

Chapter 1

Introduction to Bicycle Facilities

1. Goals and Visions for Bicycle Use

The Intermodal Surface Transportation Efficiency Act (ISTEA) set a new direction for surface transportation in America that is enunciated in its statement of policy:

“to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner.”

Provisions for bicycling, with its potential for providing economically efficient transportation, became an important policy goal of ISTEA. The Secretary of Transportation was directed to conduct a national study that developed a plan for the increased use and enhanced safety of bicycling and walking. The National Bicycling and Walking Study - Transportation Choices for a Changing America presents a plan of action for activities at the Federal, State and local levels for meeting the following goals:

- To double the current percentage (from 7.9 percent to 15.8 percent) of total trips made by bicycling and walking; and
- To simultaneously reduce by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes.

The potential for increasing the number of bicycle trips is evident in the National Personal Transportation Survey, which shows that more than a quarter of all trips are 1.6 kilometers (one mile) or less, and 40 percent are 3.2 kilometers (two miles) or less. Almost half are 4.8 kilometers (three miles) or less and two-thirds are 8.0 kilometers (five miles) or less. Approximately 53 percent of all people live less than 3.2 kilometers (two miles) from the nearest public transportation route.

New Jersey residents have become aware of the energy, efficiency, health and economic benefits of bicycling for transportation and recreational purposes. In 1995, New Jersey Department of Transportation completed a statewide plan that established policies, goals and programmatic steps to promote safe and efficient bicycling for transportation and recreation in New Jersey. Through an extensive outreach effort, residents established a statewide vision for the future of bicycling and walking for all communities in New Jersey:

“New Jersey is a place where people choose to bicycle and walk. Residents and visitors are able to conveniently walk and bicycle with confidence and a sense of security in every community. Both activities are a routine part of transportation and recreation systems.”

In order to achieve this vision for New Jersey, and to enable people in every community of the state to bicycle with confidence and a sense of security, it is necessary to plan and provide appropriate facilities that will accommodate, encourage and promote bicycling. This manual provides direction regarding how appropriate facilities for bicycling should be provided.

Since these guidelines are a companion document to NJDOT’s Pedestrian Compatible Planning and Design Guidelines, it is appropriate to discuss the relationship between pedestrian and bicycle domains in general terms. While both functions need to be carefully planned for, the movement characteristics and needs of pedestrians and bicycles differ in obvious ways. The



greater speed and size of the bicycle and rider means that, in general, bicycles are best accommodated as part of the roadway and not on sidewalks. Additional outside lane dimensions or widened shoulders perform this function most typically. For recreational pathways and other unique circumstances (e.g., certain bridges), pedestrian and bicycle movement is sometimes combined if adequate width can be provided and usage is not intense.

2. Types of Bicyclists

Bicyclists in New Jersey form a highly diverse population with varying needs and interests. These bicyclists range from advanced, highly experienced riders who ride frequently, often have special training, are confident in all traffic conditions and can negotiate with less operating space, to basic riders who are more casual in their riding practices and less comfortable riding in traffic, to young children who have not developed adequate judgement or received special training, enabling them to ride in the street unless under the strict control of a parent or other mature person.

Although advanced bicyclists represent only 20 percent of all bicyclists, they account for an estimated 80 percent of all bicycle trips. They are comfortable travelling long distances, are accustomed to using their bicycle (or bicycles) in a variety of environments, and will be the most likely to choose to bicycle for utilitarian purposes such as commuting or shopping.

Basic bicyclists are more casual riders, are less comfortable in traffic and have limited experience and skills. They form the largest group of bicyclists, but since they only occasionally cycle, basic bicyclists account for a smaller percentage of total bicycle trips. However, many casual riders may progress into becoming more confident and active riders as they gain experience.

Basic bicyclists will be more comfortable riding on lightly travelled neighborhood streets, on park or campus roads not used extensively by cars, on roadway shoulders along lightly travelled rural highways or on separate bicycle paths. Basic cyclists travel at slower speeds and for shorter distances compared to advanced cyclists, and frequently will wish to travel with other family members or friends. According to a Harris Poll reported in the National Bicycling and Walking Study, nearly half of all adults in the nation have bicycled at least once during the past year. Because of the urban character of New Jersey, it is reasonable to assume that an even higher percentage of adults would have bicycled at least once in the past year in New Jersey.

Young children form a separate group of bicycle riders. Children have minimal riding skills, little experience and limited physical capabilities. Their bicycles often may be of limited quality, limiting bicycling range. Children unfortunately also often have an inappropriately high level of confidence, or at least fearlessness, in their riding skill, and lack judgement regarding safe bicycling practices. Sidewalks in residential neighborhoods, school grounds and parks provide safe environments for young children to gain the bicycling skills they will need as they grow older. Because of their limited judgement capacity, children under the age of nine should not be allowed to ride on public streets unless actively supervised by a parent or other mature adult.

3. Types of Bicycle Facilities

Because of the great difference in skill levels among bicycle riders, different types of bicycle facilities are needed to serve riders in New Jersey. Advanced bicyclists are best served by bicycle compatible streets and highways which have been designed to accommodate shared use by bicycles and motor vehicles. Basic bicycle riders will be especially interested in riding on bikeways which are designated facilities that encourage bicycle use.

The difference between a compatible roadway and a designated roadway can be summarized as follows:



Compatible Roadways: Roads which have design features which allow a competent bicyclist to safely share the roadway with motor vehicles. Compatible roadway design guidelines differ based on traffic volumes, speeds and environmental setting. Because advanced bicyclists can be anticipated to use most of the roadways in the state, it is important that all roadways be designed to be compatible with bicycle use. See Figure 1.

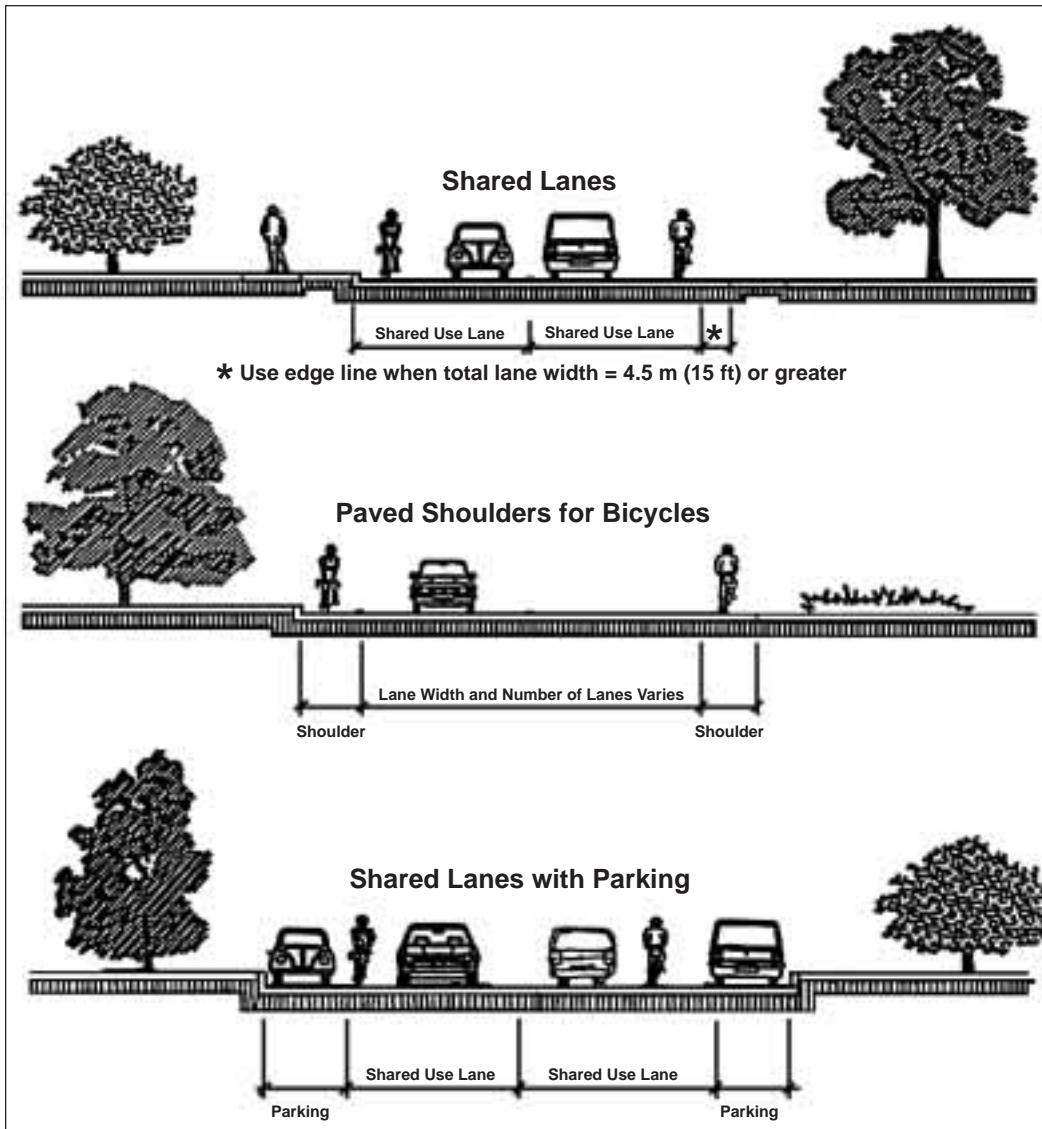


Figure 1
Types of Bicycle Compatible Roadways

Source: [Greenways Incorporated](#)

Designated Roadway: Roads on which bicycle use is anticipated and invited through the use of lane markings, signage, maps or tour guides.

Designated bicycle facilities provide greater safety for less experienced or less confident riders. Designated roadways are located where encouragement of bicycle use is desired, based on consideration of traffic conditions, pavement width and geometrics, and appropriateness and directness of the particular route. They are also often located in areas which offer especially pleasing rides such as in parks or through quiet subdivisions. Because basic riders will be more apt to be riding for pleasure, bikeways are often located in resort areas or in regional parks.



As indicated by these definitions, the designation of a roadway as a bikeway represents a proactive policy designed to encourage bicycling. Three categories of bikeways exist:

- Bicycle Routes** Roadways designated for bicycle use through the installation of directional and informational signage.
- Bicycle Lanes** A lane designated for exclusive or preferential use by bicycles through the application of pavement striping or markings and signage.
- Bicycle Paths** A bicycle facility separated from motorized vehicular traffic. A bicycle path may be located within a highway right-of-way or on an independent right-of-way. A bicycle path is not a sidewalk but may be designed to permit shared use with pedestrians.

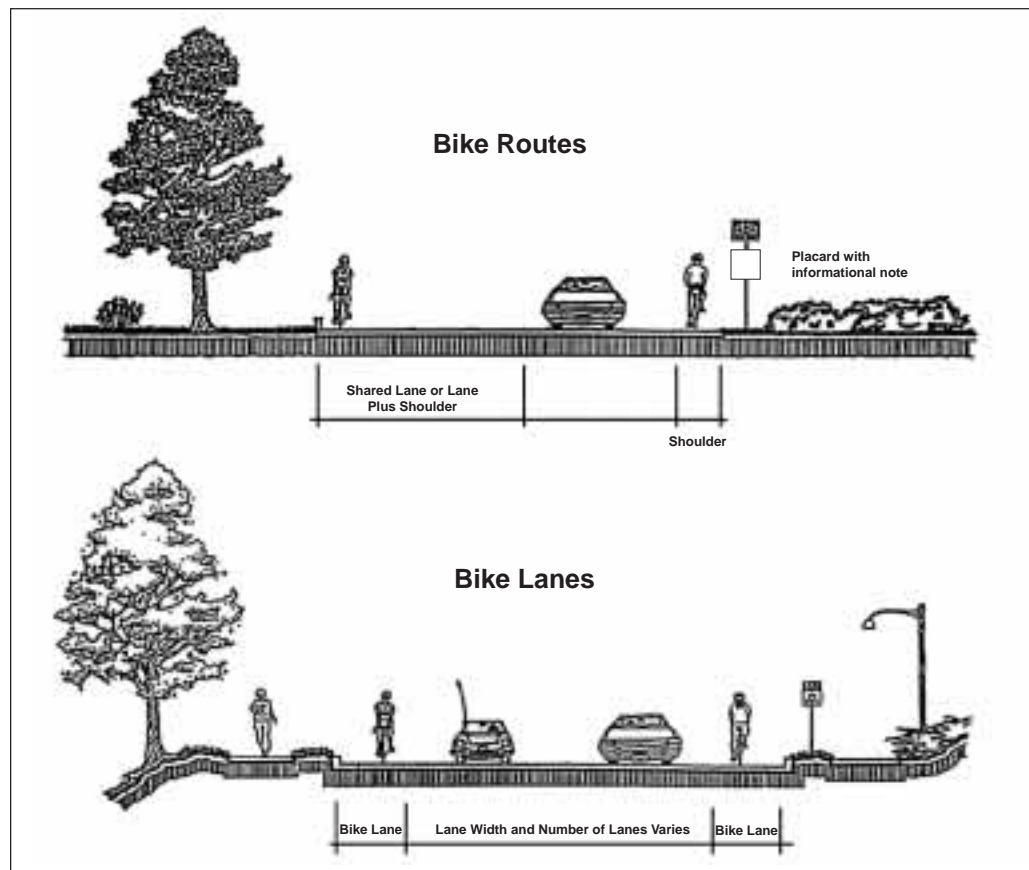
Figure 2 illustrates the difference between a bicycle route and a bicycle lane.

