Design of Bicycle Facilities

by

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I. Introduction

The purpose of this document is to provide guidelines for the design, construction, operation and maintenance of safe on-road and shared use bicycle facilities. It will provide designers with the information to develop the safest most efficient facilities possible.

A. Roadway Design Criteria and Standards

The Department incorporates the needs of bicyclists into all appropriate construction and RRR (resurfacing, restoration and rehabilitation) projects. In some instances, right-of-way constraints and safety considerations may limit the extent facilities and treatments can be applied in a given section. Considering these limitations, projects are to incorporate the needs of bicyclists to the maximum extent possible. Bicyclists can be expected to ride on all roadways except limited access highways. A lack of safe, convenient and appropriate facilities often leads to bicyclists riding in unsafe locations, such as on commercial district sidewalks. Sometimes they ride against traffic.

B. Criteria Definitions

The criteria for design of new roads or major reconstruction projects on the Florida State Highway System are found in Chapter 2 of the FDOT ‘Plans Preparation Manual’ (PPM). Design criteria for resurfacing, restoration and rehabilitation (RRR) are presented in Chapter 25 of the FDOT ‘PPM.’ Signs, signals and markings for bicycle facilities are also presented in the ‘Manual on Uniform Traffic Control Devices’ (MUTCD), Part IX.

II. Design of Bicycle Lanes

A. The Bicycle

The bicycle is a single track human propelled vehicle similar in many respects to other single track vehicles (i.e. motorcycles). Bicycles have been tinkered with for more than a century. There are many variations, but all operate according to basic principles outline in this document.

1. Dimensions, Speed, Psychological Needs

To design effectively for bicycle riders, physical details of typical riders must be understood.

User Characteristics:

Design Viewing Height	54”
Rail Height	54”
Center of Gravity (adult, child varies)	33-40”
Speed for Crossing Intersection	10 mph
Speed (level terrain)	20 mph
Downhill Speed (roads and bridges)	30 mph
Uphill Speed (roads and bridges)	5-12 mph

Likely Speeds by Age:

Child	6-9 mph
Youth	7-11 mph
Young Adult	8-15 mph
Adult	8-15 mph
Proficient Adult	12-24 mph

Senior Adult	8-15 mph
Cycling club pace	15-30 mph

Width and Distances:

Riding width, including trailers	4 ft.
Lateral clearance to seams, smooth walls, curbs	2 ft.
Lateral clearance to trees, posts	4 ft.
Lateral clearance to steep grade	6 ft.
Vertical clearage	8 ft
Psychological clearance (tunnels)	10 ft.

2. Tires

Wheels and tires on bicycles are much narrower than on those of other roadway vehicles.

Like motor vehicles, bicycles are single track vehicles, and are far more sensitive to surfaces. Unlike motorists, bicyclists must maneuver to avoid even tiny obstacles or defects. In contract, autos have complex suspension systems to overcome surface defects. Pedestrians travel slowly enough to step around most defects. Bicyclists, when surprised by potholes, seams or fissures, may suddenly swerve in order to avoid the irregularity. Thus surface irregularities are serious problems for all bicyclists. Roadside maintenance should be accomplished with this in mind. Considerations when designing for bicyclists are:

- Bicycle tires contact the ground with the equivalent of 2 times of their surface area
- Road bicycles rarely have shock absorbers or suspensions
- Sand, mud, leaves, oil and skewed railroad tracks and moisture cause slippage
- Longitudinal seams greater than ¼ inch wide impact control
- Steel (rails, bridge decks) and rubber tires do not mix well
- Bicyclist stability calls for a nearly zero vertical object deign height for roadway objects. A very small object or even a longitudinal crack can cause a bicyclist to fall.

Therefore a sight distance must be calculated base upon an obstruction flush with the surface of the road.

3. Brakes

Bicycles vary in their ability to stop quickly. Some brake designs (cantilever) approach the efficiency of autos, and others (cheap side pull) require much longer stopping distance as high speed. Coaster brakes are the least efficient design. Due to overheating they can loose further effectiveness on long downhills. Caliper (hand) brakes are inefficient when the rims are moist. Since many people bicycle infrequently, their reaction and braking response times may increase. Surfaces affect braking. Loose materials such as sand, ice and moisture can increase braking distance by a factor of 1.5 to 10.0. The following are additional concerns:

- Allow 2.5 seconds reaction time.
- Allow an added 3.0 seconds for surprised condition reaction time.
- It takes about 1.5 seconds to fully set up braking (reach, mechanical delay).
- Maximum deceleration for a bicycle is 11 mph per second.
- When rims are wet or coaster brakes are used, braking performance is 50-80% less efficient.

4. Steering

Emergency maneuvers on bicycles cannot be accomplished quickly, because it takes time to set up for a quick turn. Most people do not understand how bicycles steer. Mechanically, emergency turns take much longer on bicycles than in autos:

- To turn right bicyclists must first steer left a bit to set up a counter lean.
- It takes about 1.5 seconds to set up for a turn.
- Bicycles steer more slowly when fully loaded.
- To stay upright, riders must constantly steer bicycles to keep them in balance and under the body’s center of gravity.

5. Profile and Visibility

As many as 80% of motorists involved in car/bicycle or pedestrian/car crashes report they did not see the bicyclist or pedestrian. While this lack of recognition may be true in many cases, the motoring public must learn to regularly search for non-motorized traffic. Ultimately, increased bicycle use will increase motorist awareness. The design community can help by recognizing the following:

- Bicyclists are pencil thin in the complex visual traffic soup.
- Their curbside location often hides them from other traffic.
- Motorists tend to see what they expect to see (many are not looking for bicycles or pedestrians).
- Motorists tend to overlook objects they see infrequently.
- Bicyclists are especially hard to detect under low light and nighttime conditions.
- More bicycles and pedestrians are needed to increase detection. When bicyclist and pedestrians are common on the roadways, motorists will expect to see them As a result the motorist will detect them more readily.

B. Guidelines, Criteria and Standards

Guidelines, criteria and standards are presented to help design and construct both roadway improvements and separate lanes that accommodate the operation characteristics of “bicycles” as defined in this document. Modifications to facilities (e.g., widths, curve radii, superelevations, etc.) necessary to accommodate adult tricycles, bicycle trailers, and other special-purpose human-powered vehicles an accessories should be made using sound engineering judgment and be based on anticipated use of the facility.

It is best to estimate high levels of use. Presently there are so many disincentives for bicycling that judging the need for a bicycle facility based on existing bicycle counts or projects can be highly deceiving.

A design, such as paved shoulders, that ultimately benefits a bicyclist can usually be justified for other reasons, such as maintenance, general safety, and other joint uses. As a result, a given facility can often be justified with little or no projection of increased short tem bicycling activity.

1. History of Bicycle Facilities Design

Most urban roadways were designed and built during a period of little bicycle use. Hence, early design decisions to provide for bicyclists were often based on the assumption that it was best to separate bicycling from roadways. This assumption quickly proved unpopular with bicyclists. It led to a proliferation of conflicts due to lack of facilities: bicyclists using sidewalks and thereby hidden from motorists, or on poorly built bicycle paths, or bicycles and motorists attempting to mix on roadways with inadequate mixed use design.

2. Current Practice

New construction, as well as RRR projects must give full consideration to the needs of bicyclists. Measures should also be taken to retrofit the backlog of roadways not currently scheduled for improvement. This can and should include attention to safety needs identified through the statewide Safety Management System, and Community/Corridor Traffic Safety Programs.

Key attractions are found along main thoroughfares, and they attract bicyclists just as they attract motorists. This concept requires full consideration of bicycling for new transportation projects.

There is a wide range of facility improvements that can enhance bicycle transportation. Improvements can involve a detailed design (e.g., providing a shared use path), or they can be simple and involve minimum design consideration (e.g., changing drainage grate inlets).

Since bicyclists may ride on all non-limited access roadways, bicycle facilities should be included on all projects unless there is compelling reason not to include them. If there is a question as to whether or not some special effort, such as purchasing additional right-of-way or narrowing medians, is justified the following should be considered:

- The section is identified for bicycle improvements in the Transportation Improvement Program, the State Transportation Plan, or the Community Comprehensive Plan.

- Bicycle facilities have been requested by the local government.
- Project is within 1 mile of an urban area.
- There are other considerations suggesting bicycle facilities would be required. These include but should not be limited to the following:
  - Schools, parks or greenways near the project corridor
  - Access or connectivity
  - High bicycling volumes
  - High bicycle crash rates

C. Bicycle Lane Widths

Bicycle lanes are to be used on future urban roadway sections, whenever right of way and existing curb/drainage sections permit. Occasionally it is possible to convert wide curb lanes on multi-lane highways to bike lanes by reducing the travel lane widths to 11 ft., and turn lanes to 10 ft. The width of the bike lane is included within the motorist clear zone and horizontal clear distance. Additional clearance is not required.

Bicycle lanes have proven their value to all highway users. Among their benefits in creating a smooth, efficient and safe sharing of the highway are the following:

- Establishing the correct riding position for bicyclists.
- Sending a message to motorists that bicyclists have a right to the roadway.
- Reducing motorist and bicyclist sudden swerves (lane changing).
- Guiding bicyclists through intersections on the safest, most predictable course.
- Permitting bicyclists to pass stopped motorists and queue properly at traffic signals.
- Permitting motorists to pass bicyclists on 2-lane roadways.

There are many secondary benefits of bike lanes as well:

- Provide added border width.

- Enhance highway drainage, reduce vehicle hydroplaning.
- Create an essential buffer between the pedestrian and motorist.
- Improve opportunity for landscaping (border width).
- Reduce pedestrian/bicyclist conflicts (no longer on sidewalks).
- Increase turn radii at driveways and intersections.
- Improve sight distances.

The standard bicycle lane widths are:

• Urban (curb & gutter)	4 ft.
• Urban with Parking	5 ft.
• Rural Section	5 ft

The minimum width of an urban bike lane from the left side stripe to face of curb is 5 ft. the 18 inch gutter included on most curb and gutter sections provides for this additional requirement. Certain edge conditions may dictate additional desirable bicycle lane width.

1. Bicycle Lanes on Curb and Gutter Sections

Bicyclists do not generally ride near a gutter because of the possibility of debris, of hitting a pedal on the curb, or an uneven longitudinal joint, or of a steeper cross slope. However, many novice bike riders will ride in a gutter if the roadway is too narrow, and thus bike lanes help reduce this problem. Bicycle lanes in this location should have a minimum width of 4 ft. form the edge of pavement to the motor vehicle travel lane.

2. Bicycle/Parking Lanes

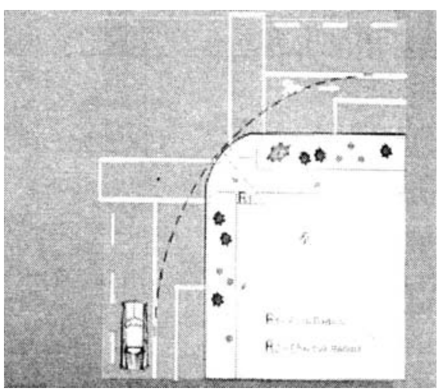
A bicycle lane may be put on an urban curbed street where a parking lane is provided. The required bicycle lane width for this location is 5 ft. The minimum combined bike lane/parking lane width is 13 ft. This space is to provide adequate width for bicyclists to avoid car doors without encroaching upon the motor vehicle lane.

