly subsequent improvements.*[1]

The *AASHTO Guide* goes on to note other actions by which bicycle use of shared roadways—regardless of lane widths or type of user—can be improved. Bicycle-safe drainage grates, smooth pavement, bicycle-safe railroad crossings, and traffic signals that respond to bicycles are all listed as examples.

Shared lanes do not usually require any special signing for bicyclists. Exceptions to this include situations when:

- Specific destinations or potential alternate routes for bicyclists need to be shown.

- A short gap exists between special bicycle facilities, such as between two trails, and bicyclists require signing to lead them to the next facility.

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SPECIAL DESIGN TREATMENTS

There are four general types of bicycle facilities that can improve upon shared roadways where traffic volumes or speeds make it prudent to do so. In three of the four cases, the facility allows bicyclists and motorists to operate parallel to each other in the same lane without coming too close and without motorists having to change lanes to pass the bicyclists.

Wide Curb Lanes

Wide curb lanes, or wide outside lanes, can be defined as right-most through traffic lanes that are substantially wider than 12 ft (3.6 m). Most practitioners agree that 14 ft (4.2 m)—usually measured from the lane stripe to the edge of the gutter pan, rather than the curb face—is the minimum width necessary to allow a bicyclist and motorist to share the same lane without coming into conflict, changing lanes, or potentially reducing the motor vehicle capacity of the lane. Where traffic speeds exceed 40 mi/h (64.4 km/h), and when annual average daily traffic exceeds 10,000, 15- or 16-ft (4.5- or 4.8-m) lanes are considered desirable.

Wide curb lanes have three widely accepted advantages.(16) They can:

- Accommodate shared bicycle/motor vehicle use without reducing the roadway capacity for motor vehicle traffic.
- Minimize both the real and perceived operating conflicts between bicycles and motor vehicles.
- Increase the roadway capacity by the number of bicyclists capable of being accommodated.

Many other benefits are claimed for wide outside lanes ranging from assisting turning vehicles in entering the roadway without encroaching into another lane to better accommodating buses and other wider vehicles.(18)

Wide outside lanes require the least amount of additional maintenance of the different facilities. The sweeping effect of passing motor vehicles and routine highway maintenance is usually enough to keep the lane free of debris and in good condition for bicycling.

Wide outside lanes are especially valuable for, and often favored by, group A riders who are not easily intimidated by high traffic volumes and speeds. These riders do not require a designated space in which to ride or designation of the street as a bike route. The same is not true for group B/C riders. Except on residential or low-volume streets, wide outside lanes are not generally sufficient to provide the degree of comfort and safety required by less skilled bicyclists or children and will do little to encourage them to ride.

Wide curb lanes will be most applicable, therefore, in urban areas on major streets where group A riders will likely be operating. If no alternative route exists for group B/C riders, a bike lane or shoulder should typically be used. The Florida Department of Transportation has recently amended its policy of always providing wide curb lanes on State highways in urban areas to that of providing bike lanes.[19]

Bike Lanes

The *AASHTO Guide* defines a bicycle lane as:

> *A portion of the roadway which has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists.*[1]

Bike lanes are sometimes referred to as Class II Bikeways, according to the classification system still used by the California Department of Transportation (Caltrans).[20]

Both Caltrans and the *AASHTO Guide* agree that bike lanes should always be one-way facilities carrying traffic in the same direction as adjacent motor vehicle traffic, and that they should not be placed between parking spaces and the curb.[1,19]

The recommended width for a bike lane is 5 ft (1.5 m), at least 4 ft (1.2 m) of which should lay to the left of the gutter pan seam. (However, the Florida DOT is currently experimenting with slightly narrower undesignated lanes in some urban areas.)

Field studies carried out as part of the research for this manual indicate that bike lanes have a strong channelizing effect on motor vehicles and bicycles.[16] The *Caltrans Highway Design Manual* describes this effect very clearly:

> *Bike lane stripes are intended to promote the orderly flow of traffic, by establishing specific lines of demarcation between areas reserved for bicycles and lanes to be occupied by motor vehicles. This effect is supported by bike lane signs and pavement markings. Bike lane stripes can increase bicyclists' confidence that motorists will not stray into their path of travel if they remain in the bike lane. Likewise, with more certainty as to where bicyclists will be, passing motorists are less apt to swerve towards opposing traffic in making certain they will not hit bicyclists.*[20]

The impact of marked bike lanes is particularly important for group B/C riders. The lanes offer a designated and visible space for bicyclists and can be a significant factor in route choice. Motorists also benefit from the channelizing effect of bike lanes.