Chapter Two of this manual provides design guidance regarding how streets and highways should be designed to be made compatible with bicycle use. Chapter Three provides planning and design guidance regarding the designation of roadways as bikeways. Chapter Four provides similar guidance regarding the planning and design of bicycle paths.

Chapter Five describes other types of facilities which are needed to make bicycling a viable travel mode for a larger portion of New Jersey’s residents. Issues addressed in Chapter Five include bicycle parking and storage, integrating bicycle use with public transportation, and ancillary facilities to aid bicyclists such as shelters, rest areas and comfort stations.

Chapter Six discusses roadway operations and maintenance activities required to support bicycling.

Figure 2
Types of Bikeways
on Highways



Source: Greenways Incorporated



Chapter 2

Bicycle Compatible Roadway/Design Treatments

Planning and designing highways to permit the shared use of roadways by bicyclists and motorists usually does not require excessive changes, effort or cost. In most cases, existing roadway widths, space, and surface conditions may be sufficient to allow safe bicycling. Bicycle compatible roadways offer additional benefits to highway users such as:

- Greater offset to fixed objects
- Additional space for disabled vehicles
- Greater recovery zone for errant motorists
- Additional space for bus pull-overs at transit stops
- Better stability of roadway pavement structure
- Additional gutter drainage capacity during rainstorms
- Space for pedestrian travel, especially during snowstorms
- Greater area for temporary snow storage
- Reduction or elimination of drop-off at edge of pavement

Because bicycle compatible roadway improvements are intended for the shared use of all highway users and are not specifically designated for bicycle use, no additional exposure to liability is incurred by the highway agency. A well designed bicycle compatible roadway should reduce accidents and exposure to liability by allowing a safer environment for all highway users.

On the other hand, failure to take reasonable measures to assure that a highway is compatible with bicycle use, even though adequate measures could have been installed, increases an agency's potential exposure to liability in the event of a subsequent accident. The guidelines presented in this chapter thus represent a minimum level of improvement which should be applied during the construction or reconstruction of all roadways in the state.

Bicycle compatible facilities provide access to the transportation system for bicycle traffic and enhance bicycle safety. Most bicycle accidents do not involve crashes with motor vehicles. Bicyclists instead lose control of their vehicles and crash. Roadways not designed or properly maintained to address the needs of bicycle traffic can contribute to these accidents. Properly designed and maintained roadways mitigate bicycle safety problems and lessen the chance of these accidents.

The more common bicycle accidents which do involve motor vehicles, such as vehicles turning or merging into the path of the bicyclist, motorist failure to yield to bicycle traffic, or bicyclist failure to yield, can also be reduced through proper roadway design which accommodates bicycle use.



1. Pavement Width

At a minimum, all highway projects shall provide sufficient width of smoothly paved surface to permit the shared use of the roadway by bicycles and motor vehicles.

Table 1 is based on the FHWA manual, Selecting Roadway Design Treatments to Accommodate Bicycles, as well as previous experience in New Jersey and other states. Pavement widths represent minimum design treatments for accommodating bicycle traffic. These widths are based on providing sufficient pavement for shared use by bicycle and motor vehicle traffic and should be used on highway projects as minimum guidelines for bicycle compatible roadways.

Considerations in the selection of pavement width include traffic volume, speed, sight distance, number of trucks and larger vehicles, and grade. The dimensions given in Table 1 for shared lanes are exclusive of the added width for parking, which is assumed to be 2.4 meters (8 feet). On shared lanes with parking, the lane width can be reduced if parking occurs only intermittently. On travel lanes where curbs are present, an additional 0.3 meters (1 foot) of width is necessary.

On very low volume roadways, having an AADT of less than 1200 vehicles per day, even relatively fast highways pose little risk for bicyclists since there will be high probability that an overtaking car will be able to widely pass a bicyclist. When an overtaking car is unable to immediately pass a bicyclist, a small delay for the motorist will be acceptable. These types of roadways are enjoyed by both bicyclists and motorists, and widening of these roads is not usually recommended. Cost of providing widening of these roads can seldom be justified based on either capacity or safety.

Similarly, moderately low volume roadways having an AADT between 1,200 and 2,000 generally are compatible for bicycle use and will have little need for widening. However, since there is a higher risk of two opposing cars meeting at the same time, and as motorists must pass a bicyclist, providing some room at the outside of the roadway is desirable on faster speed roadways. On low speed roadways, motorists should be willing to accept some minimal delay.

With AADT greater than 2,000, the probability becomes substantially greater that a vehicle overtaking a bicycle may also meet another on-coming vehicle. As a result, on these roads, some room at the edge of the roadway should be provided for bicyclists. At low speeds, little separation is needed for both a bicyclist and a motorist to feel comfortable during a passing event. With higher speeds, more room is needed.

At volumes greater than 10,000 AADT, vehicle traffic in the curb lane becomes almost continuous, especially during peak periods. As a result bicyclists on these roads require separate space to comfortably ride. In addition, improvements to the roadside border and the shoulder area will be especially valuable for motorists as well.

NJDOT guidelines for highways recommend that a full 2.4 meter (8 foot) paved shoulder be provided for all state highways. On highways having an AADT greater than 20,000 vehicles per day, or on which more than 5 percent of the traffic volume consists of trucks, every effort should be made to provide such a shoulder, both for the benefit of bicyclists and to enhance the safety of motor vehicle movement.



Table 1

Bicycle Compatible Roadway Pavement Widths

**Condition I
AADT 1200* -2000**

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	SL 3.6m (12 ft.)	SL 3.3m (11 ft.)	SL 3.0m (10 ft.)
50 km/h-65 km/h (31-40 mph)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)	SL 3.6m (12 ft.)
65 km/h-80 km/h (41-50 mph)	SL 4.5m (15 ft.)	SL 4.5m (15 ft.)	SH 0.9m (3 ft.)
>80 km/h (50 mph)	NA	SH 1.2m (4 ft.)	SH 1.2m (4 ft.)

* For volumes less than 1200 a shared lane is acceptable.

KEY: SH=shoulder SL=shared lane

**Condition II
AADT 2000-10,000**

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	SL 4.2m (14 ft.)	SL 3.6m (12 ft.)	SL 3.6m (12 ft.)
50 km/h-65 km/h (31-40 mph)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)	SH 0.9m (3 ft.)
65 km/h-80 km/h (41-50 mph)	SL 4.5m (15 ft.)	SL 4.5m (15 ft.)	SH 1.2m (4 ft.)
>80 km/h (50 mph)	NA	SH 1.8m (6 ft.)	SH 1.8m (6 ft.)

**Condition III
AADT over 10,000 or Trucks over 5%**

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)
50 km/h-65 km/h (31-40 mph)	SL 4.2m (14 ft.)	SH 1.2m (4 ft.)	SH 1.2m (4 ft.)
65 km/h-80 km/h (41-50 mph)	SL 4.5m (15 ft.)	SH 1.8m (6 ft.)	SH 1.8m (6 ft.)
>80 km/h (50 mph)	NA	SH 1.8m (6 ft.)	SH 1.8m (6 ft.)

NOTE: NJDOT minimum shoulder width of 2.4 meters (8 feet) should be provided wherever possible on roadways having an AADT greater than 10,000 vehicles.



a. Conditions Where Additional Space is Warranted

- **Sight Distance** Roadways with adequate decision sight distance will allow a motorist to see, recognize, decide on the proper maneuver, and initiate actions to avoid a bicyclist. Adequate decision sight distance is most important on high speed highways and narrow roadways where a motorist would have to maneuver out of the travel lane to pass a bicyclist.

The pavement widths given in Table 1 are based on the assumption that adequate sight distance is available. In situations where there is not adequate sight distance, additional widths may be necessary.

- **Truck Traffic** Roadways with high volumes of trucks and large vehicles, such as recreational vehicles, need additional space to minimize bicycle/motorist conflicts on roadways. Additional width will allow overtaking of bicycles by trucks with less maneuvering. Additionally, overtaking by a truck will exert less lateral force from truck drafts, and provide greater sight distance for following vehicles.

Although there is no established threshold, additional space should be considered when truck volumes exceed 5 percent of the traffic mix, or on roadways that service campgrounds or tourist travel. Where truck volumes exceed 15 percent of the total traffic mix, widths shown in the table should be increased by a minimum of 0.3 meters (1 foot).

- **Steep Grades** Steep grades influence overtaking of bicyclists by motorists. A bicyclist climbing a steep grade is often unsteady and should be afforded additional width. Also, the difference in speed of a slow, climbing bicyclist and motorist results in less time for a vehicle to maneuver around a bicyclist. The slowing of a motor vehicle on a steep grade to pass a bicyclist can result in diminished highway level of service.

A bicyclist descending a steep grade may also need more width. A high speed bicyclist will tend to move into the travel lane to avoid roadside hazards. Where descending grades exceed 6 percent, and bicycle traffic is anticipated, signing should be placed along the descending lane to advise bicyclists and alert motorists of bicyclists in the travel lane (see Section 5 - Traffic Control Devices).

Additional space should be considered on the ascending lane when the grade exceeds 3 percent. Where the grade exceeds 5 percent, a minimum of a 1.5 meter (5 foot) wide shoulder or 4.8 meter (16 foot) wide curb lane in urban conditions is desirable to afford safe shared use with minimal impact on level of service.

b. Treatment for Unavoidable Obstacles

Short sections of roadways with unavoidable obstacles that result in inadequate width are acceptable on bicycle compatible roadways if mitigated with signing or striping. Typical examples include bridges with narrow widths and sections of roadway that cannot be widened without removing significant street trees. These conditions preferably should not exist for a distance greater than 0.4 kilometers (one quarter mile) or on high speed highways. Zebra warning striping should be installed to shift traffic away from the obstacle. See Figure 3. Figure 4, Bicycle Compatible Hazard Marking, is another option when an obstacle cannot be removed. In this case pavement markings alert the bicyclist that the travel lane width will narrow. In both situations, where bicycle traffic is anticipated, a share the road sign should be used to supplement any striping. See Figure 5 - Share the Road Sign. On longer sections of roadway, edge striping should be added to narrow the travel lane and apportion pavement space for a partial shoulder.