Bicycle lanes should always be placed between the parking lane and the motor vehicle traffic lane. Bicycle lanes between the curb and the parking lane can create obstacles for bicyclists from opening car doors and provide poor visibility at intersections and driveways. They also prohibit bicyclists from making left turns; therefore, this placement should not be considered.

This treatment may not be appropriate on sections with narrow motorist lanes.

Transition taper lengths around parking lanes are based on speed, sight distance, type of vehicles, and related factors. Make sure that both the bicyclist and motorist are given adequate information and decision-making time.

When parking and bike lanes are used in a pattern as shown in the graphic below, the motorist ends up with added turning radii; sometimes a needed bonus for trucks and busses. To reduce maintenance, and improve the life of markings, make sure bike lane markings may be kept out of the turning radius. To reduce wrong way bike riding, always use directional arrows in bike lanes.



3. Paved Shoulders and Rural Bike Lanes

Adding or improving shoulders often can be the best way to accommodate bicycles in rural areas. Paved shoulders also provide a significant safety benefit to motor vehicle traffic. Where funding is limited, adding or improving shoulders on uphill sections first will give slow moving bicyclists needed maneuvering space and decrease conflicts with faster moving motor vehicle traffic.

4. Shoulder Width

The minimum paved shoulder width is 5 ft. when designated as a bike lane or intended to accommodate bicycle travel. The combined width of the paved shoulder or bike lane and the width of the adjacent motor vehicle travel lane determine whether or not bicyclists and motorists can safely pass each other. The standard 12 ft. travel lane and 5 ft. shoulder provides for adequate separation of bicyclists and motor vehicles when speeds exceed 45 mph; the percentage of trucks, buses, and recreational vehicles is high, or static obstructions exist at the right side.

At speeds above 45 mph, bicyclists need a 6 ft. minimum lateral separation from trucks. The full 12 ft. width travel lane in combination with a 5 ft. paved shoulder accommodates this lateral separation need.

Due to the buildup of debris, and the trapped condition a bicyclist faces, shoulders on bridges are especially important. Bridge shoulder width, as a minimum, should match the approach roadway shoulder width.

Bridges exceeding a 3% grade benefit from wider shoulder widths. The added width compensates for climbing wobble conditions and higher descent speeds.

5. Wide Curb Lanes

Wide curb lanes no longer meet state requirements and are not used on new construction on state roadways. Local jurisdictions may still use them. They are a "least preferred" option. Although wide curb lanes benefit motorists and bicyclists by proving additional operating space compared to a 12 ft. lane, many cyclists are not comfortable using these facilities. In some conditions, a wide curb lane may still be the only practical option.

D. General Signing and Marking of Bike Lanes

Designated bike lane should be marked with signs and pavement markings. The bike lane is separated from the regular travel lane by a 6-8 inch solid lane line. Pavement markings are used within the lane to designate the bike lane. The diamond shape Preferential Lane Symbol is used as required by the 'MUTCD.' Additionally, the bicycle symbol may be used to clarify the purpose of the bike lane and an arrow to provide guidance on legal direction of travel. Bicycle Lane signs are used to supplement the pavement markings.

1. Directionality

Bicycle lanes should always be one-way facilities, be marked as such, and carry traffic in the same direction as adjacent motor vehicle traffic. Two-way bicycle lanes on one side of the roadway are unacceptable because they promote riding against the flow of motor vehicle traffic. Wrong-way riding is a major cause of bicycle crashes and violates the Rules of the Road stated in the 'Uniform Vehicle Code'.

2. Wrong Way Signs

A sign may be placed on the back side of the Bike lane sign to notify bicyclists when they are riding the wrong direction in a bike lane. The proposed sign for this purpose is a "Wrong Way" with a "Bikes" supplemental plate. This sign, in addition to the lane directional arrow, is intended to reduce wrong way riding. This sign also makes it easier for police to cite bicyclists and defend a violation before a judge.

3. Bicycle Lanes on One-Way Streets

On one-way streets, bicycle lanes should be on the right side of the street, except in areas where a bicycle lane on the left will decrease the number of conflicts (e.g. those caused by heavy bus traffic).

Although not recommended, contra-flow bike lanes (those in an opposing direction from the normal traffic flow) on one-way streets may be allowed to provide connectivity for bicycles within a roadway system. They can be used to fill gaps in the system or provide a more convenient route for bicyclists. Bicyclists using these lanes will be coming from a direction motorists do not expect. Also, traffic control, signs and signal, must be provided for the contra-flow bicyclists. Ideally, instead of using contra-flow bike lane, the lane could be put on a parallel facility.

4. Designated versus Undesignated Bike Lanes

In some cases, the designer may not wish to designate a bike lane with pavement markings and signs. Undesignated bike lanes differ from shoulders in being striped to the left of right turn lanes. This allows for the eventual designation of the bike lane.

Preliminary research and observations reveal a wider separation of motorists and bicyclists when wide curb lanes are converted to lanes of even as little as 3–3.5 ft. However, in many instances, this substandard width is best left undesignated.

There are some cases where even a full width 4 ft. space may be left undesignated. Decisions on when to designate and leave undesignated should be made by a joint partnership of the Department and the local Bicycle Advisory Committee (BAC). The following are some reasons a designer may wish to leave a bike lane unmarked:

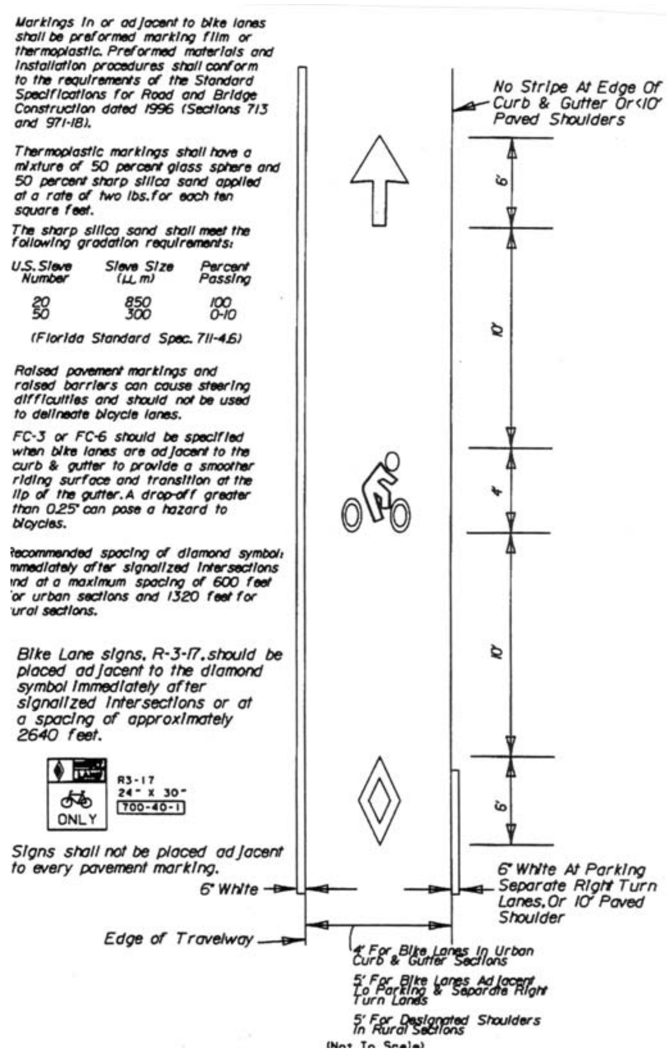
- Short or discontinuous
- Rural with low probability of use
- First segment, to be joined later by other pieces

There are, however, advantage s to marking a bike lane. Some of the advantages of designating a bike lane are as follows:

- Reminds motorist to stay alert for bicyclists
- Creates a true system of support
- Provides system continuity
- Further reduces likelihood of wrong way sidewalk riding
- Allows signing warning against wrong way riding

Additionally, marking a bike lane changes the way the facility is treated in law. Motorists are not allowed to park in a bike lane. Also, motorists entering the roadway from a side street are required to yield to bicyclists within a bike lane.

The following illustration details the pavement markings for a designated bicycle facility.



E. Bicycle Lane Treatments at Intersections

Bicycle lanes and their position is an important consideration in intersection design. A bicycle is a vehicle. As such, the bicyclist is required (with the left turn as an exception) to ride through an intersection just as a motorist would drive through the intersection. The bicyclist should travel thorough the intersection on the right side of the rightmost lane for the direction of travel.

1. Bicyclists' Movements

At intersections without right turn lanes, bike lanes encourage bicyclists to keep to the right and motorist to keep to the left, so both operators are somewhat discouraged from merging in advance of turns. Thus, some bicyclists will begin left turns from the right-side bicycle lane and some motorists will begin right turns form the lane to the left of the bicycle lane. Both maneuvers are contrary to established Rules of the Road and result in conflicts.

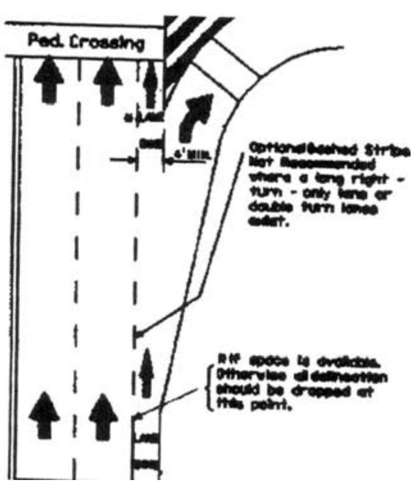
To promote proper behavior, the bike lane striping should be discontinued 50 ft. prior to an intersection without a right turn lane. This encourages motorists and bicyclists to merge in advance of the intersection. In this way most bicyclists behave as follows:

a. Straight Through Bicyclists

Straight through bicyclists move to the left, merging into the travel lane, staying alert to right turning motorists. Competent bicyclists often do this early in the taper. Novice bicyclists more typically complete the maneuver closer to the intersection, where speeds are lower. Either works well in practice.

b. Right turning Bicyclists

Right turning bicyclists simple turn right by staying to the right. It is best if they center themselves in the turn lane. Staying too far to the right encourages motorists to pass them while turning.



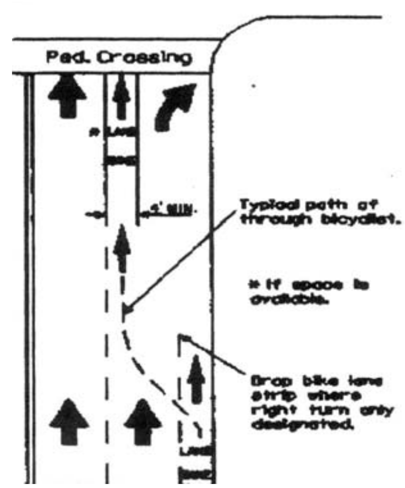


Illustration of bike lane with a right-turn lane or slip lane.