Use of bike lanes does require an additional commitment to maintenance. Bike lanes must be kept free of debris and loose gravel to remain useful and safe, which may require routine sweeping beyond that necessary for streets with no bike lanes. As motor vehicles are not allowed in the lanes, they cannot sweep the debris aside as they do in ordinary (12-ft [3.6-m]) traffic lanes. The bike lane stripes themselves must be maintained on a regular basis.

Other important issues include the presence of on-street parking and the number and complexity of intersections. Parking movements and car doors opening have the potential to cause crashes, so bike lanes should be designed to minimize these conflicts. For example, on streets with parking lanes:

- Bike lanes should be at least 5 ft (1.5 m) wide.

- Bike lanes should be placed between the outer motor vehicle lane and the parking lane.

- Both sides of the bike lane should be marked. The righthand marking will demarcate where motor vehicles should park and will allow sufficient clearance for a bicyclist to avoid car doors that are opening.

- Bike lanes are not advisable where angled parking is present.

Bicycle lanes can complicate turning movements at intersections if they encourage bicyclists to keep right and motorists to keep left, regardless of their turning intentions. Some jurisdictions have addressed this issue by ending bike lanes in advance of intersections, or by striping the lane with a broken, rather then a solid, white line in advance of the intersection to encourage merging.[14,15]

It is the conclusion of the current study that bike lanes do have wide applicability, especially for group B/C riders in urban areas. When average daily traffic flows exceed 10,000 or average motor vehicle speeds exceed 30 mi/h (48.3 km/h), 5-ft (1.5-m) bike lanes will attract and serve group B/C riders better than wide outside lanes or other design treatments.

Shoulders

AASHTO's "Policy on the Geometric Design of Highways and Streets" defines a shoulder as:

> *... the portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and for lateral support of the subbase, base and surface courses.*[21]

Shoulders are also useful as places for bicyclists to ride. AASHTO and many States explicitly recognize that adding or improving shoulders is often the best way to accommodate bicyclists—especially in rural areas.[22]

Shoulders should be a minimum of 4 ft (1.2 m) wide when designed to accommodate bicycle travel. While group A (and even some group B/C cyclists) will benefit from shoulder widths as narrow as 1 or 2 ft (0.3 to 0.6 m), these facilities should not be signed for bicyclists if they fail to meet prevailing State and/or AASHTO guidelines.

As traffic speeds increase, traffic mix includes heavier vehicles and trucks, and traffic volumes rise, added width is desirable. For example, once vehicle speeds exceed 40 mi/h (64.4 km/h) and AADT is 2,000 or more, shoulder widths should usually be increased to 6 ft (1.8 m).

In urban areas, wide curb lanes are usually preferable to shoulders for group A riders and bike lanes are usually preferable for group B/C riders. One exception will be on high-speed urban arterials (more than 50 mi/h [80 km/h]) where 6-ft (1.8-m) shoulders will serve group A riders better than wide curb lanes. Bike lanes, if used along these routes, should also be at least 6 ft (1.8 m) wide.

Bicyclists will use shoulders where they are paved and maintained to the same surface standard as regular travel lanes. Where shoulders are designated as bike facilities, it is essential to keep them in good repair and free of debris, which often means a regular inspection and maintenance program.

Other surface irregularities, such as rumble strips, textured paving, and raised lane markers and reflectors, should be avoided on routes explicitly intended for bicyclists as they can cause falls or force bicyclists to ride in the traffic lane. Where the use of rumble strips is necessary, they should be located so as to leave a portion of the shoulder free for bicyclists.

Some State vehicle codes may, under a strict interpretation, prohibit or restrict the use of shoulders by all vehicles, including bicycles. Other States require bicyclists to use shoulders where they exist and are of an adequate standard for riding.[16] Additional research may be required to determine the exact legal status of bicyclists using shoulders in a particular State.

Comparable differences exist regarding the treatment of bicycles on controlled-access freeway or Interstate highway shoulders. Eighteen western States allow bicyclists to use some or all of such shoulders (except in urbanized areas), whereas in all eastern States except New Jersey, such use is currently prohibited. Additional attention should be given to accommodating bicycle use on controlled-access freeway shoulders where such use provides the only crossing of a river, lake, freeway, or other barrier.

Separate Bike Paths

The *AASHTO Guide* defines a bicycle path or bike path as:

> *A bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way.*[1]

Separate bike paths are also known as Class I Bikeways, according to the classification used by the Caltrans. They also may be referred to as "multi-use trails" or "greenways," even though they are slightly different facilities.[20] A trail typically runs along an independent right of way such as an abandoned railroad corridor, and a greenway is a park-type corridor of land that may or may not incorporate a trail within its boundaries.