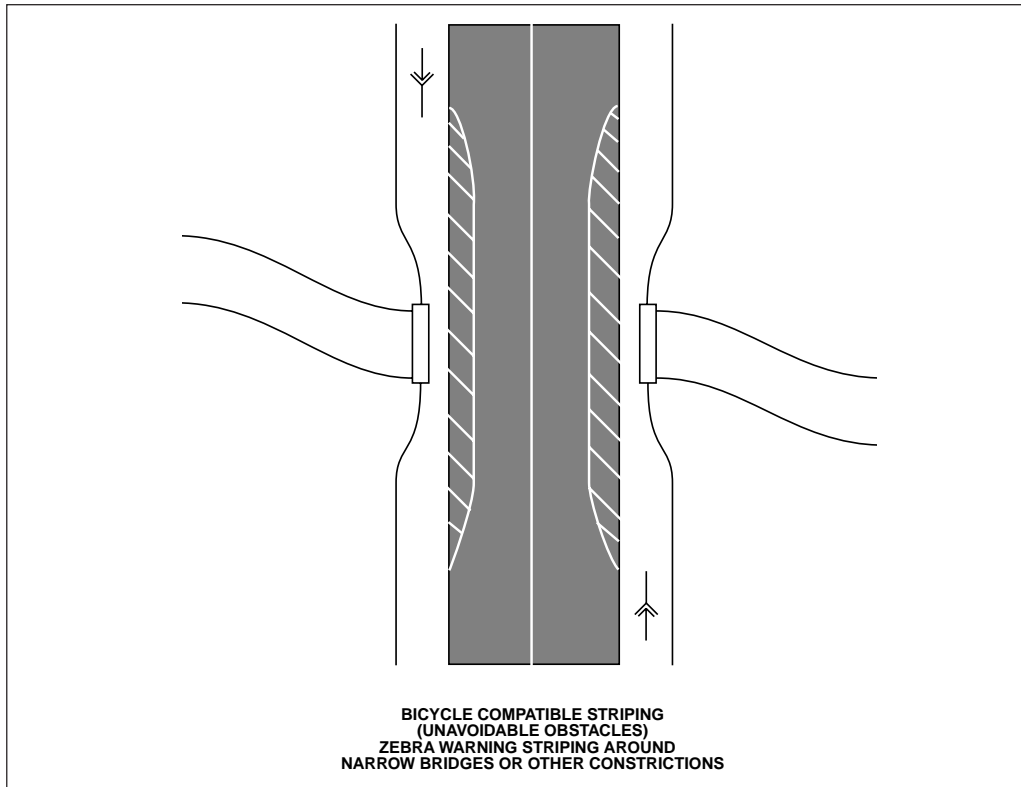


Figure 3
Zebra Warning Striping

Source: Adapted from *NJDOT Bicycle Compatible Roadways*, NJDOT, 1982

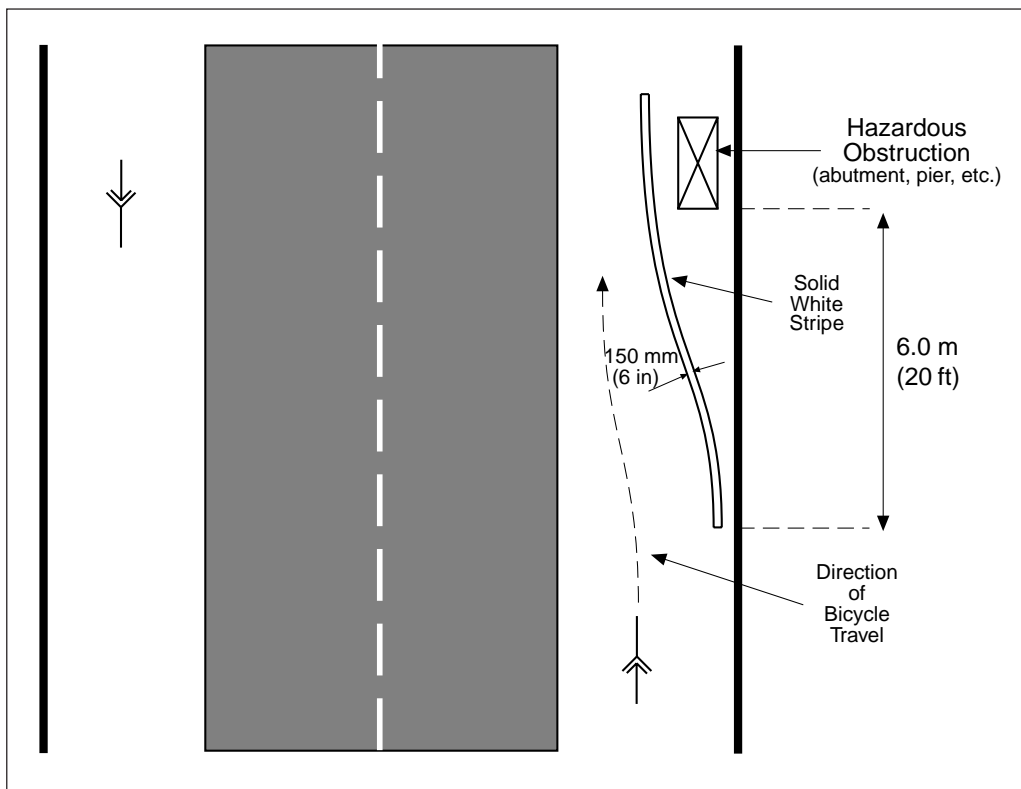


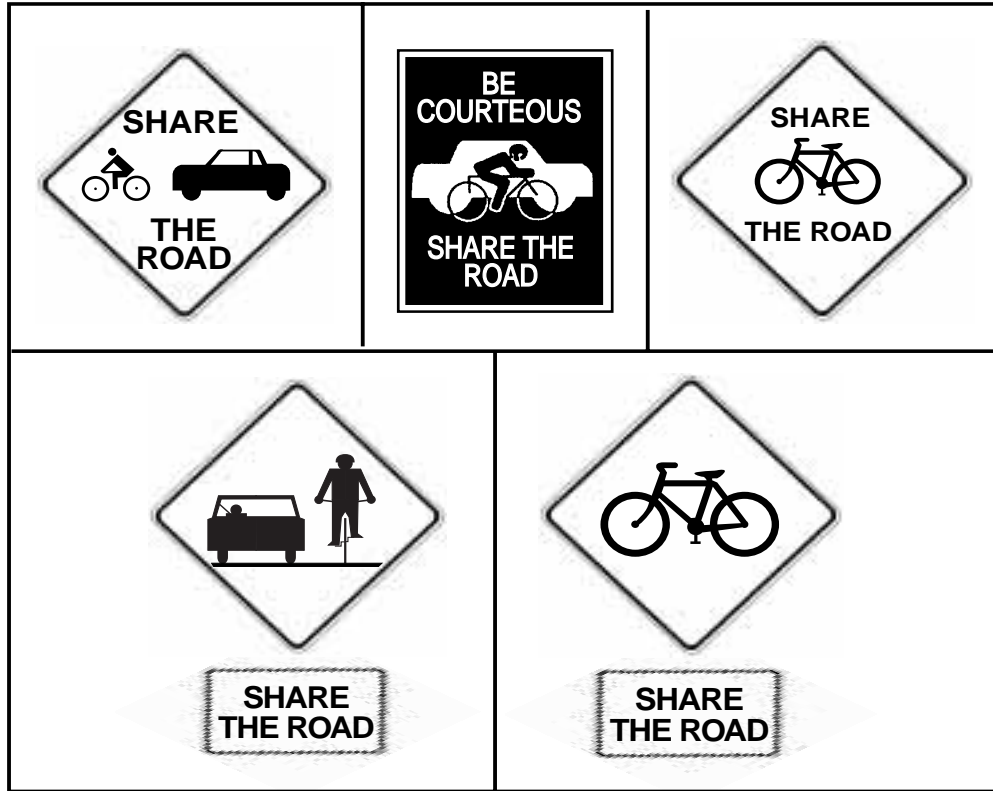
Figure 4
Bicycle Compatible Hazard Marking

Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982



Figure 5

Share the Road Sign



Source: Bicycle Federation of America

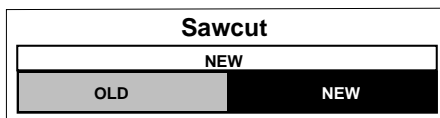
NOTE: These represent examples of signs used by others. NJDOT is in the process of adopting an approved sign.

2. Pavement Design

With their narrow, high pressure tires, and lack of suspension, bicycles require a smooth riding surface without obstructions or pavement irregularities. On roadways with rough surfaces and hazards, a bicyclist will ride as close to the smooth wheel track in the travel lane as possible. These conditions will affect the level of service of the roadway.

a. Pavement Surface

Where shoulders are employed to provide the pavement width necessary to accommodate bicycle traffic, pavement surface should be as smooth as the adjacent travel lane. Bituminous concrete is preferred over concrete where shoulders are employed. The outside pavement area (where bicycle traffic normally operates) should be finished free of longitudinal seams. On portland cement concrete, pavement transverse expansion joints (if necessary) should be sawcut to ensure a smooth ride.



Source: NJDOT

In areas where bituminous shoulders are added to existing pavement, or pavement is widened, pavement should be sawcut to produce a tight longitudinal joint. The pavement section at the sawcut should match the existing section to minimize wear and opening of the joint. See Figure 6.

b. Rumble Strips

Rumble strips provide positive guidance for motorists on freeways. However, they present a difficult obstruction and potential hazard to bicyclists. Use of rumble strips should be avoided on all land service roadways.



c. Raised Roadway Reflectors

Raised roadway reflectors provide substantial benefits in areas of poor visibility. However, when used on the edge line they are a surface irregularity which can be hazardous to bicycle traffic. Therefore, raised reflectors should only be used along interior lane lines or center lines, not edge lines.

d. Utilities

Bicycle traffic is more sensitive to pavement irregularities than is motor vehicle traffic. During construction, appurtenances should not be left projecting above the pavement surface. Repeated resurfacings without adjusting the utility cover neck flange or drainage grate frames results in the covers being sunken below the pavement surface, a hazardous condition to bicycle traffic which bicyclists refer to as “black holes.” Therefore, utility covers and drainage grates should be adjusted to fit flush with the roadway surface in all new construction, reconstruction and resurfacing projects.

3. Bridges

Bridges serve an important function by providing bicycle access across barriers. However, some features found in bridges can be unsuitable where bicyclists are to be accommodated. The most common of these are curb-to-curb widths that are narrower than the approach roadways (especially where combined with relatively steep grades), open grated metal deck (found on many movable spans), low railings or parapets and certain types of expansion joints that can cause steering difficulties.

Sidewalks are generally not acceptable for bicycling. However, in a few limited situations, such as on long or narrow bridges, designation of the sidewalk as an alternate facility can be beneficial provided that curb cuts and appropriate signing are provided.

Bridge railing or barrier curb parapets should have railings at least 1.4 meters (4.5 feet) high as shown in Figure 7.

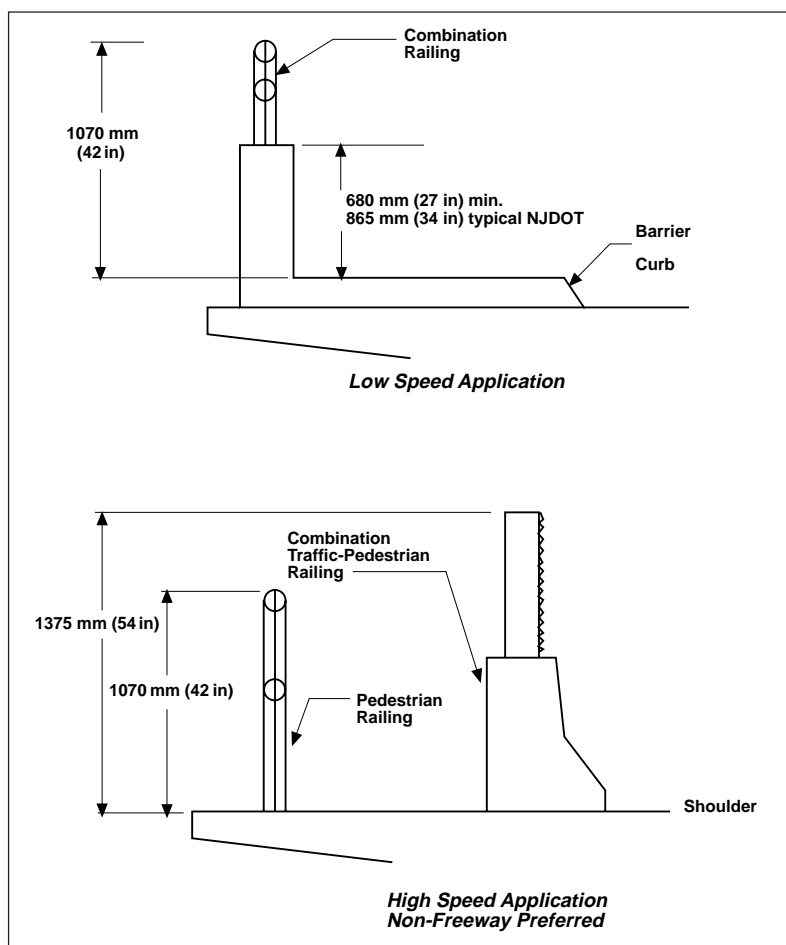


Figure 7

Bicycle Accommodations on Bridges (Bridge Railing or Barrier Curb Parapet Treatments)

Source: NJDOT



4. Drainage Facilities

Stormwater drainage facilities and structures are usually located along the edge of roadway where they often present conflicts with bicyclists. Careful consideration should be given to the location and design of drainage facilities on bicycle compatible roadways.

a. Drainage Inlets and Grates

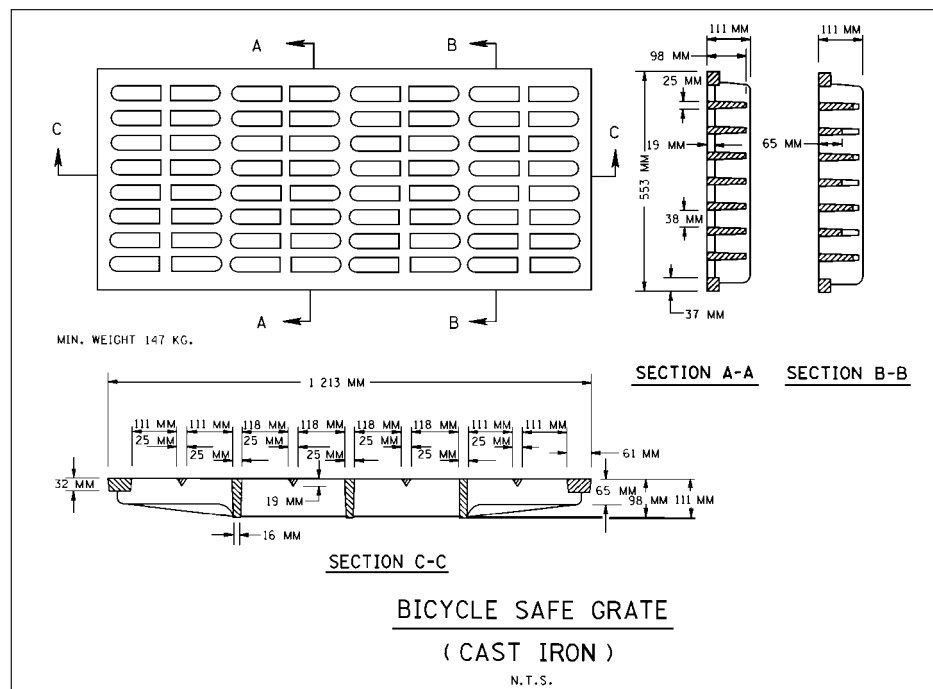
All drainage grate inlets pose some hazard to bicycle traffic. The greatest hazard comes from stream flow drainage grates which can trap the front wheel of a bicycle and cause the cyclist to lose steering control or have the narrow bicycle wheels drop into the grate. A lesser hazard is caused by bicyclists swerving into the lane of traffic to avoid any type of grate or cover.