Illustration of bike lane when parking lane becomes right-turn-only lane.

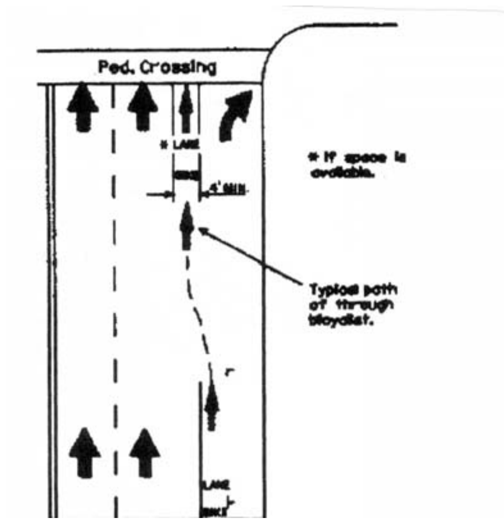


Illustration of bike lane with right lane become right-turn-only lane.

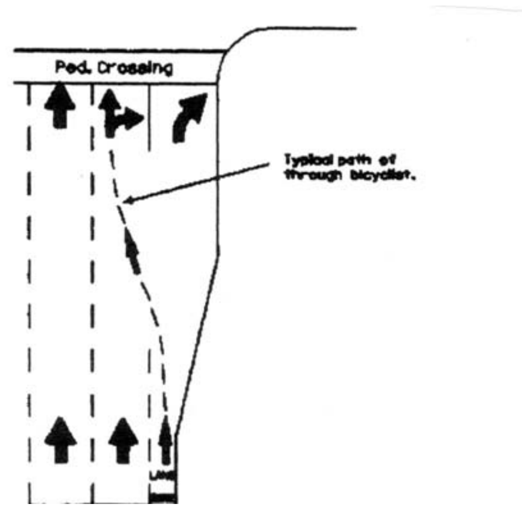


Illustration of bike lane with optional right-turn and through-right lanes.

c. Left Turning Bicyclists

Left turning bicyclists search, signal and move left if traffic gaps occur. Others may choose to go straight through the intersection to the far side, pivot their bikes, and when the light changes, complete their movement. Both procedures are permitted under Florida traffic law. The second method is referred to as a “box left hand turn.”

2. Bike Lane Position at Intersections

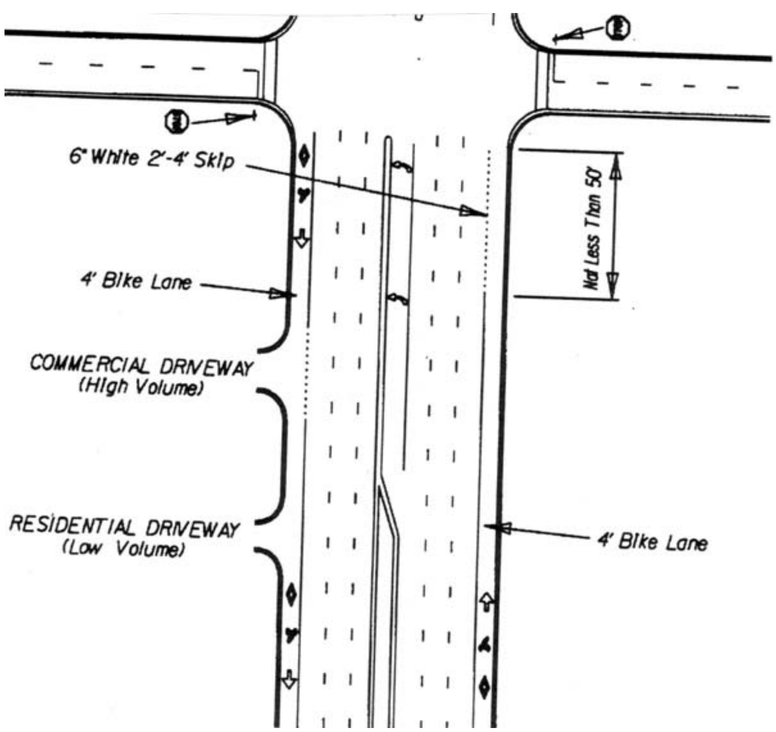
Bike lane striping assumes and supports the idea bicyclists will function as vehicles. Bicycles are required to ride as nearly as possible to the right side of the lane serving the movement they are making. This requires bicycles riding through intersection with right turn lanes, and possibly those turning left at intersections with left turn lanes, to ride between parallel flows or queues of traffic. The inclusion of bike lanes provides space for the bicyclists to do this with more safety and comfort than if the bike lanes were not present.

a. Intersections with Driveways

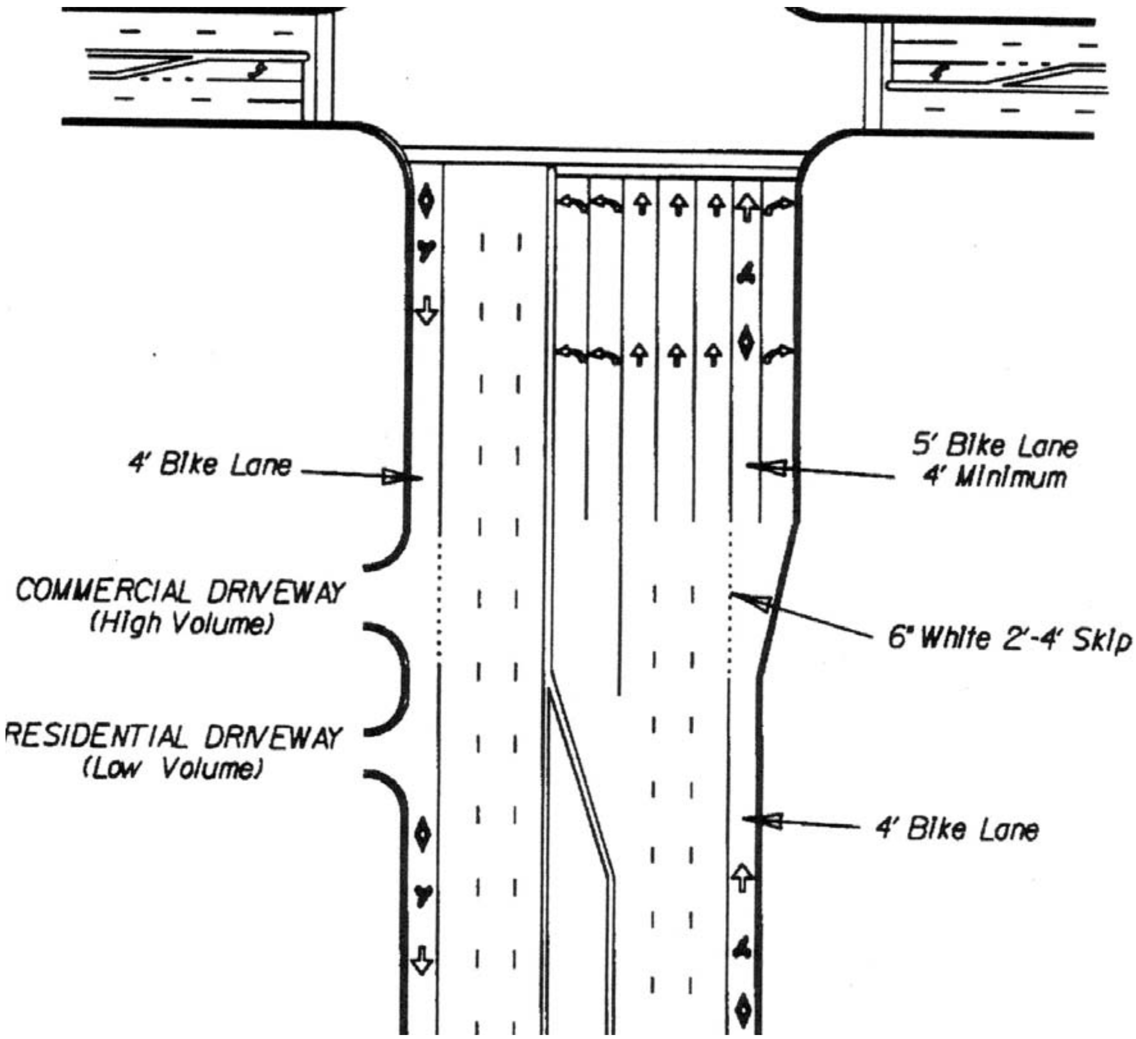
Bike lane striping at driveway is dependent upon edgeline striping. At low volume residential type driveway where the edgeline is continuous, the bike lane striping is also continuous. At high volume commercial driveways where the edgeline is discontinued (but regular vehicle lane striping is continuous), the striping separating the bike lane from the regular travel lane becomes a 2–4 ft., or dotted, skip line.

b. Roadway Intersections

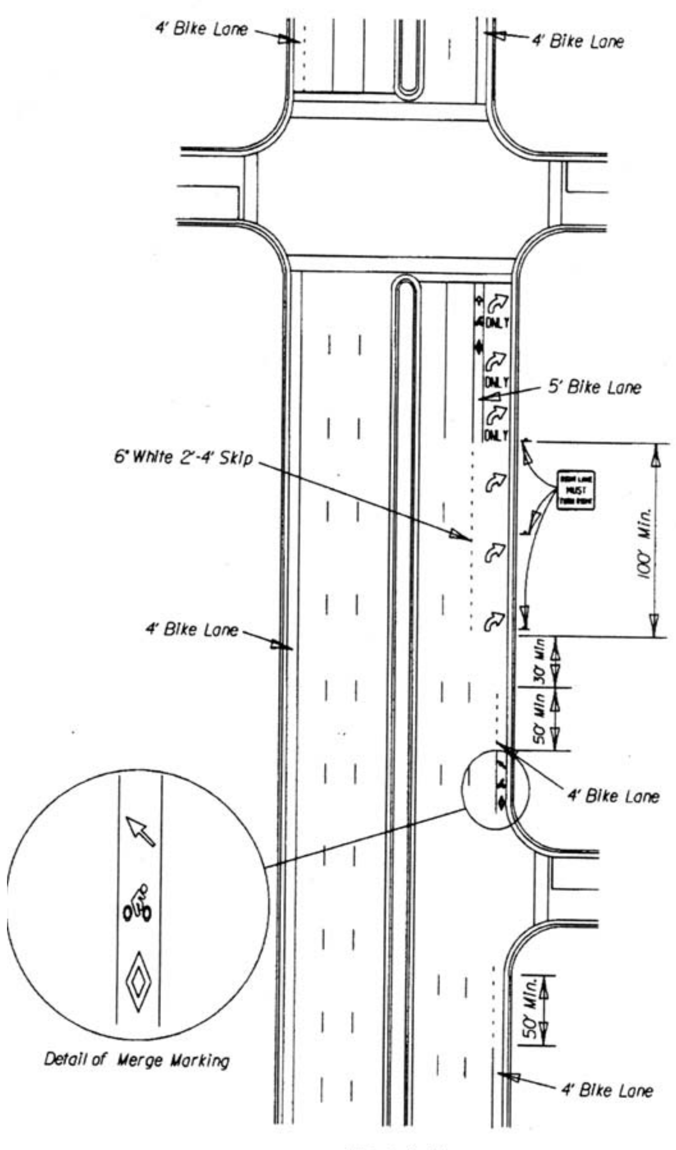
On roadways without right turn lanes, the line separating the bike lane from the regular travel lane should become a dotted line (2-4 ft.), not less that 50 ft. prior to the intersection. By using this skip line we allow right turning motorists to merge into the bicycle lane so the turn can be make from the right side of the roadway. The skip line also serves to inform motorists they are encroaching on the bike lane.