Two-way bike paths should be at least 10 ft (3 m) wide. Where possible, especially if bicycle or pedestrian traffic is expected to be high, paths should be a minimum of 12 ft (3.6 m) wide. Given the variety of users of most bike paths, 8-ft (2.4 m) widths will generally not be adequate. One-way bike paths have a limited application as without strict enforcement, they will be used as two-way facilities. If they are provided, however, they should be at least 5 ft (1.5 m) wide.

Bike paths are a valuable addition to the highway system and to the range of facilities available to planners and engineers seeking to improve conditions for all categories of bicyclist. They can serve both a transportation and recreation function and have proven to be significant generators of bicycle use. Both groups A and B/C riders (as well as other nonmotorized users) can benefit from the absence of motor vehicle traffic on these paths.

Bike paths are not inherently more dangerous than other bicycle facilities if they are well designed, thoughtfully applied, and adequately maintained. For example, paths should not have their continuity destroyed by frequent motor vehicle cross flows and intersections with highways. These increase potential conflicts and are likely to make the route less popular with riders seeking to maintain momentum, particularly group A.

Where adequate, uninterrupted right of way is available, separate bike paths can be used to good effect in providing long, continuous routes for commuting or recreation trips, access to destinations not otherwise available to bicyclists, and as cut-throughs between buildings and other breaks in the street network.

OTHER POSSIBLE IMPROVEMENTS

Sidewalks

The *AASHTO Guide* states quite simply that "Sidewalks are generally not acceptable for bicycling."[1]

This statement is qualified by a recognition that in a few, specific instances, such as on long, narrow bridges, the designation of a sidewalk as a bicycle facility may be beneficial. Many States share this view.

> *Sidewalks are generally inappropriate for use by adults because they put the adult bicyclist in conflict with motorists using driveways, and with pedestrians, utility poles and signposts. Also, the cyclist is generally not visible or noticed by the motorist so that the cyclist suddenly emerges at intersections, surprising the motorist and creating a hazardous condition.*[15]

Traffic Calming

Still relatively new to the United States, widespread neighborhood traffic calming aims to reduce the dominance and speed of motor vehicles. Measures employed to achieve this include physical alterations to the horizontal and vertical alignment of the road and changes in priority. For example, speed humps, diverters, traffic throttles, traffic islands, sidewalk extensions, and mini-traffic circles have all been utilized to calm or tame traffic. Low speed zones—for example, 20 mi/h (32.2 km/h) or lower—are often introduced along with a package of these physical changes.[23]

Traffic calming was started as a means to reduce the impact of traffic in residential neighborhoods and around schools. During the 1980's, the principles of traffic calming were extended and are now being applied to major roads in urban areas.

Four key benefits have been attributed to traffic calming:

- An average one-third reduction in road accidents.
- A greater feeling of security, particularly among vulnerable road users such as bicyclists and pedestrians.
- Reclamation of roadway space for nontraffic activities such as play and social interaction.
- Environmental improvements through landscaping and a reduction in the intrusive presence of motor vehicles.[23]

Much of the pioneering work in this field has been in Europe, particularly Germany and the Netherlands. In areas of traffic calming in both countries it is rare to see special facilities for bicyclists since many of the benefits of traffic calming—slower vehicle speeds, better driver discipline, less traffic, environmental improvement —directly benefit bicyclists, especially group B/C riders.

Nevertheless, according to the Cyclists Touring Club in the United Kingdom:

> *Ill-designed traffic-calming schemes can inconvenience or even endanger cyclists. Balanced on two wheels and without the benefit of suspension, cyclists are particularly susceptible to changes in surface height and texture or may be put at risk by poorly-considered road narrowing.*[23]

Careful design of traffic-calming schemes can overcome these potential pitfalls and ensure that the benefits of such work encourage bicycling and make the activity safer.[23,24]

Some U.S. cities, such as Seattle, have developed traffic-calming techniques similar to those found in European countries, but not to the same geographic extent.

Other Roadway Improvements

It is possible to marginally improve some roadways for bicyclists—particularly group A riders—by providing as little as 2 ft (0.6 m) of usable riding surface to the right of the edge stripe. While this will not meet the design specifications necessary for a designated bicycle facility, it can provide an improved operating environment for both bicyclists and motor vehicles and will reduce the impact of bicycles on highway capacity.

This and other marginal roadway improvements should be considered when the opportunity arises and there is no other option—such as wider shoulders, a bike lane, or wide curb lane—because of lack of space.

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