A “bicycle safe” drainage grate with acceptable hydraulic characteristics has been developed by NJDOT’s drainage section (Figure 8). This inlet grate should be used in all normal applications and should be installed flush with the final pavement. Where additional drainage inlet capacity is required because of excessive gutter flow or grade (greater than 2 percent), double inlets should be considered. Depressed grates and stream flow grates should not be used except in unique or unusual situations which require its use and only outside the lane sharing area. Where necessary, depressed grates should only be installed in accordance with the NJDOT Roadway Design Manual on shoulders 1.8 meters (6 feet) wide or greater. Where projects offer the possibility for replacement of stream flow grates located in the lane sharing area, these grates should be replaced with the “bicycle safe” grate.

When roads or intersections are widened, new bicycle safe drainage grates should be installed at a proper location at the outside of the roadway, and existing grates and inlet boxes should be properly retired and removed, and the roadway reconstructed. Drainage grate extensions, the installation of steel or iron cover plates or other “quick fix” methods which allow for the retention of the subsurface drain inlet are unacceptable measures since they will create a safety hazard in the portion of the roadway where bicyclists operate.

Figure 8

NJDOT “Bicycle Safe”
Drainage Grate



Source: Standard Roadway Construction Details, NJDOT



b. Manholes and Covers

Manholes and covers should be located outside of the lane sharing area wherever possible. Utility fixtures located within the lane sharing area or any travel lane used by bicycle traffic should be eliminated or relocated. Where these fixtures cannot be avoided the pavement surface should be made flush with the particular facility.

c. Combination Curb and Gutter

These types of curbs greatly reduce space available for bicyclists. They should only be used on low volume streets or where grades dictate special drainage conditions. The width of the gutter pan should not be used when calculating the width of pavement necessary for shared use by bicyclists. On steep grades, the gutter should be set back an additional 0.3 meters (one foot) to allow space to avoid high speed crashes caused by the longitudinal joint between the gutter pan and pavement. In general, the combination curb and gutter is not recommended. Where it is used, pavement width should be calculated by adding 0.3 meters (one foot) from the curbed gutter.

5. Traffic Control Devices

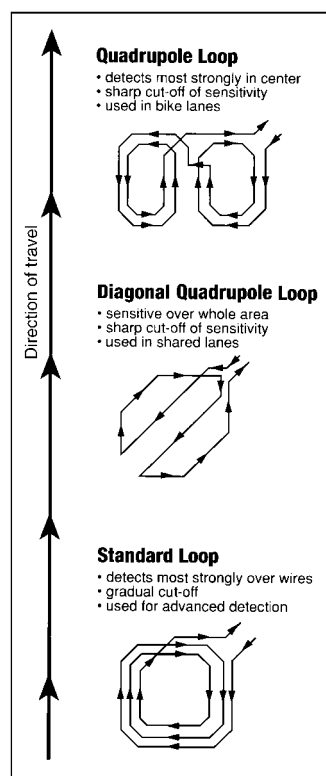
As legitimate users of New Jersey's roadways, bicyclists are subject to essentially the same rights and responsibilities as motorists. In order for bicyclists to properly obey traffic control devices, those devices must be selected and installed to take into account their needs. All traffic control devices should be placed so they can be observed by bicyclists who are properly positioned on the road. This includes programmed visibility signal heads.

a. Traffic Signals and Detectors

Traffic-actuated signals should accommodate bicycle traffic. Detectors for traffic-activated signals should be sensitive to bicycles and should be located in the bicyclist's expected path. Examples of successful installation of bicycle sensitive signal detectors, are shown in Figure 9.

Stenciling should direct cyclists to the point where their bicycle will set-off detectors.

For the sake of riders who have vehicles with insufficient amounts of iron to be detected, and to add redundancy in the event of failure of the bicycle sensitive loop detectors, pedestrian push buttons should be provided at all signalized intersections and mounted in a location which permits their activation by a bicyclist without dismounting. Where left turn lanes are provided and only protected left turns are allowed, bicycle sensitive loop detectors should be installed in the left turn lane or a pedestrian style push button should be provided accessible to a bicyclist in the turn lane to permit activation of the left turn phase.



Source: City of San Diego Traffic Signal Bicycle Detection Study, 1985

Figure 9

Recommended Loop Types for Bicycle Detection



Where moderate or heavy volumes of bicycle traffic exist or are anticipated, bicycles should be considered in the timing of the traffic signal cycle as well as in the selection and placement of the traffic detector device. In such cases short clearance intervals should not be used where bicyclists must cross multi-lane streets. According to the 1991 AASHTO *Guide for the Development of Bicycle Facilities*, a bicycle speed of 16 km/h (10 mph) and a perception/ reaction time of 2.5 seconds can be used to check the clearance interval. Where necessary, an all-red clearance interval can be used.

b. Signing

Bicycle compatible roadways usually do not require regulatory, guide or informational signing in excess of that necessary for motorists, i.e., exclusively for bicyclists. In certain situations, however, additional signing may be needed to advise both motorists and bicyclists of the shared use of the roadway, including travel lane.

Share the Road: This sign (see Figure 5) is intended for use on roadways under the following conditions:

- Shared lanes (especially if lane widths do not comply with Table 1) with relatively high posted travel speeds of 65 km/h (40 mph) or greater.
- Shared lanes (conforming with Table 1) in areas of limited sight distance.
- Situations where bicycle compatible shared lanes or demarcated shoulders or marked bike lanes are dropped or end, and bicycle and motor vehicle traffic must begin to share the travel lane.
- Other situations where it is determined advisable to alert motorists of the likely presence of bicycle traffic, and to alert all traffic of the need to share available roadway space.

Allowed use of Full Lane: This sign (Figure 10) is intended to advise motorists and bicyclists that bicycle traffic may be expected to move to the center of the travel lane in order to increase its visibility or avoid roadway obstacles in certain situations. These conditions include:

Figure 10

“Allowed Use of Full Lane” Sign



Source: *Bicycle Blueprint*, 1993

- Steep descending grades where bicycle traffic may be operating at higher speeds and requires additional maneuvering room to shy away from pavement edge conditions.
- Steep ascending grades, especially where there is no paved shoulder or the shared lane is not adequately wide; bicycle traffic may require additional maneuvering room to maintain balance at slow operating speeds.
- High volume urban conditions especially those with travel lanes less than the recommended width for lane sharing.

Note: Though not formally adopted by NJDOT, this sign has been used to advise motorists that under certain conditions bicycle traffic can be expected to operate in the center of the travel lane, and is included here to highlight this concept of bicyclists “taking the lane.”



6. Intersections and Driveways

Sand, gravel and other debris in the bicyclist’s path present a potential hazard. In order to minimize the possibility of debris from being drawn onto the pavement surface from unpaved intersecting streets and driveways, during new construction, reconstruction and resurfacings, all unimproved intersecting streets and driveways should be paved back to the right-of-way line or a distance of 3.0 meters (10 feet) (Figure 11). Similarly, where curb cuts permit access to roadways from abutting unpaved parking lots, a paved apron should be paved back to the right-of-way line or 3.0 meters (10 feet) from the curb line. These practices will lessen the need for maintenance debris removal. The placement of the paved back area or apron should be the responsibility of those requesting permits for access via curb cuts from driveways and parking lots onto the highway system.

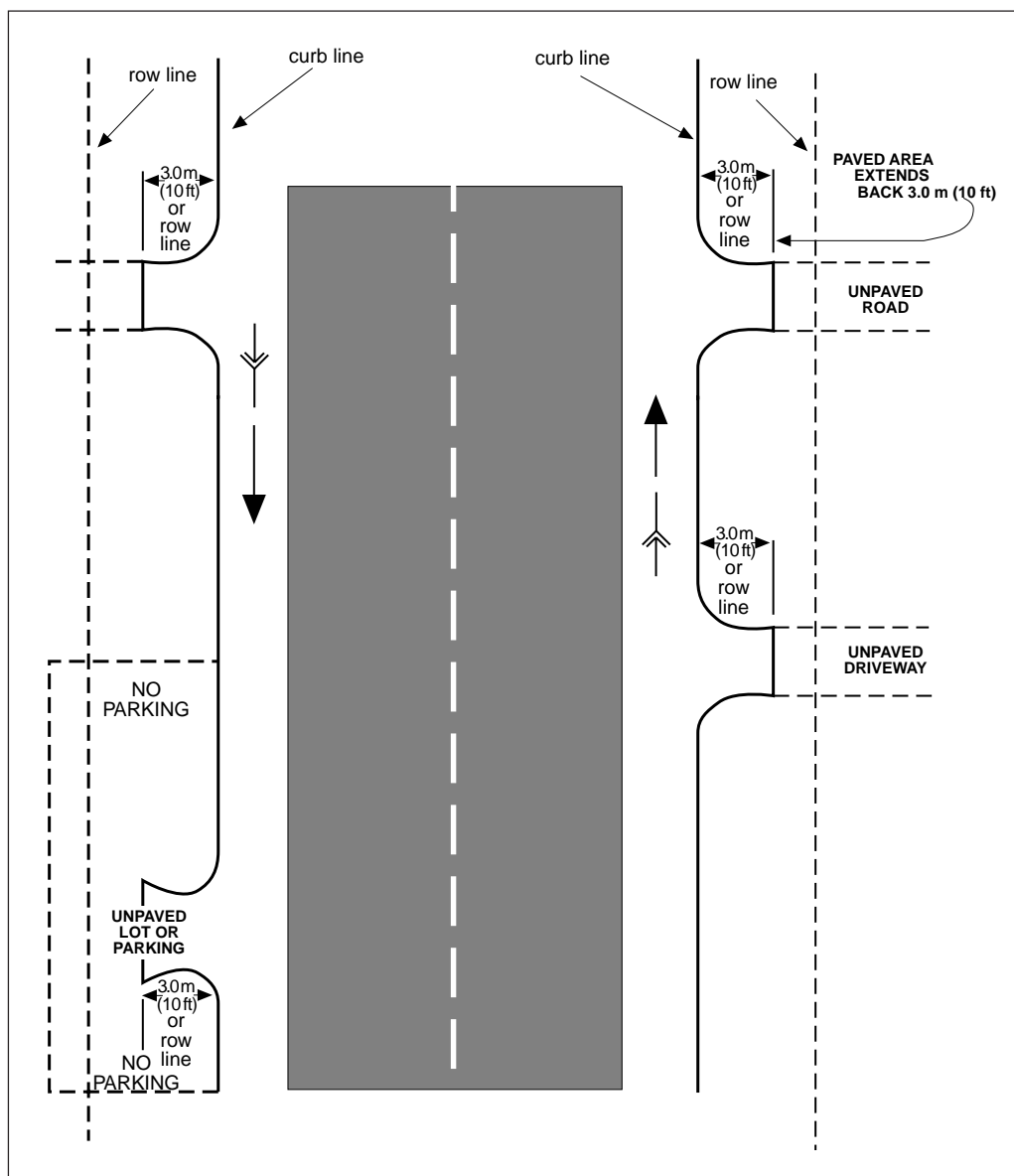


Figure 11
Bicycle Compatible Intersection with Unpaved Streets and Driveways

Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982



High speed, wide radius intersection designs may enhance safety for motor vehicles by minimizing speed differentials between entering and exiting vehicles and through vehicles. However, these designs exacerbate speed differential problems faced by bicyclists travelling along the right side of a highway and encourage drivers to fail to yield the right-of-way to bicyclists. As a result, where wide radius curb returns are being considered, specific measures should be employed to ensure that the movement of bicyclists along the highway will be visible to motorists and to provide bicyclists with a safe area to operate. One method to accomplish this would be to stripe (dash) a bicycle lane through the intersection area. In this event, share the road signs should be posted in advance of the intersection to alert existing traffic, and yield to bicyclist signs should be posted on the approach to the intersection. In general, however, curb radii should be limited to distances which communicate to the motorist that he or she must yield the right-of-way to bicyclists traveling along the roadway or to pedestrians walking along the sidewalk or roadway margin.