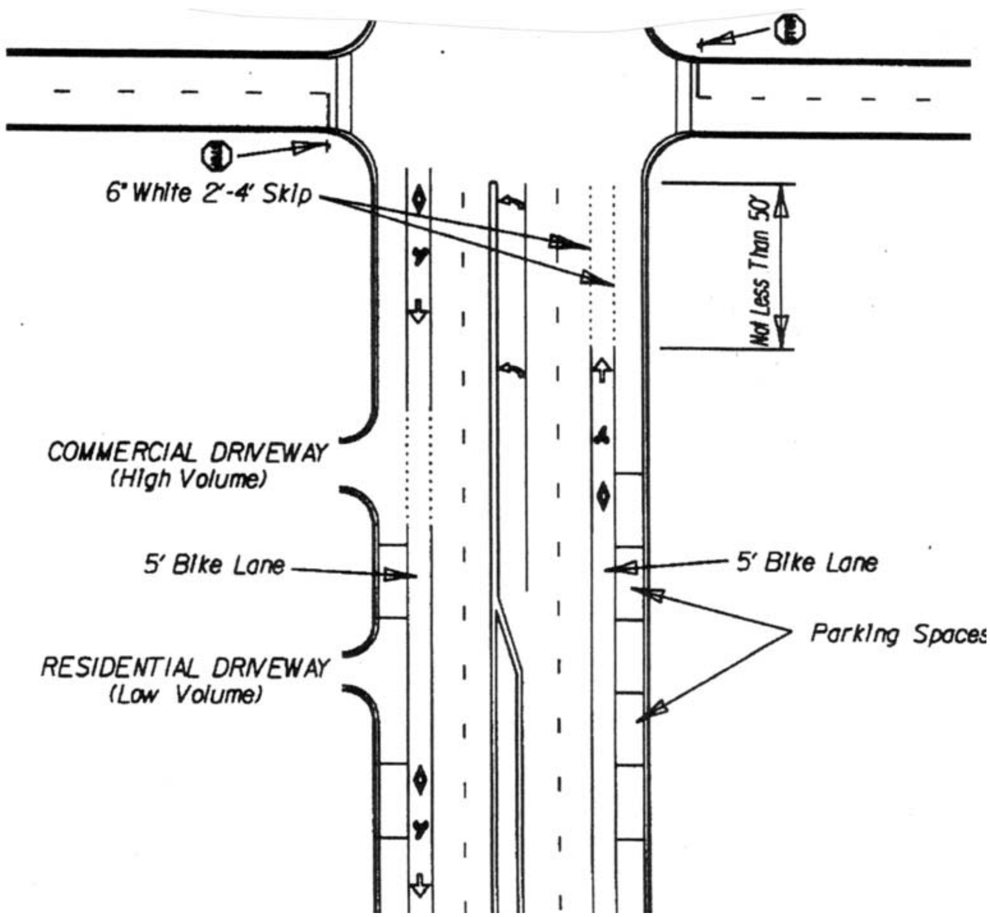
When a right turn lane is present, a lane is provided for the through bicyclist between the regular through lane an the right turn lane. Through the turn lane taper the right edge line of the bike lane is discontinued and the line separating the bike lane and regular travel lane becomes a dotted line.



On the approach to a right lane drop, the bike lane is shifted from the right side of the roadway to between the dropped lane and the through lane. Dotted lines are used to provide a transition area where the bicyclist can move to the left. A similar technique is used at tee intersections. Pavement markings warning the bicyclist to yield may be used prior or to the transition area.



On a road with on-street parking the bike lane is continuous with solid edge lines beyond the parking to not less than 50 ft. prior to the intersection where the edge lines become dotted lines.



In cases where there is a right turn lane and a shared through/right turn lane, the bike lane must be terminated prior to the intersection. Designers should weigh the confusion created for bicyclists and motorists before applying this treatment.

3. Traffic Signals

There may be a case when a signal is required to cross bicyclists across a roadway (possibly a trail intersection). The MUTCD's Part IV should be consulted for warrants and other requirements relating to signal installation. Since bicycles are vehicles, warrants used for motor vehicles are considered appropriate for bicyclists. Signal Warrant Four for school crossings is also considered appropriate for bicyclists.

a. Traffic Signal Timing

At intersections where bicycle traffic exists or is anticipated, bicycles should be considered in the timing of traffic signal cycles, as well as the traffic detection devices. Normally, a bicyclist can cross an intersection under the same signal phasing arrangement as motor vehicles. On multi-lane street crossings, special consideration should be given to ensure short clearance intervals are not used. An all-red clearance interval is often used in intersections today and benefits bicyclists who need the extra time. With wider and wider intersection design, the traffic engineer must pay close attention to crossing times. The desire to keep lanes full width and to add more turn lanes must be balanced by alternatives that provide protective channeling, reduced crossing width or other designs. For the above reasons, geometric designers and operations staff must work closely to create supportive bicycle crossings.

To check the clearance interval, a bicyclist's speed of 10 mph and a perception/reaction/braking time of 2.5 seconds should be used. Detectors for traffic-actuated signals should be sensitive to bicycles and should be located in the bicyclist's expected path, including left turn lanes. In some situations, the use of pedestrian-actuated buttons may be a preferred alternative to the use of detectors, provided they are placed so they do not require bicyclists to dismount or make unsafe leaning movements. Push buttons intended for use by bicyclists must always be on the right side of the travelway. Where programmed visibility signal heads are used, they should be checked to ensure they are visible to bicyclists who are properly positioned on the road. Signal systems should be designed to permit the bicyclist to detect any change in traffic signals.

b. Signal Loop Markings

One of the most frequent motorist complaints against bicyclist is they run red lights. However, when bicyclists approach red traffic signals they have no way of determining where they need to place their bikes to be detected by the signal. Even conscientious bicyclists may get discouraged waiting for a green signal and run the red light. Eventually, this can lead to a disregard for traffic signals and hazardous riding practices for bicyclists.

Many traffic signals in urban areas are activated by detector loops embedded in the roadway. These traffic detector loops respond to the electrical field variations included by the metal in a vehicle over the detector loop.

The sensitivity of these loops should be adjusted to detect a bicycle without sensing passing vehicles in adjacent lanes. This can be facilitated by using a short length (under 50 ft.) quadrapole loop. This minimizes sensitivity outside the loop while increasing it within.

Detector loops are not usually installed across the entire lane and it is quire possible a bicycle on the far right side of the road will not be detected. Some children's bicycles have plastic rims, and thus greatly reduces the chance of being detected. By marking the part of a signal loop where the bicycle will be detected, preferably on the right side of the lane, we would be helping bicyclists obey the law.

c. Bicycle Actuated Signals

In some instances it may be desirable to place a traffic signal loop within the bicycle lane. If a loop is installed, bicyclists should be informed of the loop's presence by a pavement symbol and sign.

Advance loops have also been used in bike lanes. By placing the signal loops in advance of the intersection the signal can change prior to the cyclists' arrival. Trails may be another appropriate place for advance loops.

4. Limited Access Intersections

Crossing the intersection terminal on freeway ramps poses special hazards to bicyclists due to speed of entry and exit, long tapers and expansive roadway crossing widths. Bicyclists can be aided through several principles of design:

- Slow the speed of the bicyclist on final approach, and create a yield for the bicyclist.
- Create a right angle crossing and a reasonable viewing distance by separating the bicyclist with a jughandle pathway, and crossing the bicyclist at a point in the ramp where the motorist is attended to steering control as opposed to an over-the –shoulder gap assessment.

F. Roadway Treatments

Bicycle-safe design practices should be followed to avoid the necessity for costly subsequent improvements. Because most highways have not been designed with bicycle travel in mind, there are often many things that can be done to improve the roadway for bicyclists. In addition, the desirability of adding facilities such as bicycle lanes, shoulder improvements and wide curb lanes (the least preferred option) should be considered.

Roadway conditions should be examined and hazardous conditions removed. The controlling feature of the design of every bicycle facility is its location (i.e., whether it is on the roadway or on an independent alignment).

1. Lighting

On-road bicycle facilities should be lit to the same levels as the roadways. The Plans Preparation Manual (PPM) gives the following standards:

For major arterials:

Illumination level (Average initial lux) = 16

Uniformity ratio: avg./min. 4:1 or less

For all other roadways:

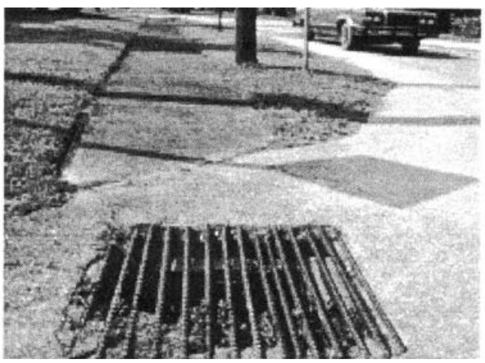
Illumination level (Average initial lux) = 11

Uniformity ratio: avg./min. 4:1 or less

2. Drainage Gates

Drainage grate inlets and utility covers are potential problems to bicyclists. Typical drainage grates can be:

- slippery
- not flush with the road surface
- a prime location for debris and water, and
- capable of trapping bicycle wheels



When a new roadway is designed, all such grates and covers should be kept out of bicyclists' expected path, or they should be designed to accommodate bicycle traffic, as described below.

On roadways where bicyclists will be permitted, curb inlets should be used, wherever possible, to eliminate exposure of bicyclists to grate inlets. It is important that grates and utility covers be adjusted flush with the surface, including after a roadway is resurfaced.

Parallel bar drainage grate inlets can trap the front wheel of a bicycle, resulting in loss of steering control and often serious damage to the bicycle wheel and frame and/or injury to the bicyclist. Grates with parallel slat design that trap bicycle wheels are still used frequently in some roadway and many non-roadway environments, such as in parking lots, across driveways, and other hazardous locations. These grates should be replaced with bicycle-safe and hydraulically efficient ones. Designers must be vigilant always to specify bicycle safe inlet grate designs.

As a last and temporary resort, identifying a grate with a pavement marking would be acceptable in some situations. As indicated in the MUTCD, parallel bar grate inlets deserve special attention. Because of the serious consequences of a bicyclist missing the pavement marking in the dark or being forced over such a grate inlet by other traffic, these grates should be physically corrected as described above, as soon as practical, after they are identified.

3. Railroad Crossings

At highway grade crossings of railroads, the rails should ideally be at a right angle to the road. The greater the crossing deviates from this ideal angle, the greater is the potential for a bicyclist’s front wheel to be trapped in the flangeway causing loss of steering control. It is also important that the roadway approach be at the same elevation as the rails.

Consideration should be given to the materials of the crossing surface and to the flangeway depth and width. If the crossing angle is less than approximately 45 degrees (crossing angles of 30 degrees or less are considered exceptionally hazardous), consideration should be given to widening the outside lane, paving the shoulder or providing a bulbed out bicycle lane to allow bicyclists adequate room to cross the tracks at a right angle. The approach and departure shoulder should be paved, and should provide sufficient length to allow the bicyclist to merge into a gap in traffic. Where this is not possible, commercially available compressible flangeway fillers can enhance bicyclist safety. In some cases, abandoned tracks can be removed. Warning signs and pavement markings should be installed in accordance with the MUTCD. Additional pavement markings directing the bicyclist toward the best crossing angle should be considered.

Ensure any crossing designs are approved by the state rail office and the appropriate railroad.

4. Pavements

Often the right-most portion of a highway deteriorates first in a highway cross section. Since this is an area of a roadway where bicyclists generally ride to stay out of traffic, it is imperative pavements be selected and constructed to provide long life. Pavement surface irregularities can do more than cause an unpleasant ride. Gaps between pavement slabs or drop-offs at overlays parallel to the direction of travel can trap a bicycle wheel and cause loss of control. Holes and bumps can cause bicyclists to swerve into the path of motor vehicle traffic. Thus, to the extent possible, pavement surfaces should be free of irregularities and the edge of the pavement should be uniform in width. On older pavements it may be necessary to fill joints, adjust utility covers or, in extreme cases, overlay the pavement to make it suitable for bicycling.

5. Rumble Strips

Rumble strips can be a deterrent to bicycling on shoulders and their benefits should be weighted against the probability bicyclists will ride in the motor vehicle lanes to avoid them. As a general rule, rumble strips should only be used on curves, approaches to narrow bridges and other locations where there is a high potential for benefit.

6. Bicycle Sharing Roadway Signing

Special guidelines have been issued for the use of “Bicycle Sharing Roadway” signs. These signs are to inform motorists that bicyclists and motor vehicles are legally required to use/share travel lanes. These signs are generally used where safety problems or inappropriate motorist behavior indicate a need to remind users they are sharing the roadway with others. These signs may be appropriate for long narrow bridges in both urban and rural locations. Also, these signs can be used when a bike lane ends and the bicyclist is required to move into the roadway.

Designated bicycle facilities are not eligible for this sign. As a general rule, unless there is a special safety or road courtesy problem, corridors with paved shoulders or bike lanes will not be considered for this sign. As with any sign, overuse tends to breed disrespect for those cases where they are needed most.

7. Bicycle Routes

It may be advantageous to sign some urban and rural roadways as bicycle routes. When providing continuity to other bicycle facilities, a bicycle route can be relatively short. However, a bicycle route can also be quite long. For longer bicycle routes, a standard bicycle route marker with a numerical designation in accordance with the MUTCD can be used in place of a bicycle route sign. The number may correspond to a parallel highway, indicating the route is a preferred alternate route for bicyclists.

It is often desirable to use supplemental plaques with bicycle route signs or markers to furnish additional information such as direction changes in the route and intermediate range distance and destination information. Bicycle route signing should not end at a barrier. Information directing the bicyclist around the barrier should be provided.

Overall, the decision whether to provide a bicycle route should be based on the advisability of encouraging bicycle use on a particular road instead of on parallel and adjacent highways. The roadway width, along with factors such as the volume, speed and types of traffic, parking conditions, grade and sight distance should be considered when determining the feasibility of bicycle routes.

Generally, bicycle traffic cannot be diverted to a less direct alternate route unless the favorable factors outweigh the inconvenience to the bicyclist. Roadway improvements, such as adequate pavement width, drainage grates, railroad crossings, pavement smoothness, maintenance schedules and signals responsive to bicycles, should always be considered before a roadway is identified as a bicycle route.

8. Bicycle Boulevards

In contrast to bicycle routes, bicycle boulevards offer more support to bicyclists by enhanced signing, traffic controls and connections. Bicycle boulevards serve as a primary route for bicyclists through a collection of lower speed side roads where traffic controls favor the through movement of bicyclists. Motorists attempting to use the same route for distance travel are thwarted through an occasional traffic diverter, a series of roundabouts, and other devices used to slow or rechannel motor vehicles. Boulevards may also have special trails, bridges or connections, offering the rider the most direct and quiet routing to primary destinations such as a downtown.

9. Special Neighborhood Bike Lane

Special bike lanes can be created on highly select local streets by restricting auto movement to one way, placing a low median divider of at least 70 inch width, and with a 6 inch curb face on the motor vehicle traffic side. The bicycle side can have a zero curb height to allow additional maneuvering width. The created space can thus be dedicated for bi-directional bicycle travel. Such treatments call for special side entry signing to alert motorists of the bidirectional bike travel. These local bicycle streets should only be considered with full involvement of the neighborhood, and where at least 60% of the residents approve of the design. Other criteria include the number of conflict points and the volumes of traffic and potential bicycle traffic.

G. Existing Hazardous Conditions

There are some conditions that deserve special attention because of the danger they pose to bicyclists. Special efforts should be made to eliminate these hazardous conditions.

1. Continuous Right Turns

In some cases, designers have permitted right turn only lanes for extended distances. Drivers using these lanes do not always turn at the first available location, making these de facto through lanes. These right turn lanes should be discontinued with a raised island breaking up the through movement.

Continuous right turn lanes present a problem for the designer. To be consistent, the bike lane must be between the through and right turn lanes. This puts bicyclists in the continuous high conflict zone. They must negotiate high speed, accelerating, or decelerating traffic that is passing on the right and left or weaving across the bike lane. The difficulty in predicting motorist movements within these lanes can also make continuous turn lane hazardous to pedestrian and motorists.

2. Continuous Through Lanes

In a few isolated cases, at tee intersections, designers have permitted a continuous green through lane on the long leg, allowing motorists to continue higher speed through movement, while traffic is entering from their left. This creates an impossible merge condition for bicyclists and pedestrians. Both bicyclists and pedestrians become trapped in an interior lane. For this reason such operations are discouraged in most urban applications.

3. Intersection Improvements

Since facilities are commonly installed on a project-by-project basis, bicycle lanes should be provided even for such short sections as an intersection improvement. If desired, the lane markings and signing can be left out until a longer facility can be connected. Designers should extend the bike lane portion of such intersection improvements into a logical merge locations, allowing the bicyclist to accept a comfortable gap. This lane extension may require extending the normal length of the project several hundred additional feet.

4. Climbs and Descents

Bicyclists require additional room to climb and descent. Six to eight feet is recommended for the ascent side, and ten to twelve feet is recommended for the descent. Typically the descent requires bicyclist to take the full lane. Speeds of 30 mph or greater are common. Special signs to create the best actions of motorists and bicyclists have been developed.

5. Bike Lane Conditions and Maintenance

If a drainage grate exists within a bike lane or shoulder area it should be marked to steer bicyclists around it.

Utility covers are also a hazard for bicyclists. The surface is slippery when wet. They also tend to be higher than the surrounding roadway surface. The asphalt around utility covers must be maintained to provide a smooth ride. Where possible they should be relocated to outside the bicyclists expected path.

Adequate pavement surface, bicycle-safe grate inlets, safe railroad crossings and traffic signals responsive to bicycles should also be provided on all urban roadways. These treatments should be provided especially where bicycle lanes are designated. Raised pavement markings and raised barriers can cause steering difficulties for bicyclists and should not be used to delineate bicycle lanes.

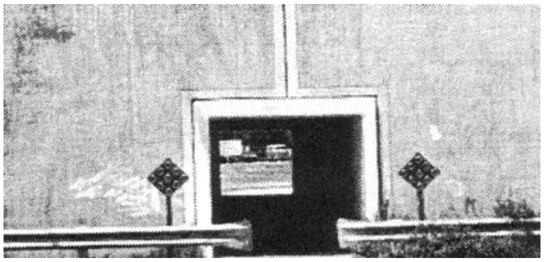
H. Bridges, Tunnels and Overpasses

Bicycle use is largely dependent upon convenience. Any barrier causing bicyclists to travel long distances to avoid it is a serious disincentive to bicycling. Common barriers include water, canyons and gullies, rails, freeways and major arterials. Occasionally, bridges, overpasses and tunnels are the only way to overcome the barrier and provide needed linkages within the bicycle transportation system. Indeed, without linkages, there can be no system. Every manner of barrier, whether man-made or natural, must be bridged. No new barriers should be created.

Most bridges used by bicyclists will be roadway bridges. An 8 ft. shoulder on bridges is usually adequate to serve bicyclists. Where frequent use by inexperienced riders or children is expected it may be appropriate to include a wide sidewalk physically separated from the roadway.

Roadway tunnel must also accommodate bicyclists. An 8 ft. shoulder should be provided thorough all tunnels.

Meant to protect autos, guardrails also impact bicyclists. The designer must be alert so guardrails and all design treatments benefit all users. This guardrail treatment makes the entrance to the tunnel seem more constricted.



I. Bicyclists at Roundabouts

A number of studies have shown that crashes involving bicyclists increase at roundabout-controlled intersections. However, the countries doing the studies have varying design standards. Florida has developed a Roundabout Design Guide. Under these standards, bicyclists should fare well at roundabouts for two reasons: first, there is no possibility of a left hand or cross-motorist turning crash. Second, the right turning conflict can be fully controlled by the bicyclist. By claiming the lane upon entering the roundabout, a bicyclist can enter and exit the roundabout without conflict from an overtaking motorist. The only remaining threat is for the bicyclist to watch for the entering motorist.

J. Traffic Calming

In traffic calming, the designer must pay special attention to the elements of designing collector and local roads, making sure speeds are kept low.

As a general rule, well designed neighborhoods need little traffic calming. Many of these principles apply to developments already in place where motorists exceed prudent neighborhood speeds (20 mph).

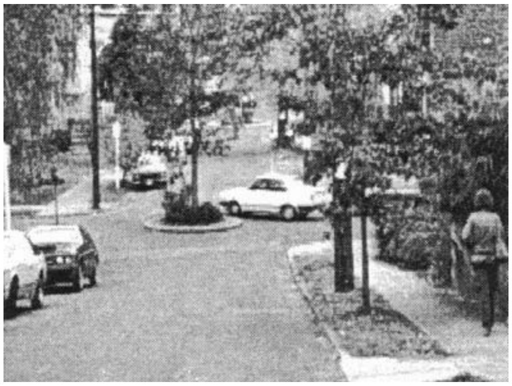
Some traffic calming treatments may not be appropriate on the State Highway System. The Department is investigating how traffic calming techniques may be used on its system.