7. Roadside Obstacles

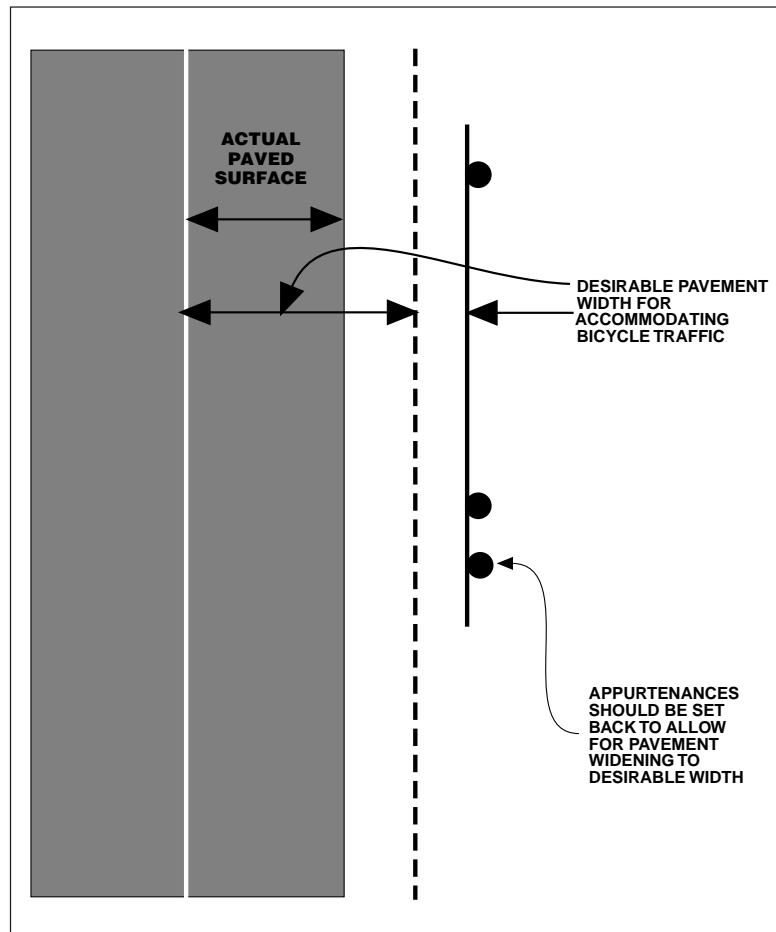
In order to make certain that as much of the paved surface as possible is usable by bicycle traffic, sign posts, light standards, utility poles, and other similar appurtenances should be set back 0.3 meters (1 foot) minimum “shy distance” from the curbing or pavement edge with exceptions for guide rail placement in certain instances. Additional separation distance to lateral obstructions is desirable.

Where there is currently insufficient width of paved surface to accommodate bicycle traffic, any placement of these appurtenances, should, where feasible, be set back far enough to allow room for future projects (widening, resurfacings) to bring pavement width into conformance with these guidelines (Figure 12).

Vertical clearance to obstructions should be a minimum of 2.6 meters (8 feet, 6 inches).

Figure 12

Bicycle Compatible Placement of Appurtenances for Future Projects



Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982



8. Railroad Crossings

As with other surface irregularities, railroad grade crossings are a potential hazard to bicycle traffic. To minimize this hazard, railroad grade crossings should, ideally, be at a right angle to the rails. This minimizes the possibility of a bicyclist's wheels being trapped in the rail flangeway, causing loss of control. Where this is not feasible, the shoulder (or wide outside lane) should be widened, or "blistered out" to permit bicyclists to cross at right angles (Figure 13).

It is also important that the railroad grade crossing be as smooth as possible. Pavement surface adjacent to the rail should be at the same elevation as the rail. Pavement should be maintained so that ridge build-up does not occur next to the rails.

Other options to provide a smooth grade crossing include: removal of abandoned tracks; use of compressible flangeway fillers, timber plank crossings, or rubber grade crossing systems.

These improvements should be included in any project which offers the opportunity to do so.

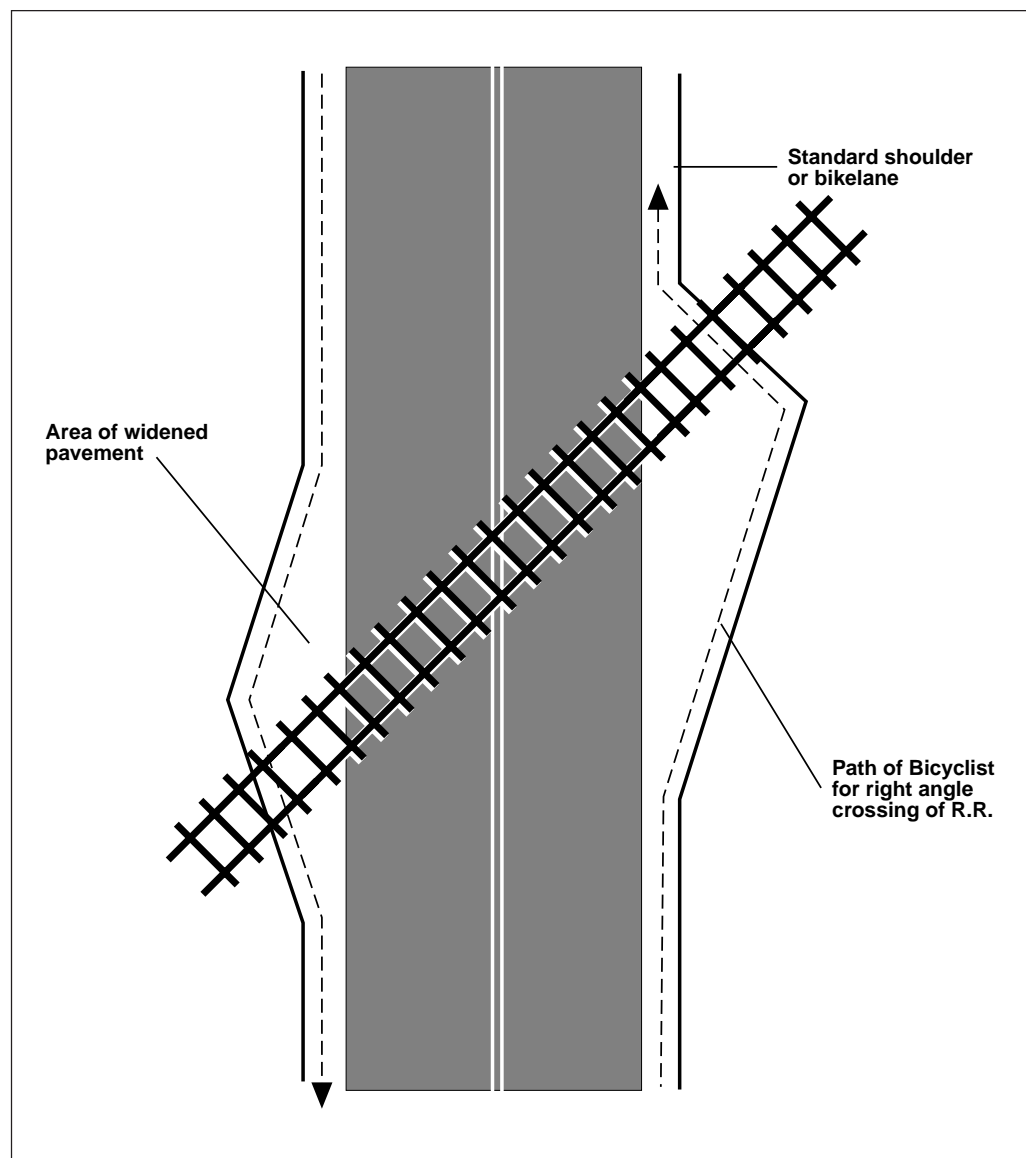


Figure 13

Surface Widening for Bicycles at Non-Perpendicular Railroad Crossings

Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982

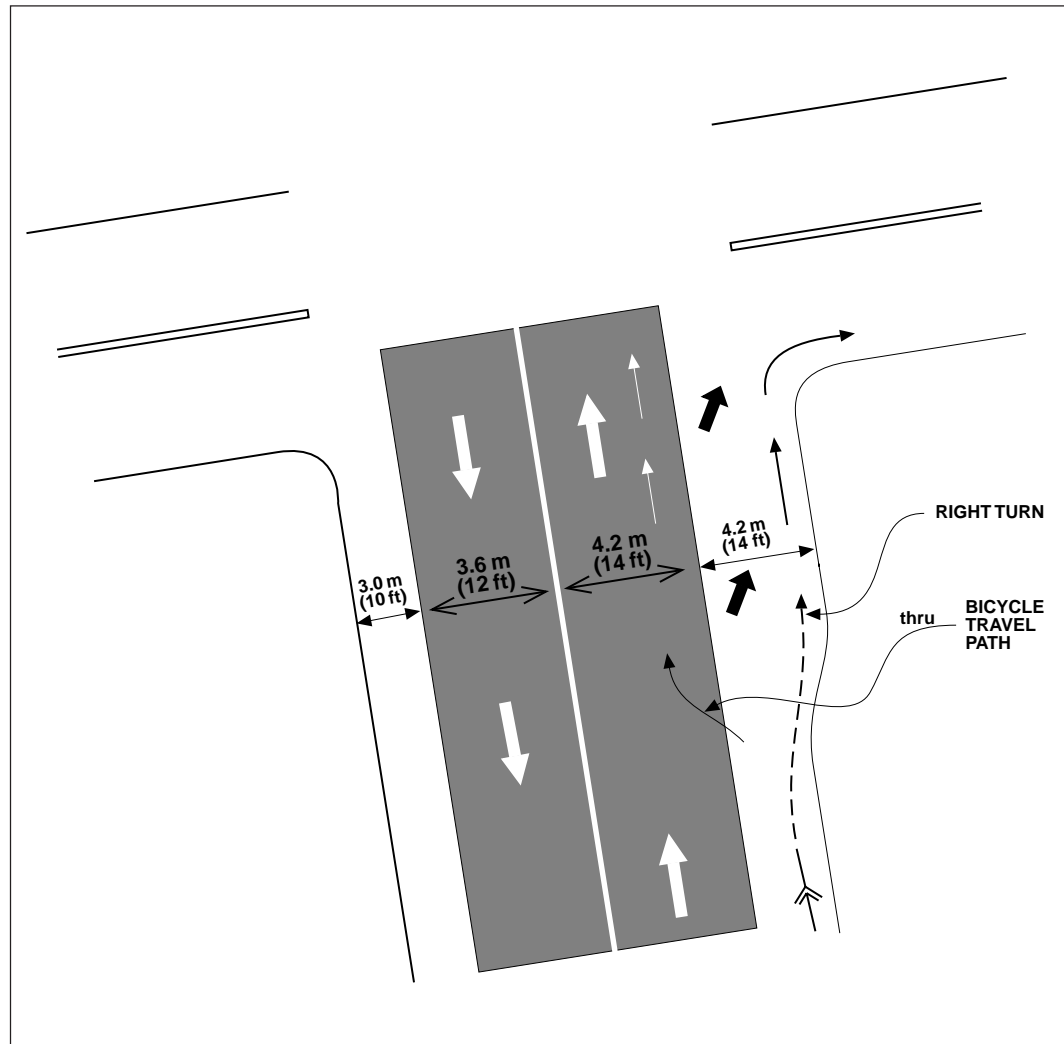


9. TSM Type Improvements

Transportation Systems Management (TSM) improvements are minor roadway improvements which enhance motor vehicle flow and capacity. They include intersection improvements, channelization, the addition of auxiliary lanes, turning lanes and climbing lanes. TSM improvements must consider the needs of bicycle traffic in their design or they may seriously degrade the ability of the roadway to safely accommodate bicyclists. Designs should provide for bicycle compatible lanes or paved shoulders. Generally, this requires that the outside most through lane and (if provided) turning lane be 4.2 meters (14 feet) wide (Figure 14). Auxiliary or climbing lanes should conform with Table 1 by either providing an adjacent paved shoulder or a width of at least 4.5 meters (15 feet) (Figure 15). Where shared lanes and shoulders are not provided, it must be assumed that bicycle traffic will take the lane.