If traffic calming is used, there are several key techniques to be used:

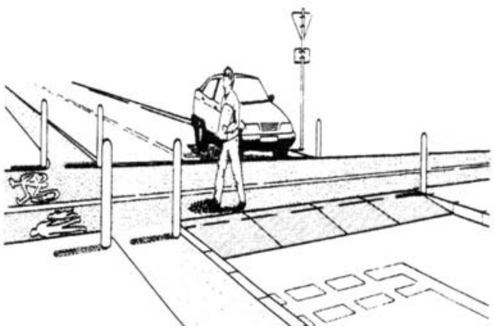
- Keep blocks short
- Provide tight turning radii
- Provide tree canopies
- Permit narrow lanes, or medians
- Slow speeds at intersections
- Create constant movement to maintain flow (avoid stop signs in favor of roundabouts)

Bicyclists are concerned with things they don't see (speed bumps), but they don't mind speed humps or tables. Use tapers and full openings for bicycle movement. Some of the graphics showing speed humps show treatments that allow bicyclists to ride through the treatments. The approach to a speed table, a raised intersection, or other raised object should be 1:6. A more sudden rise creates problems, and a shallower rise has reduced effect. Always mark changes in elevations with roadway markings and signs. This increases their effectiveness. Because bicycles lack adequate lighting, street lighting should be used with traffic calming features.

Traffic calming features should only be installed after a complete engineering study and extensive neighborhood involvement process. After installation, a follow-up study is needed to determine if the treatment had the desired effect.



A small traffic circle or vehicle speed hump can be used to slow the vehicles at a pedestrian crossing location.



V. Design of Shared Use Paths

A. Definition

Shared use paths are facilities on exclusive rights-of-way and with minimal cross flow by motor vehicles. Since bicycle paths are almost always used by pedestrians, joggers, in-line skaters, equestrians and bicyclists, they will subsequently be referred to as shared use paths.

Shared use paths scan serve a variety of purposes. They can provide a school age child or a commuting bicyclist with a shortcut through a residential neighborhood (e.g., a connection between two cul-de-sac streets). Located in a park, they can provide an enjoyable recreational opportunity. Shared use paths can be located along abandoned railroad rights-of-way, the banks of rivers and other similar areas. Shared use paths can provide bicycle access to areas that are otherwise serviced only by limited access highways and closed to bicycles. Appropriate locations can be identified during the planning process.

Shared use paths should be thought of as extensions of the highway system that are intended for the exclusive or preferential use of bicycles and pedestrians in much the same way as freeways are intended for the exclusive or preferential use of motor vehicles.

There are many similarities between the design requirements for shared use paths and those for highways (e.g., in determining horizontal alignment, sight distance requirements, signing and markings). On the other hand, some criteria (e.g., horizontal and vertical clearance requirements, grades and pavement structure) are dictated by operational characteristics of bicycles that are substantially different from those of motor vehicles. The designer should always be conscious of similarities and differences between bicycles and motor vehicles and how these similarities and differences influence the design of shared use paths.

B. Shared Use Paths Adjacent to Roadways and Sidewalk Bike Paths

When two-way, shared use paths are located immediately adjacent to roadways some operational problems may occur:

- Unless shared use paths are paired, they require one direction of bicycle traffic to ride against motor vehicle traffic, contrary to normal rules of the road.
- When the path ends, bicyclists going against traffic will tend to continue to travel on the wrong side of the street. Likewise, bicyclists approaching a path often travel on the wrong side of the street to get to the path.
- At intersections, motorists entering or crossing the roadway often will not notice bicyclists coming from the right, as they are not expecting or looking for contra-flow vehicles.
- Bicyclists using the roadway are often subjected to harassment my motorists who feel that in all cases, bicyclist should be on the trail instead.
- Bicyclists using shared use paths generally are required to stop or yield at all cross streets and driveways.
- Stopped cross street motor vehicle traffic or vehicles exiting side streets or driveways may block the path crossing.
- Because of the proximity of motor vehicle traffic to opposing bicycle traffic, barriers are often necessary. They keep motor vehicles separated from shard use paths and bicyclists from traffic lanes.
- Many bicyclists' destinations may be on the opposite side of the street from where the bicycle path is locates. This is a common situation when shared use paths are built along railway corridors.

Using sidewalks as pathways further increase the hazards. Providing a sidewalk shared use path is unsatisfactory for a variety of reasons:

- Sidewalks are typically designed for pedestrian speeds and maneuverabilities.
- They are not the safest for higher speed bicycle use.
- Conflicts are common between pedestrians and bicyclists.
- Conflicts with fixed objects (e.g.,. parking meters, sign posts) are also common

- Walkers, joggers, skateboards can, and often do, change their speed and direction almost instantaneously, leaving bicyclists insufficient time to react to avoid collisions.
- Pedestrians often have difficulty predicting the direction an oncoming bicyclist will take.
- At intersections, motorists are not often looking for bicyclists entering the crosswalk area, particularly when motorists are making a turn.

For the above reasons, bicycle lanes may be the best way to accommodate bicycle traffic along a highway corridor. If the intent is also to accommodate pedestrians, sidewalks must be provided.

Bicyclists riding on sidewalks can be expected in residential areas with young children. With lower bicycle speeds and lower motor vehicle speeds, potential conflicts are somewhat lessened, but they still exist. Although this type of bicycle sidewalk use is generally accepted, it is inappropriate to sign a sidewalk as shared use path or bicycle route, if doing so would prohibit or discourage bicyclists from using an alternate facility that might better serve their needs.

Use of commercial district sidewalks pose extreme risk to the bicyclist, pedestrian and motorist. Many communities do not permit such riding.

C. Mixing Users

Is it best to mix bicyclists, pedestrians and equestrians or to keep them separate? The question is best answered in terms of volume and user type. Horses prefer a softer surface and space away from bicyclists, tricyclists and skaters. At low volumes of each group a fully mixed path is observed to work. Once volumes increase, there is a need to provide separate spaces. Increased volumes also require lower operating speeds. The most universal answer is to provide a simple “wheels ‘n heels” design that separates the bicyclists from the pedestrians by marking designated areas. ADA accessible paths must be designed as such. Circular pathways should normally restrict wheeled vehicles (and in-line skaters) to one direction.

Using the same path for bicycles and horses create an unsatisfactory and possibly dangerous mix. Horses startle easily and may kick out suddenly, if they perceive bicyclists as a danger. A shared use path and bridle path are also incompatible in their surface design requirements. Bicycles function best on hard surfaces; horses function best on soft surfaces. A compromise to accommodate both would result in a less that adequate surface for both. Separate portions of the right-of-way should be used for equestrian needs.

Mixing of high speed bicyclists with pedestrians, tricyclists or people using wheel chairs is another concern. In addition to separate areas for different users, some paths may require a speed limit. This might be the case on a commuter path for children going to school.

D. Width

The pavement width and the operating width required for shared use paths are primarily design considerations. According to FDOT's 'PPM', the minimum paved width for a two-directional shared use path is 12 feet. This width is required because most paths are heavily used, are shared by bicyclists, joggers and in-line skaters, must accommodate occasional maintenance vehicles, have sections with steep grades, and are used by recreational bicyclists who like to ride two abreast.

The minimum width of a one-directional, bike path is 5 feet. Eight feet may be considered on sections where maintenance vehicle have no other access. It should be recognized, however, that one-way bike paths almost certainly will be used as two-way facilities unless effective measures are taken to assure one-way operation. Without such design and enforcement, it should be assumed that shared use paths will be used as two-way facilities. They should be designed accordingly.

1. Reducing Width

The Florida Greenbook's minimum width requirement for paved paths is 10 ft. However, only under extreme constraints should building a path less than 12 feet wide be considered. A thorough analysis should be performed to ensure all of the following criteria are met.

- Bicycle traffic will be low, even on peak days or during peak hours (most paths actual usage rates far exceed preconstruction estimates).

- Pedestrian on in-line skater use of the facility will be only occasional.
- There will be good horizontal and vertical alignment providing safe and frequent passing opportunities.
- The path will not be subject to maintenance vehicle loading conditions that would cause pavement edge damage.

2. Increasing Width

Under certain conditions it may be necessary or desirable to increase the width of a shared use path up to 22 ft.. Examples include:

- substantial bicycle volume
- probable shared use with joggers, in-line skaters and other pedestrians
- use by large maintenance vehicles
- steep grades
- sharp curves
- places where bicyclists will be likely to ride two abreast

E. Horizontal Clearances

A minimum, 4 feet of clearance is desirable to provide distance from trees, poles, walls, fences, guardrails or other lateral obstructions. A 2 feet width graded area should be maintained adjacent to both sides of the pavement. A wider graded area on either side of the shared use path can serve as a separate jogging path. Any edge drop-off should be eliminated.

Embankments are especially hazardous to bicyclists. A 6 foot lateral separation is desirable from any embankment that would create difficulties for bicyclists (greater than or equal to a 3:1 slope). Otherwise an appropriate safety railing should be installed.

A wide separation between a bicycle path and canals, ditches or other significant depressions is essential for safety. A minimum 6 foot separation from the edge of the bike path to the top of slope is desirable. If this is not possible, a positive barrier such as dense shrubbery or chain link fence shall be provided.

A wide separation between a shared use path and adjacent highway is desirable to confirm to both bicyclists and motorists that the shared use path functions as an independent way for bicycles. When this is not possible and the distance between the edge of the shoulder (this includes both the paved and grassed shoulders) and the shared use path is less than 5 feet, a suitable physical divider may be considered. Such dividers serve both to prevent bicyclists from making unwanted movements between path and highway shoulder and to reinforce the concept that the shared use path is an independent facility. Where used, dividers should be a minimum of 3.5 feet high, to prevent bicyclists from toppling over them. They should be designed so they do not become an obstruction or visually shield small cyclists from motor vehicle traffic.

F. Vertical Clearances

The vertical clearance to obstructions should be a minimum of 8 ft. However, vertical clearance may need to be greater to permit passage of maintenance vehicles and, in under crossings and tunnels, a clearance of 10 ft. is desirable for adequate physical and psychological vertical shy distance. Equestrian trails should be designed with a 10 ft. vertical clearance.

G. Design Speed

The speed a bicyclist travels is dependent on several factors, including the type and condition of the bicycle, the purpose of the trip, the surface condition and location of the shared use path, the speed and direction of the wind and the physical condition of the bicyclist. Shared use paths should be designed for speeds at least as high as the preferred speed of the faster bicyclists. However, paths should not be designed to encourage speed.

1. AASHTO Design Speed

According to AASHTO's 'Guide for the Development of Bicycle Facilities,' a minimum design speed of 20 mph should be used; however, when the downgrade exceeds 4 percent, or where strong prevailing tailwinds exist, a design speed of 30 mph is advisable.

On unpaved paths, where bicyclists tend to ride slower, a lower design sped of 15 mph can be used. Similarly, where the grades or the prevailing winds dictates, a higher design sped of 25 mph can be used. Since bicycles have a higher tendency to skid on unpaved surfaced, horizontal curvature design should take into account lower coefficients of friction for unpaved conditions.

2. Reduced Design Speeds

There is a growing concern that the 20 mph design speed prescribed by AASHTO may create too great of an operating speed differential between families riding and high speed bicyclists. It may be different types of paths require difference design speeds. Urban paths used by school children may have a lower requirement than rural paths with a large percentage of high speed cyclists.

Intersection approaches may be another location that would benefit from a low design speed. Reducing the speed of path users approaching intersections could allow for the replacement of some STOP signs with YIELD signs. Unless the speed reduction is obvious, posting of the recommended speed and changed condition is essential. Since most bicycles don't have speedometers, signing, however is limited in its effectiveness. Any designs using low design speeds should be evaluated for safety and effectiveness.

H. Horizontal Alignment and Superelevation

The minimum radius of curvature negotiable by a bicycle is a function of the superelevation rate of the path, the coefficient of friction between the bicycle's tire and the path and the speed of the bicycle.

According to AASHTO, the minimum design radius of curvature can be derived from the following formula:

$$R = V^2 / 15(e/100+f)$$

Where:

R = Minimum radius of curvature (ft.)

V= Design speed (mph)

E = Superelevation rate as a %

F = Coefficient of friction

For most shares use path applications the superelevation rate should not exceed 2% (the maximum allowed by ADA for pedestrian paths and the minimum necessary to encourage adequate drainage). A steeper cross slope cannot be handled by wheelchairs. The minimum superelevation rate of 2% will be adequate for most conditions and will simplify construction. If a path is fully to be used by bicyclists, a maximum superelevation rate of 6% may be used. At lower speeds this superelevation acts as a cross slope. This is the maximum cross slope for bicycle facilities as small children on bicycles may have trouble negotiating steeper cross slopes.

The coefficient or friction depends upon speed; surface type, roughness and condition of asphalt; tire type and condition; and whether the surface is wet or dry. Friction factors can be determined by extrapolating from values used in highway design, design friction factors for paved shared use paths can be assumed to vary from 0.30 at 15 mph to 0.22 at 30 mph.

Although there is no data available for unpaved surfaces, it is suggested that friction factors be reduced by 50% to allow a sufficient margin of safety.

When substandard radius curves must be used on shared use paths because of right-of-way, topographical or other considerations, standard curve warning signs and supplemental pavement markings should be installed in accordance with the 'MUTCD." The negative effects of substandard curves can also be partially offset by widening the pavement through the curves.

I. Grades

Grades on shared use paths should be kept to a minimum, especially on long inclines. Grades greater than 5% are undesirable, because ascents are difficult for many bicyclists to climb and descents cause some bicyclists to exceed the speeds at which they are competent. Where terrain dictates, grades greater than 5% and less than 500 feet long are acceptable, when a higher design speed is used and additional width is provided. Grades steeper than 3% may not be practical for shard use paths with crushed stone surfaces.

Grades can be increased to 6% for bridges where wide paved shoulders (10 feet) or paths are provided and a leveling off at the base permits adequate recover before an intersection or other conflict point. ADA rules apply (a level area is needed for 10 feet each 30 feet).

J. Sight Distance

To provide bicycles with an opportunity to see and react to the unexpected, a shared use path should be designed with adequate stopping sight distances. The distance required to bring a bicycle to a full controlled stop is a function of the bicyclists perception and brake reaction time, the initial speed of the bicycle, the coefficient of friction between the tires and the pavement and the braking ability of the bicyclist.

Bicyclists frequently ride two abreast on shared use paths; and, on narrow shared use paths, bicyclists have a tendency to ride near the middle of the path. For these reasons, and because of the serious consequences of a head-on bicycle crash, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for bicyclists traveling in opposite directions around the curve.

Minimum Stopping Sight Distance

$$S = V^2/30(f+g) + 3.67V$$

Where: S = minimum sight distance (feet)

V = velocity (mph)

f = coefficient of friction (use 0.25)

g = grade (feet/feet) (rise/run) (descent is negative and ascend is positive)

Where this is not possible or feasible, consideration should be given to widening the path through the curve, installing a yellow center strip, installing a "CURVE AHEAD" warning sign in accordance with the 'MUTCD,' or proper combination of these alternatives.

1. Path/Roadway Intersections

Path intersections with roadways are important considerations in shared use path design. The following principles apply. If alternate locations for shared use paths are available, the one with the most favorable intersection conditions should be selected.

2. Crossing Limited Access Roadways and Other High-Speed , High-Volume Roadways

For crossing freeways and other high-speed, high-volume arterials, a grade separation structure may be the only possible or practical treatment. Unless bicycles are prohibited from the intersecting highway, providing for turning movements must be considered. In many cases, however, the cost of a grade separation will be prohibitive.

3. Assigning Right-of-Way

When intersections occur at grade, a major consideration is the establishment of right of way . According to the Traffic Control Devices Handbook, the following conditions should normally be assigned right of way:

- heavier volume of traffic;
- higher speed traffic; and
- superior classification of highway

Because some paths have daily traffic exceeding 1000 users, the roadway could be required to yield right of way to the path. Bicycles are considered vehicles and should be counted as such when determining the traffic control.

A common mistake at an intersection is to assign the through priority to the wrong traffic. Some designers assume that because the bicyclist has more to lose if hit by an auto, the bicyclist should stop at virtually all intersections, including driveways and even sidewalks. This assumption is incorrect. It can lead to unsafe practices confusion, and increase the potential for a bad crash.

Another common operations error is to stop traffic in both directions ”just to be safe” when there is a clear majority of movement on one alignment. This also leads to confusion. Four-way stops should be avoided. They are even trickier with paths than they are with roadways. There is a general tendency for motorists at 4-way stops to over-yield to bicyclists, again creating unsafe expectations and practices. At times a motorist motions a bicyclist on in one direction, begins to move, then is confronted by another bicyclist coming the other direction.

The type of traffic control to be used (signal, stop sign, yield sign, etc.) and location, should be provided in accordance with the ‘MUTCD.’ Traffic volumes for paths being developed will have to be estimated. An evaluation after the path is in use should be done to confirm the proper treatment is being used.

4. Traffic Control at Intersections

Sign type, size and location should also be in accordance with the ‘MUTCD.’ Care should be taken to ensure the shared use path signs are located so motorists are not confused by them and that roadway signs are placed so bicyclists are not confused by them.

Bicyclists need to be warned in advance of intersections. Stopping sight distance at intersections should be checked and adequate warning should be given to permit bicyclists to stop before reaching the intersection, especially on downgrades. Yellow centerline striping and advance pavement markings (the word STOP or YIELD) may be appropriate. STOP and YIELD messages should be in standard lettering so they are distinguishable from other markings that may be on the path.

Changes in surfaces can alert the bicyclist to upcoming intersections. Brick or stone inserts across the path are one method. Changing the asphalt mix to a coarser grade would give a rougher surface suggesting a slower speed be used. A speed bump or change to a loose surface is not recommended. A pullout near the intersection with benches, water fountains or navigational information, can act as a resting and gathering point for riders.

Advance warning signs of all crossing should be on the roadway in advance of the intersection as prescribed in the 'MUTCD.' Signs should be erected about 750 feet in advance of the crossing location in rural areas or areas where speeds are greater than 35 mph and 250 feet in urban residential or business districts where speeds are low.

Often shared use paths intersect busy roads and thus need signals. Instead of traffic lights, a flashing bicycle crossing signal can be used. This signal can be a pedestrian crossing signal that has been modified for cyclist use. The signal actuation mechanism should be mounted on the right side of the path approximately 4 feet above the ground. This allows the cyclist to activate the signal without dismounting. Another method of activating the signal would be a detector loop in the path. At some crossing locations, where optimum progression is not a factor, the designer may consider giving the shared use path user a "hot response" or immediate call, to encourage bicyclists with the shortest possible wait. This feature increases the number of path users that wait for the signal.

5. Designing Crossings

There are times when it is preferable that the at-grade crossing of a shared use path and a highway be at a locations away from the influence of intersections with other highways. Controlling vehicle movements at such intersections is more easily and safely accomplished through the application of standard traffic control devices and normal Rules of the Road. Right of way should be assigned and sight distance should be provided so as to minimize the potential for conflict resulting from unconventional turning movements.

Junctions should cross at right angles wherever possible. If the pathway parallels a roadway, or intersects the roadway at an acute angle, jughandle final approaches to the crossing point should be considered.

Intersections must be designed with proper sight distances. The traffic control devices used (stop or yield signs) will in part depend upon the available sight distances. Shared use path intersections and approaches should be on relatively flat grades so required sight distances will be minimized.

Intersection design should limit turning speeds so motorists do not exceed 10 mph for right turns and 20 mph for left turns. At crossings of high volume multi-lane arterial highways where signals are not warranted, consideration should be given to providing a median refuge area for bicyclists and pedestrians.

Bicyclists, elderly adults, and mobility disabled, all need median cuts as well as cuts through channelized islands.

6. Median Refuge

A refuge is a place in the middle of a road where bicyclists and pedestrians can wait safety before crossing the next lane of traffic. A refuge allows a path user to cross one direction of traffic at a time without waiting until both directions are clear. A refuge separates conflicts and simplifies the crossing procedure. The refuge can be simply a cut in the existing median or a structure can be built specifically as a refuge. Although they can be used on 2-lane roadways, they are especially helpful on multi-lane roadways.

The minimum median width to meet the needs of bicyclists should be at least 10 ft. If large numbers of bicyclists can be anticipated, a storage space o f 12-14 ft. is preferred. The median cut should be as wide as the path. The cut may be angled 45 degrees toward the approach traffic. This forces bicyclists to stop for the second search, and orients them to look directly into the source of danger.

Lighting should be used for median crossings. Advanced warning signs should be used for the motorist approach, and approach speeds should be regulated and further constricted by design, when practical.

K. Signing and Marking Path Sections

Adequate signing and marking are essential on shard use paths. They alert bicyclists to potential conflicts and convey regulatory messages to both bicyclists and motorists at highway intersections. In addition, guide signs such as those indicating directions, destinations, distances route numbers and names of crossing streets should be used in the same manner as they are used on highways. In general, uniform application of traffic control devices, as described in the MUTCD, will tend to encourage proper bicyclist behavior.

Where conditions make it desirable two separate to directions of travel, a solid yellow line should be used to indicate no passing or no traveling to the left of the line. This is particularly beneficial in the following circumstances:

- For heavy volumes of bicycles
- On the approach to intersections
- On vertical and horizontal curves with restricted sight distance
- On unlighted paths where night time riding is expected

Edge lines can also be very beneficial where nighttime bicycle traffic is expected. The desire to omit lines for aesthetic reasons is common, but is sometimes contrary to operations and safety needs.

General guidance on signing and marking is provided in the MUTCD. Care should be exercised in the choice of pavement marking materials. Some marking materials are slippery when wet and should be avoided in favor of more skid resistant materials. Adding glass beads to thermoplastic increases skid resistance.