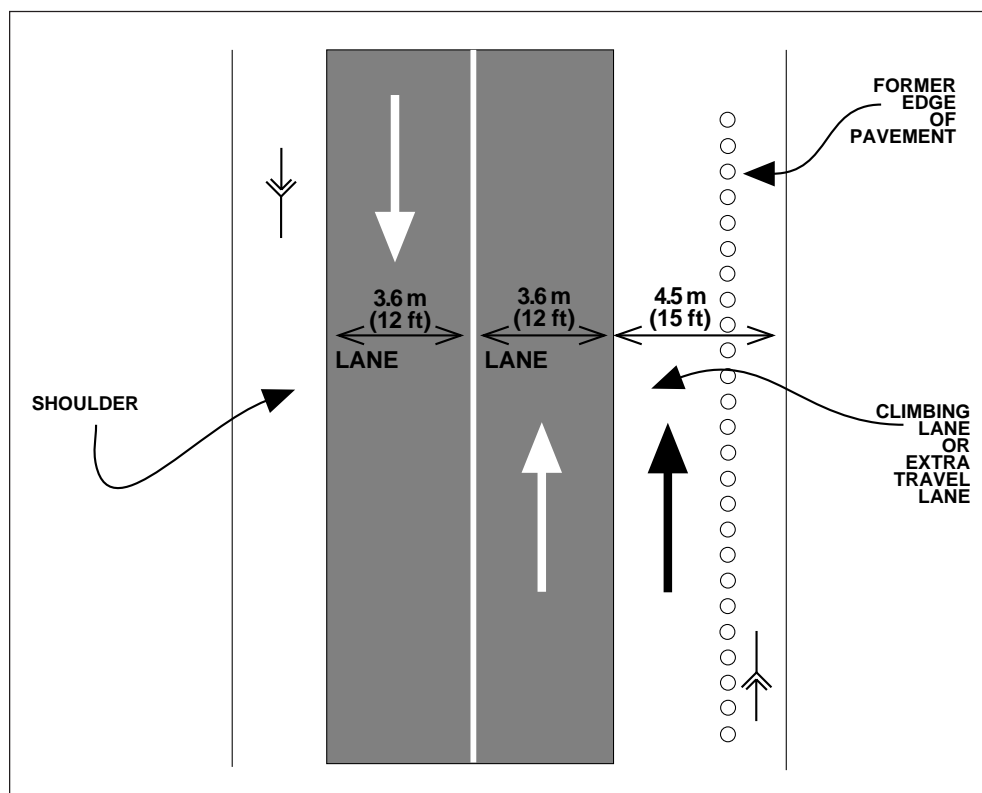
Figure 14

Bicycle Compatible
TSM Shoulder
Converted to
Turning Lane



Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982



**Figure 15**

Bicycle Compatible TSM Shoulder Converted to Climbing Lane or Extra Travel Lane

Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982

10. Marginal Improvements/Retrofitting Existing Highways

There may be instances or locations where it is not feasible to fully implement guidelines pertaining to the provision of adequate pavement space for shared use due to environmental constraints or unavoidable obstacles. In such cases, warning signs and/or pavement striping must be employed to alert bicyclists and motorists of the obstruction, alert motorists and bicyclists of the need to share available pavement space, identify alternate routes (if they exist), or otherwise mitigate the obstruction.

On stretches of roadway where it is not possible to provide recommended shoulder or lane widths to accommodate shared use, conditions for bicycle traffic can be improved by:

- striping wider outside lanes and narrower interior lanes (Figure 16);
- providing a limited paved shoulder area by striping a narrow travel lane. This tends to slow motor vehicle operating speeds and establish a space (with attendant psychological benefits) for bicycle operation.

Where narrow bridges create a constriction, “move over” zebra striping should be used to shift traffic away from the parapet and provide space for bicycle traffic (Figure 3).

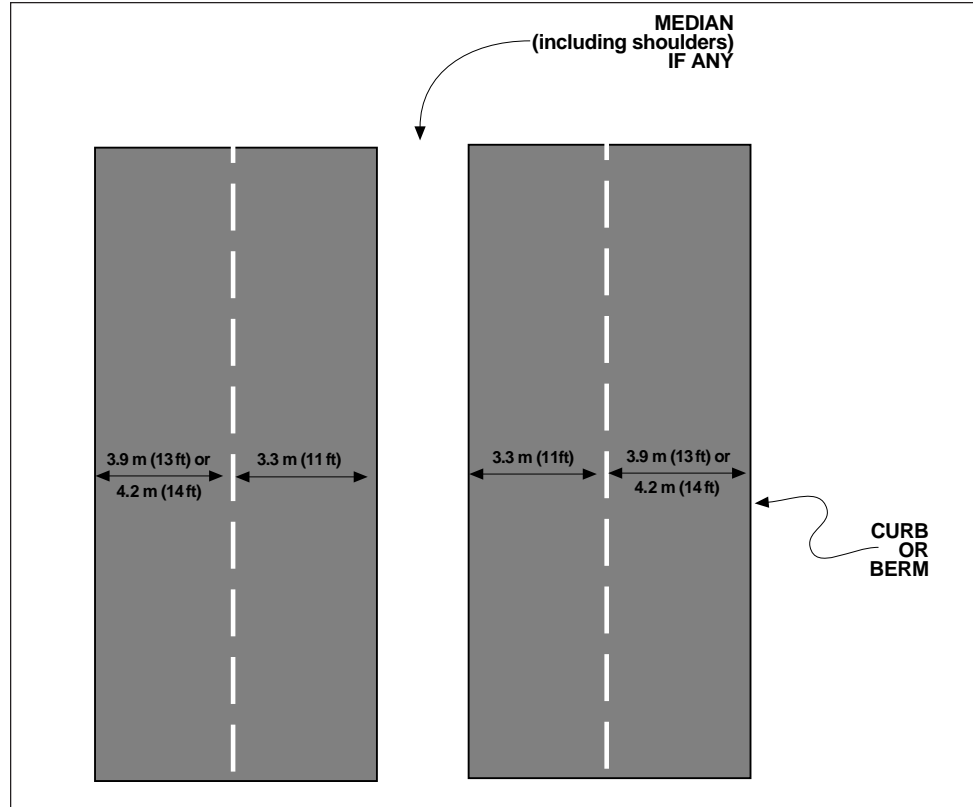
Other possible strategies, to be employed as appropriate, are shown in Figure 17. These include:

- elimination of parking or restricting it to one side of the roadway.
- reduction of travel lanes from two in each direction to one in each direction plus center turn lane and shoulders.
- reduction of the number of travel lanes in each direction, and the inclusion or re-establishment of paved shoulders.



Figure 16

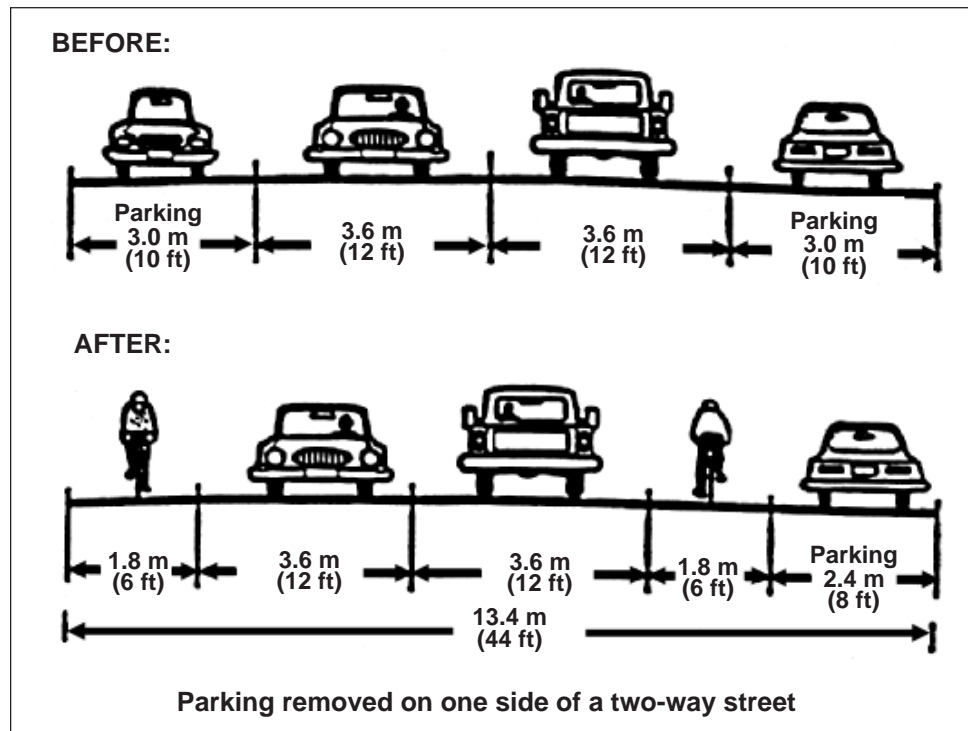
Bicycle Compatible Restriping (Multi-Lane Curbed Section Roadway) (No Shoulder)



Source: Adapted from *Bicycle Compatible Roadways*, NJDOT, 1982

Figure 17

Retrofitting Roadways to Include Bicycle Lanes



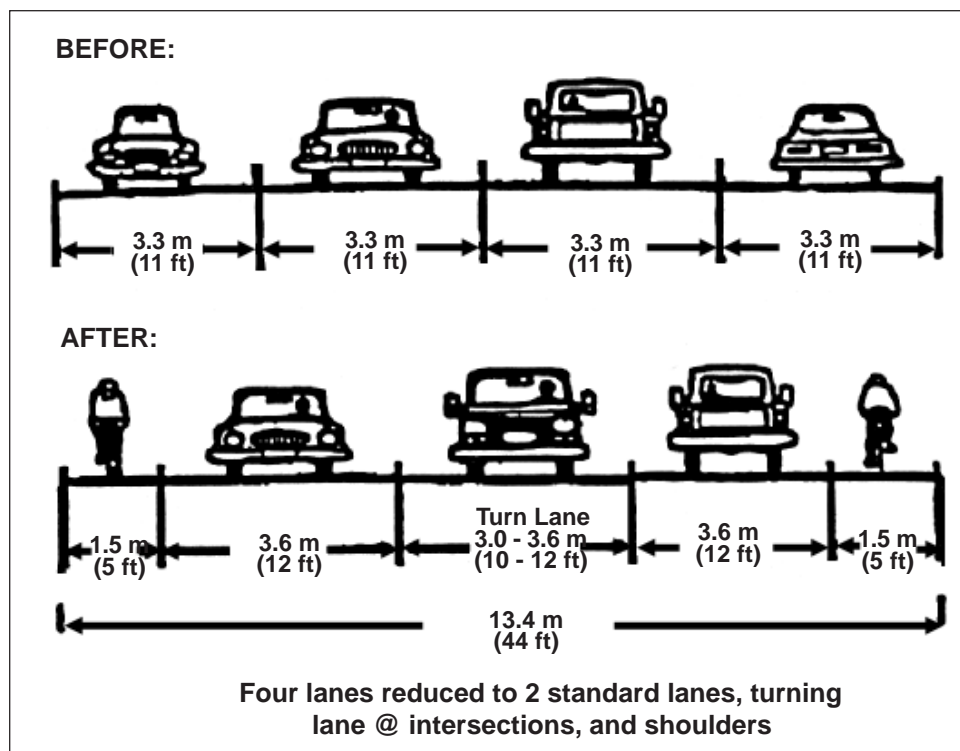


Figure 17

Continued

Source: Adapted from *Oregon Bicycle Plan*, 1990

11. Permits and Access Control

a. Driveway and street intersections

Frequent access driveways, especially commercial access driveways, tend to convert the right lane of a land service highway and the shoulder area into an extended auxiliary lane for acceleration and deceleration. Frequent turning movements, merging movements and vehicle occupancy of the shoulder can severely limit the ability of bicyclists to utilize the roadway. As a result, access control measures should be employed to minimize the number of entrances and exits onto highways. For driveways having a wide curb radius, consideration should be given to marking a bicycle lane through the driveway intersection areas. As with other types of street intersections, driveways should be designed with sufficiently tight curb radii to clearly communicate to motorists that they must yield the right-of-way to bicyclists and pedestrians on the roadway.

b. On-site circulation and facilities

Entrance and exit driveways should be sufficiently wide to accommodate bicycles. Lane widths for shared lanes presented in Table 1 should be incorporated into the design of all driveways. In general, shared lane use of driveways will be more appropriate than use of a shoulder because of the low speed of traffic on a driveway, the relatively low traffic volumes and the frequency of intersections with parking aisles.

Review of developments for transportation impacts should address how on-site bicycle facilities are planned. Bicycle storage racks should be provided at commercial facilities at locations convenient to building entrances and covered from the elements. This is especially important at retail and service establishments. At employment sites, secure bicycle racks and/or lockers should be provided. For a further discussion regarding bicycle storage facilities, see Chapter 5 - Supplemental Facilities.



c. Reconstruction responsibilities

Construction activities controlled through the issuance of permits, especially driveway, drainage, utility or street opening permits, can have an important effect on the quality of a roadway's surface in the portion of the roadway where bicyclists operate. Permit conditions should ensure that pavement foundations and surface treatments are restored to their preconstruction condition, that no vertical irregularities will result, and that no longitudinal cracks will develop. Strict inspection and control of construction activities is required, and a five year bond should be held to assure correction of any deterioration which might occur as a result of faulty reconstruction of the roadway surface. Spot widenings associated with new access driveways frequently result in the relocation of drainage grates. Any such relocation should be designed to close permanently the old drainage structure and restore the roadway surface. New drainage structures should be selected and located to comply with drainage provisions established in these guidelines.

12. Traffic Calming

a. What is "traffic calming?"

Traffic calming is a relatively new and very different approach to managing the roadway environment. Traffic calming seeks to reduce the dominance and speed of motor vehicles. It employs a variety of techniques to reduce vehicle speeds. Measures can include physical alterations to the horizontal and vertical alignment of the road and changes in priority. In some cases it may be possible to introduce a 30 km/h (20 mph) zone as part of a package of measures. First developed and applied in several European countries, the principles and techniques of traffic calming are arousing considerable interest in the US today. Traffic calming has been used in the US, to retrofit existing residential neighborhoods suffering from excessive through-traffic and in the design of new planned developments. Some techniques employed to calm traffic are familiar to US traffic engineers, others less so. What is different about traffic calming is its use as an overall integrating concept in designing for pedestrians and bicyclists over large areas. Traffic calming is rapidly being seized upon by many local communities and interest groups as an integrated alternative to conventional road planning and design. Its implementation is bound to be controversial because traffic calming reverses and challenges many currently accepted approaches to roadway design.

Aside from accident and casualty reduction, the benefits claimed for traffic calming are manifold. Slower vehicle speeds can create better driver discipline; less acceleration and braking reduces fuel consumption, vehicle emissions and noise intrusion. Furthermore, the smoother flow of vehicles may actually improve travel times. Traffic calming also provides an opportunity for environmental improvements. Aside from a reduction in noise and air pollution from motor vehicles, aesthetic improvements such as plantings can easily be incorporated into a program of physical alterations to the road space.

In residential areas, traffic calming is frequently applied to foster the concept that roads are "living areas" and should therefore be made safe and attractive. Here particularly, changes to the street scene are applicable, and, where possible, traffic calming should provide community areas, including play spaces and places where people can sit and chat.

Traffic calming need not, however, be confined only to minor roads. In urban and suburban areas, arterial streets and highways carrying fast, heavy traffic generally pose the greatest danger to vulnerable user groups. Measures that reduce the speed and dominance of motor vehicles and facilitate safe passage for bicyclists and pedestrians are thus even more necessary on such main roads. However, the techniques seen as applicable to main



urban thoroughfares generally differ from those employed to calm traffic on minor residential roads. A greater variety of features have been developed for minor roads where stricter speed control is unlikely to adversely affect roadway capacity or levels of service.

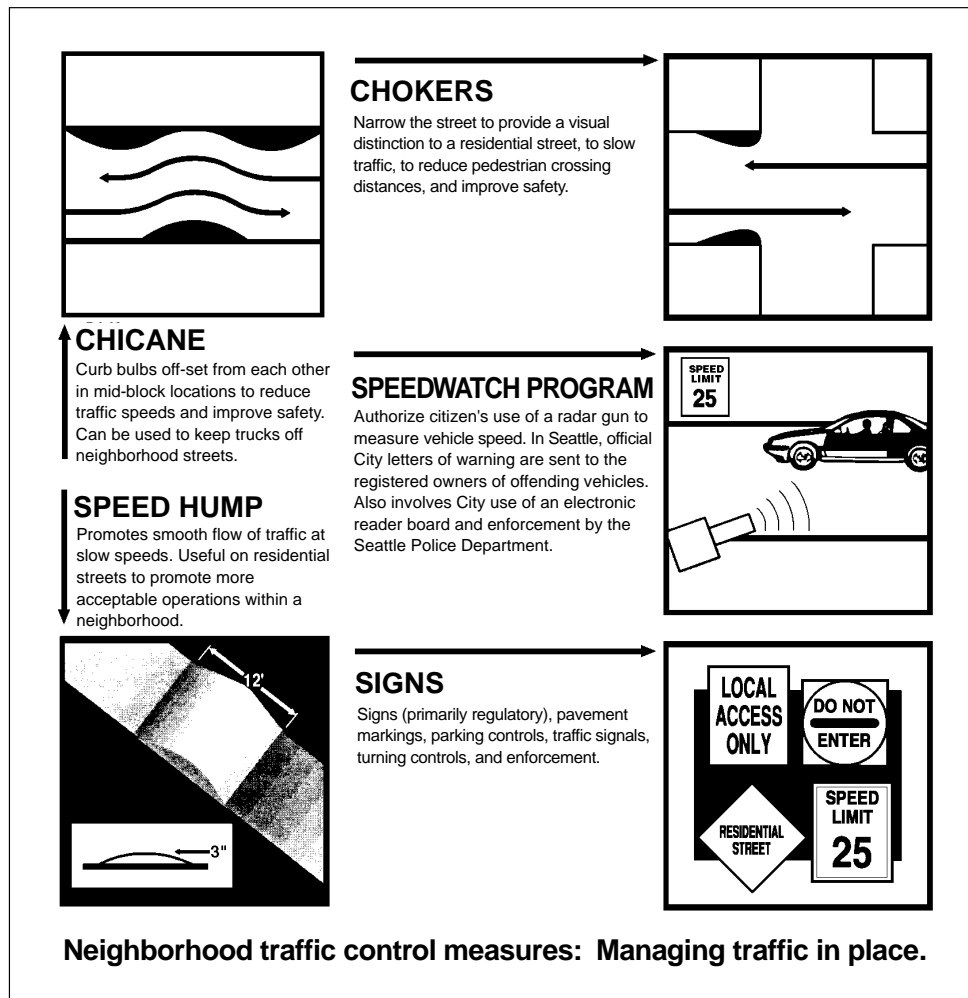


Figure 18
Traffic Calming Techniques

Source: *Design and Safety of Pedestrian Facilities*, ITE, 1994

Normally, traffic calming should be applied as an area-wide technique. To apply it only to a particular street can easily shift accidents, pollution and traffic into neighboring areas.

In order that traffic calming may realize its full potential in terms of creating a safer and more attractive urban environment, it must be part of a wider and longer-term strategy to reduce dependence on private motor vehicles in towns and cities, and promote a modal shift in favor of walking, cycling and public transit.

The growing popularity of traffic calming is attributable to four perceived benefits:

- A significant reduction in road accidents and their severity.
- A greater feeling of security, particularly among vulnerable road users.
- Reclamation of roadway space for non-traffic activity such as play and social interaction.
- Improved visual and aesthetic environments created by landscaping and a reduction in the intrusive presence of motor vehicles.



b. Traffic Calming and Bicyclists

In areas subject to traffic restraint or low speed limits, special facilities for bicycles are not usually needed or provided since traffic calming offers many inherent benefits for bicyclists. Mixing with slower traffic, bicyclists can move around in comparative safety. Traffic calming also offers a more bicycle-friendly alternative to wholly pedestrianized streets. Some traffic calming measures may also be particularly appropriate on older and narrower streets, which are too narrow to allow for the provision of special bicycling facilities.

Nevertheless, poorly-designed traffic-calming facilities can inconvenience or even endanger bicyclists. Bicyclists are particularly susceptible to changes in surface height and texture, and may be put at risk by poorly-considered road narrowing. Speed-reducing measures should not be so “harsh” as to discourage bicyclists from using traffic-calmed areas.

c. Design Guidelines to Accommodate Bicyclists

To avoid losing the inherent benefits of traffic calming for bicyclists by pushing them onto busier routes, the following general design guidelines should be followed in the implementation of traffic-calming schemes.

Figure 19

Bicycle Slip-thru
Speed Hump



Source: *Cyclists and Traffic Calming*, 1982

- Where possible, provide bicyclists with alternatives to by-pass physical obstacles such as *chicanes* or ramps; the recommended minimum width for a bicycle pass is 690 millimeters (27 inches).

- Where a reduction in roadway width is employed as a speed control measure, careful consideration should be given to how motorists and bicyclists can safely share the remaining space.

- Surface materials, particularly on ramps, should have a good skid resistance, while textured surfaces should not be so rough that they endanger the stability of bicyclists or cause severe grazing if the bicyclist should fall.
- A smooth transition on entry and exit ramps should be provided. Inclines should be clearly indicated and have a gradient of not more than 1:6 (16%).
- If the traffic-calming feature (or, indeed, any other traffic-management feature) is to be installed on a road with a gradient, it must be noted that bicyclists are likely to approach it at quite different speeds uphill and downhill. This should be taken into consideration in designing the feature.

Three general observations should be noted from successful traffic-calming schemes that have been implemented:

- Where consistently low speeds less than 30 km/h (20 mph) are required, such as in residential areas, physical traffic-calming features should be positioned sufficiently close together to deter unnecessary acceleration and braking.
- The use of appropriate signing is important to remind drivers that they are entering a traffic restraint area; public awareness campaigns facilitate the acceptance of lower speeds.
- Sympathetic speed limits, such as 30 km/h (20 mph) in residential areas, are used to reinforce the physical speed control measures.



d. Traffic Calming Techniques

Examples of traffic calming techniques are listed and illustrated in Figures 18 through 23. More detailed illustrations and descriptions can be found in the companion document to these guidelines, *NJDOT Pedestrian Compatible Planning and Design Guidelines*. These techniques are a selection of some current measures employed. Similarly, the descriptions of the various features are for illustrative purposes and should not be interpreted as rigid design criteria. It is recognized that the appropriate application of different traffic-calming techniques is dependent on the physical setting. As a result, the selection of appropriate techniques requires application of professional judgement and creativity.

Road Humps and Speed Tables

Description: Raising the surface of the road over a short distance, generally to the height of the adjacent curb. Humps are longer than speed bumps and can be round or flat topped; the latter are known as “speed tables” and can extend over 3.0 to 9.1 meters (10 to 30 feet). Humps may extend curb-to-curb, or may be cut back at the curb by 200 millimeters (8 inches) with tapered sides to facilitate drainage and permit a bicycle bypass.

While generally employed on residential roads, humps are permitted on main roads subject to a speed limit of 50 km/h (30 mph) or less. On higher speed roads, these concepts may still be appropriate to call attention to important pedestrian crossings or areas of congestion. However, care must be taken in design to provide appropriate vertical transitions.

Speed tables frequently are coincident with a pedestrian crossing.

Design Considerations: To ensure the effectiveness of road humps while enabling bicyclists to negotiate them with a reasonable degree of comfort:

- gradients on the approach and exit slopes should not exceed 1:6 (16%);
- ramp faces should be clearly indicated;
- all materials employed should be skid resistant;
- the leading edge of ramps should be flush with the road surface;
- humps should be situated sufficiently far from an intersection to allow turning bicyclists to regain an upright position before they encounter the obstruction.

Where flat top humps (speed tables) are coincident with a pedestrian crossing they should extend from curb-to-curb.

Speed humps in the vicinity of bus stops should be designed to permit buses to either completely clear the raised roadway or to straddle the hump. (Bus passengers are particularly vulnerable to the adverse effects of humps.)



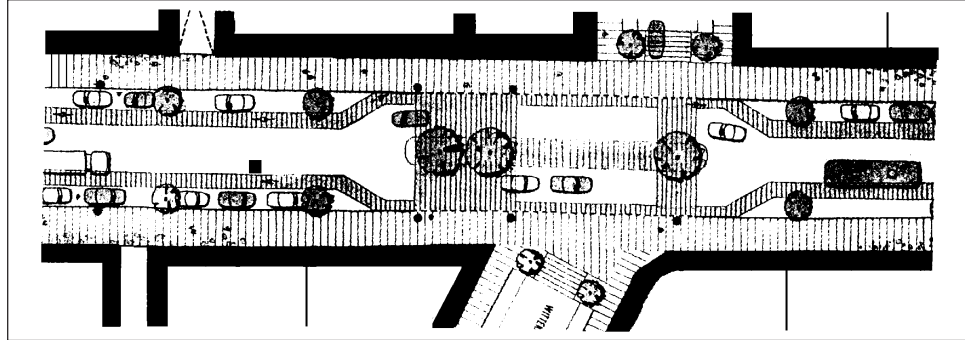
Source: *Traffic Calming*, CART, 1989, STOP, 1993

Figure 20

Speed Table



Figure 21
Mix of Traffic
Calming Elements



Source: *Traffic Calming*, CART, 1989, STOP, 1993

Chicanes

Description: Physical obstacles or parking bays staggered on alternate sides of the roadway so that the route for through vehicles is tortuous.

Design Considerations: In the implementation of chicanes, consideration should be given to the safe passage of bicyclists. This could be achieved by permitting them to by-pass chicanes; alternatively, signs to indicate directional priority may help. Similarly, chicanes must be designed to allow vehicles with large turning radii to negotiate the roadway. To permit street cleaning equipment to operate effectively, the curb radius should always be at least 0.9 meters (3 feet).

A reduction in sight distance should not be used in isolation to reduce speeds, as alone this could be potentially dangerous. A reduction in sight distance may be appropriate to avoid excessive land or ROW takings or as a reinforcing measure only where other physical features are employed which will effectively reduce operating speed.