L. Path Termination

When share use paths terminate at existing roads, it is important to integrate the path into the existing system of roadways. Care should be taken to properly design the terminals to transition the traffic into safe merging or diverging situations. Appropriate signing is necessary to warn and direct both bicyclists and motorists regarding these transition areas. Care must be take so wring way riding is discouraged.

M. Median Ramps/Cuts and Raised Crossings

Ramps for curb cuts at intersections should be the same width as the shared use paths. Curb cuts and ramps should provide a smooth transition between the shared use paths and the roadway.

An alternative treatment is to install a speed table at the crossing. At locations where the path is given priority over the intersection roadway, the crossing may be raised to the level of the path.

N. Staircases

Although ADA requires ramps, stair cases may be used in addition to ramps or be present on existing routes. Staircases can pose a problem for cyclists if the bicycle has to be carried up or down the staircases. A simple solution is to build concave or trough type ramps on either side of the staircase. These ramps allow bicyclists to roll their bicycles up or down the staircase without having to carry them. Each ramp should be at least 6 inches wide. Preferably there should be two ramps; one for ascending and the other for descending. A concave ramp is preferred as it will help keep the bicycle wheels centered on the ramps.

O. Pavements

Designing and selecting pavement sections for shared use paths is in many ways similar to designing and selecting highway pavement sections. A soils investigation should be conducted to determine the load-carrying capabilities of the native soil and the need for any special provisions. The investigation need not be elaborate, but should be done by or under the supervision of a qualified engineer.

1. Materials

Hard, all-weather pavement surfaces are usually preferred over those of crushed aggregate, sand, clay or stabilized earth since these materials provide a much lower level of service. In some low-use areas, limestone screens, or other porous materials have proven economical.

Good quality pavement structure can be constructed of asphaltic or portland cement concrete. Because of wide variations in soils, loads, materials and construction practices, it is not practical to present specific or recommended typical structural sections that will be applicable statewide. Decisions should be based on the principles outline above and attention to local governing conditions. Experience in highway pavement, together with sound engineering judgment, can assist in the selection and design of a proper shared use path pavement structure. Experience also may identify energy conserving practices, such as the use of sulfur extended asphalt, asphalt emulsions and fused waste materials.

2. Pavement Loads

Several basic principles should be followed to recognize some basics differences between the operating characteristics of bicycles and those of motor vehicles. While loads on shared use paths will be substantially less than highway loads, paths must be designed to sustain without damage wheel loads of occasional emergency, patrol, maintenance and other motor vehicles.

Special consideration should be given to the location of motor vehicle wheel loads on the path. When motor vehicles are driven on shared use paths, their wheels will usually be at or very near the edges of the path. Since this can cause edge damage that, in turn, will result in the lowering of the effective operation width of the path, adequate edge support should be provided. Edge support can be either in the form of stabilized shoulders or additional pavement width. Constructing a typical pavement width of 12 feet, where right-of-way and other conditions permit, eliminates the edge raveling problem and offers two other additional advantages over shoulder construction. First, it allows additional maneuvering space for bicyclists. Second, the additional construction can cost less than constructing shoulders because the separate construction operation is eliminated.

3. Surface Preparation

It is important to construct and maintain a smooth riding surface on shard use paths. Shared use path pavements should be machine-laid. Soil sterilants should be used where necessary to prevent vegetation from erupting through the pavement. On portland cement concrete pavements, transverse joints should be saw cut to provide a smooth ride. Normally these joints should be spaced at twice the pavement width, e.g. 10 feet wide equals 20 feet space. On the other had, skid resistance qualities should not be sacrificed for the sake of smoothness. Broom finish or burlap drag concrete surfaces are preferred over trowel finishes, for example.

4. Driveways and Crossings

At unpaved highway or driveway crossings of shared use paths, the highway or driveway should be paved a minimum of 10 feet on each side of the crossing to reduce the amount of gravel being scattered along the path by motor vehicles. The pavement structure at the crossing should be adequate to sustain the expected loading at that location. In areas where climates are extreme, the effects of freeze-thaw cycles should be anticipated in the design phase.

P. Structures

An overpass, underpass, small bridge, drainage facility or facility on a highway bridge may be necessary to provide continuity to a shared use path.

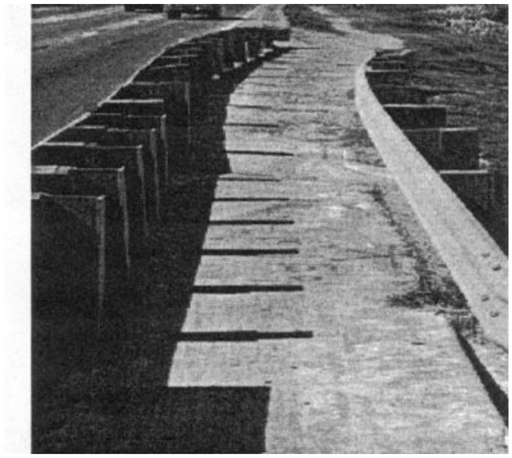
1. Width

On new structures, the minimum clear width should be the same as the approach width of the pavement shared use path. The desirable clear width should include a minimum 2 foot wide clear area. Carrying the clear areas across the structures has two advantages. First, it provides a minimum horizontal shy distance form the railing or barrier. Second, it provides needed maneuvering space to avoid conflicts with pedestrians and other bicyclists who are stopped on the bridge. Access by emergency, patrol, and maintenance vehicles should be considered in establishing the design clearances of structures on shared use paths. Similarly, vertical clearance may be dictated by occasional motor vehicles using the path. Where practical, a vertical clearance of 10 feet is desirable for adequate vertical shy distance.

Bridge designs to support maintenance and emergency vehicles can be prohibitively expensive barriers to prevent motor vehicle crossings, and alternate access should be provided to keep bridge costs affordable.

2. Railings, Fencing, Barriers

AASHTO recommends railings, fences or barriers on both sides of a shared use path structure be a minimum of 3.5 feet high. Also, smooth rub rails should be attached to the barriers at handlebar height of 3.5 feet.



Sections of guardrail can be a hazard to those they were placed to protect. A falling bicyclist can be seriously hurt. The addition of protective pipes minimizes the threat of puncture wounds.

3. Bridges

Bridges designed exclusively for bicycle and pedestrian traffic may be designed for pedestrian live loadings. On all bridge decks, special care should be taken to ensure that bicycle safe expansion joints are used.

Where it is necessary to retrofit a shared use path onto an existing highway bridge, several alternatives should be considered in light of what the geometrics of the bridge will allow.

One option is to carry the shared use path across the bride on one side. This should be done where:

- The bridge facility will connect to a shared use path at both ends.
- Sufficient width exists on that side of the bridge or can be obtained by widening or restriping lanes, and
- Provisions are made to physically separate bicycle and pedestrian traffic from motor vehicle traffic as discuss above.

A second option is to provide either wide curb lanes or bicycle lanes over the bridge. This may be advisable where:

- The shared use path transitions into bicycle lanes at one end of the bridge, and
- Sufficient width exists or can be obtained by widening or restriping.

4. Tunnels

Tunnels are often less successful than bridges for reasons of security, confinement, drainage and other factors. The problems associated with tunnels can often be mitigated in large part by splitting the elevation change with the roadway to be crossed, submerging the tunnel half way and raising the roadway the other half. If a multi-lane highway is being crossed, a skylight can be used to flood the tunnel with light at midsection.

Q. Drainage

The recommended cross slope of 2% adequately provides for drainage. Sloping in one direction instead of crowning is preferred and usually simplifies the drainage and surface construction. A smooth surface is essential to prevent water ponding and ice formation.

Where a shared use path is constructed on the side of a hill, a ditch of suitable dimensions should be placed on the uphill side to intercept the hillside drainage. Such ditches should be designed so that no undue obstacle is presented to bicyclists. Where necessary, catch basins with drains should be provided to carry the intercepted water. Drainage grates and manhole covers should be located outside the travel path of bicyclists. To assist in draining the area adjacent to the shared use path, the design should include considerations for preserving the natural ground cover. Seeding, mulching, sodding of adjacent slopes, swales and other erodible areas should be included in the design plans.

R. Lighting

Fixed-source lighting reduces crashes along shared use paths and at intersections. In addition, lighting allows the bicyclist to see the path direction, surface conditions and obstacles. Lighting for shared use paths is important and should be considered where riding at nighttime is expected. Paths receiving nighttime use commonly serve college students or commuters. The following standards can be used for shared path lighting:

Illumination level (Average initial lux) = 25

Uniformity ratio: avg./min. 4:1 or less

max./min 10:1 or less

AASHTO recommends 5–22 lux depending on the location.

Lighting is essential at highway/path intersections. Lighting should also be considered through underpasses or tunnels and when nighttime security could be a problem.

Light poles should meet the recommended horizontal and vertical clearances. Luminaires and poles should be at a scale appropriate for a shared use path. Lighting should be placed wherever there is signage and accessible electricity. This is particularly important for warning signs. All intersections should be lit far enough back from the intersection in order to allow the bicyclist and motorist enough time to see the intersection and act appropriately. The effect of incidental lighting on the path and on cyclists also needs to be considered. The most common example occurs when a path parallels a road. The lights of oncoming traffic will shine directly on bicyclists. This can cause momentary blindness that is dangerous on a curving path or in the face of oncoming bicycle traffic. In this case low level path lighting is recommended. The designer should keep in mind that in certain areas lighting is prone to high levels of vandalism.

S. Restriction of Motor Vehicles

Shared use paths often need some form of signing, curbing or other physical barrier at highway intersections to prevent unauthorized motor vehicle from using the facilities. When using medians, path medians, separators or islands, use permanently reflectorized materials for nighttime visibility and paint a bright color to improve daytime visibility. Advanced chevron markings and a center line should also be used to alert the bicyclist approaching the intersection. Curbing with tight radii leading up to the roadway can often prevent motorists from attempting to enter the path. Medians should be set back from the intersection 25 feet to permit bicyclists to exit the roadway fully before navigating the reduced pathway width.

An alternative method of restricting entry of motor vehicles is to split the entry way into two 5 foot sections separated by low landscaping. Operators of emergency vehicles know they can still enter if necessary by straddling the landscaping. The higher maintenance costs associated with landscaping should be acknowledged, however, before this alternative method is selected.

T. Path Heads and Rest Stops

Any long shared use path or path network needs rest stops. These should be at intermediate points, scenic lookouts, or near amenities such as restaurants, convenience stores, beaches, picnic areas, parking lots, etc. Any rest stop should be away from the path so bicyclists can pull of the path and not block traffic. A rest stop should have, as a minimum, a bench, shade, a parking rack and a trash receptacle. In addition, water fountains and washroom facilities should be included at one or more rest stops on the pathway.

Other amenities which should be considered include interpretive signage, information kiosks, emergency call boxes, emergency weather instructions, shelters, watering facilities for horses (where applicable), hitching posts, rest rooms and intermodal connections (including airboats).