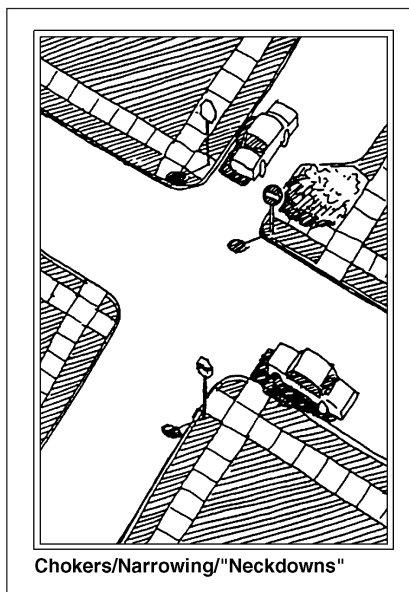
Chicanes offer a good opportunity to make environmental improvements through planting or landscaping. However, preference should be given to low-lying or slow-growing shrubs to minimize maintenance and ensure a reasonable degree of visibility.

Measures should be employed to ensure that chicanes are clearly visible in the dark.

Traffic Throttles/Chokers or Neck-downs

Figure 22

Choker/Neckdown



Chokers/Narrowing/"Neckdowns"

Description: The narrowing of a two-way road over a short distance to a single lane. Sometimes these are used in conjunction with a speed table and coincident with a pedestrian crossing.

Design Considerations: Throttles are generally only appropriate where traffic flows are less than 4-5,000 vehicles/day. Above this level considerable delays will occur in peak periods.

To reduce the risk of bicyclists being squeezed, throttles should generally be used in conjunction with other speed control measures, such as a speed table at the narrowing. Slower-moving drivers will be more inclined to allow bicyclists through before trying to pass. Where bicycle flows are high, consideration should be given to a separate right-of-way for bicyclists at the pinch point, possibly by means of a not-quite-central refuge.

Clear signing should indicate traffic flow priorities.



A textured surface such as blockwork may be used to emphasize pedestrian crossing movement. Substituting this for the normal roadway surface material may also help to impress upon motorists that lower speeds are intended.

Nevertheless, such measures should not confuse pedestrians with respect to the boundary of the roadway area over which due care should still be taken, especially where a road is raised to the level of the adjacent walkway. As with all crosswalks, appropriate care must be taken to alert the blind and others with limited vision of the presence of a crossing. A tactile material should be provided at the approach which can be detected with long cane techniques. Similarly a contrasting color and texture should be provided for the benefit of the visually impaired.

Roundabouts or Traffic Circles

Description: Small radius traffic circles located at street intersections or mid-block locations. Some have raised centers, others are little more than painted circles on the road.

Design Considerations: Roundabouts should preferably have sufficiently raised and highly visible centers to ensure that motorists use them correctly rather than over-running. Frequently, roundabouts with an interior area greater than 7 square meters (75 square feet) are planted. Small roundabouts may be only painted islands with a flexible barrier.

Complementary speed reduction measures, such as road humps on the approach to roundabouts can improve safety. Clear signing is essential.

The design of roundabouts must ensure that large radius vehicles will be able to negotiate the roadway, in particular, garbage trucks, fire engines, moving vans and school buses, all of which can be anticipated in residential areas. However, on low speed streets with AADT less than 2000, it is appropriate to assume that these large vehicles can encroach into the opposite lane when entering or exiting a roundabout.

Raised Intersections

Description: The roadway is raised at a street intersection with a visible roadway ramp on each approach. The platform created in the intersection is elevated to curb level and should have a distinctive surfacing.

Physical obstructions such as bollards or planters can be used to restrict the area to which vehicles have access.

Design Considerations: Roadway ramps should not exceed a maximum gradient of 1:6 (16%).

Distinctive surfacing materials should be skid resistant, particularly on inclines. Ramps should be clearly marked to enable bicyclists to identify and anticipate them, particularly in conditions of poor visibility.

As with all crosswalks, care must be taken that visually impaired people have adequate cues to advise them of the roadway area. Tactile strips may be appropriate and color variation will aid those who are partially sighted.

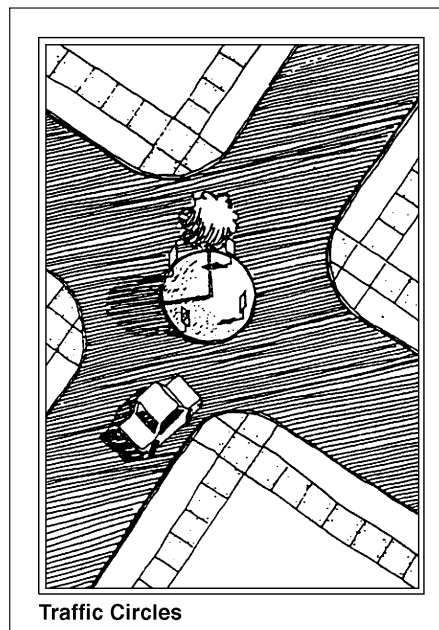


Figure 23

Traffic Circle



Plug “No-Entry” (with Bicycle Slip)

Description: A cul-de-sac created by blocking access in one direction at one point in the street to motor vehicles. Unlike a traditional cul-de-sac, a “plugged” street remains open for use by bicyclists and pedestrians.

Design Considerations: Bicycle exemption should be provided as a general rule, and designed to minimize the likelihood of obstruction by parked vehicles.

Signing should acknowledge the continued existence of the route as a through one for bicyclists.

Irregular or Textured Surfaces

Description: The use of non-asphalt roadway surfaces such as brick, paving blocks or blockwork, cobblestones to reinforce the concept of a “traffic restricted” area.

Design Considerations: Care must be taken in the choice of materials to ensure that they do not pose a danger or deterrent to bicyclists and pedestrians. Cobblestones present special difficulties and are particularly discouraging for bicyclists on steep slopes because they make it harder to maintain momentum when riding uphill. Similarly, paving stones with chamfered edges impair a bicyclist’s stability and should be avoided.

Cobblestones or other rough surface should not be used along pedestrian routes since they represent both an obstacle and a danger for persons in wheelchairs, walkers or other devices.

In residential areas consideration must be given to the noise that might be generated from textured surface materials.

Tortuous Roads

Description: Roads designed to meander, occasionally turning sharply, reducing the image or perception of a straight and open road, thereby encouraging low vehicular speeds.

This technique is often used in new housing developments, incorporating courtyards or cul-de-sacs and thus removing through traffic.

Design Considerations: Tortuous roads are generally planned during the design of a new road rather than superimposed on an existing one. The siting of buildings may be used to accent the meanders.

Designers should be aware of the need to assure accessibility to residential properties, both in terms of emergency vehicles and service vehicles. Tortuous roads will not be viable if they severely restrict accessibility.

“Woonerf” or Shared Surfaces

Description: The traditional distinction between pedestrian space and vehicular space is removed and a “living courtyard” or common area is shared by both pedestrians and vehicles.

This technique is common in European communities and is created by narrowing the street entry on either end, typically on short, isolated residential streets, and installing obstacles such as planters, parking, etc., at irregular intervals to slow traffic.

Design Considerations: Woonerfs are generally acceptable for short distances only and should be used in conjunction with other physical speed control features such as textured pavement or posted 10 to 15 km/h (8 to 10 mph) speed limit signs.



Chapter 3

Designating Bikeways on Highways

1. Bicycle Routes on Highways

A bicycle route is a suggested way to get somewhere. In a community, a bicycle route may consist of a set of signs designating a preferred way to get from a residential area to a park or to a shopping area. A network of such routes may show bicyclists how to get to many destinations throughout the community. In some cases, looped systems of scenic routes have been created to provide users with a series of recreational experiences.

In rural areas, signed and numbered touring routes can help long-distance bicyclists ride across the state on a network of carefully-chosen, quiet country roads. Often, such bicycle routes are keyed to a user map.

Overall, the decision to select one road over another for a bicycle route should be based on the advisability of encouraging bicycle use on that particular road. While the roads chosen for bike routes may not be completely free of problems, they should offer the best balance of safety and convenience of the available alternatives. In general, the most important considerations are pavement width and geometrics, traffic conditions, and appropriateness for the intended purpose.

Attributes which describe how appropriate a particular road is for a bicycle route include directness, scenery and available services. Directness is important for bicyclists traveling for a purpose. For recreational riders, this factor is not as important. For recreational bicyclists, on the other hand, varied and attractive scenery is one of the most important factors. Recreational riders, particularly those riding more than a few kilometers (miles), will be interested in services (food, water, restrooms). A route without such services will be less desirable than one with occasional stopping places.

a. Designating Bike Routes

When designating a bicycle route, the placement and spacing of signs should be based on Part IX of the MUTCD. For Bike Route signs to be functional, supplemental plates may be placed beneath them when located along routes leading to high demand destinations (e.g., “To Downtown,” “To State College,” etc., see Figure 24 for typical signing).

Since bicycle route continuity is important, directional changes should be signed with appropriate arrow subplaques. Also, signing should not end at a barrier. Information directing the bicyclist around the barrier should be provided.

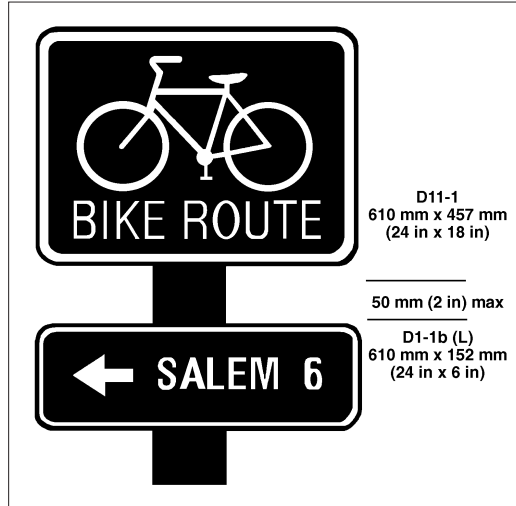
According to the MUTCD (Part 2A-6), “Care should be taken not to install too many signs. A conservative use of regulatory and warning signs is recommended as these signs, if used to excess, tend to lose their effectiveness. On the other hand, a frequent display of route markers and directional signs to keep the driver informed of his location and his course will not lessen their value.”



Bike route: The Bike Route sign (see Figure 24) is intended for use where no unique designation of routes is desired. However, when used alone, this sign conveys very little information. It should be used in conjunction with supplemental plaques giving destinations and distances. See Part 9B-22 of the MUTCD for specific information on subplate options.

Figure 24

Functional Signing



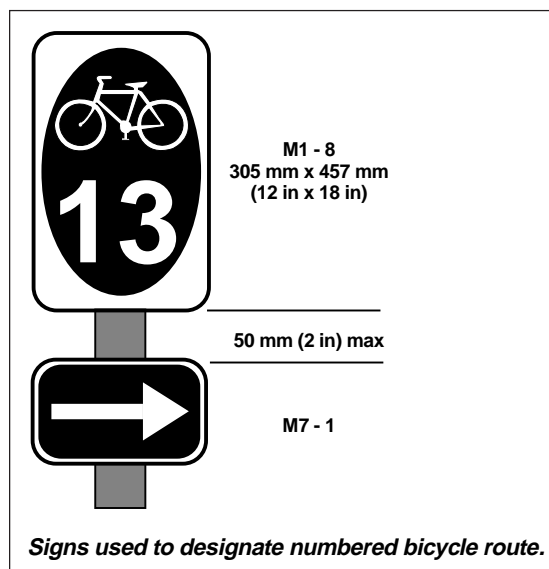
Source: *Manual on Uniform Traffic Control Devices*, FHWA, 1988

Numbered bike route: The numbered bike route sign (see Figure 25) is used to establish a unique identification for a state or local bicycle route. The sign may be combined with directional arrow subplates OM7-1 through M7-7.

One use of this type of sign is for long touring bicycle routes. The number may, for example, correspond to a parallel highway, indicating the route is a preferred alternate route for bicyclists. This sign also is used in communities with multiple bicycle routes.

Figure 25

Numbered Bicycle Route Sign



Source: *Manual on Uniform Traffic Control Devices*, FHWA, 1988

Such signs are often used in conjunction with user maps, which tell the bicyclist where each route goes.

Numbering of bicycle routes, at the state and county level, should be coordinated with the NJDOT Bicycle/Pedestrian Advocate to assure continuity.



2. Bicycle Lanes on Highways

Bicycle lanes can be considered when it is desirable to delineate available road space for preferential use by bicyclists and motorists, and to provide for more predictable movements by each. Bicycle lane markings, as exemplified in Figure 26, can increase a bicyclist's confidence in motorists not straying into his/her path of travel. Likewise, passing motorists are less likely to swerve to the left out of their lane to avoid bicyclists on their right.

Bicycle lanes should always be one-way facilities 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 accidents and violates the Rules of the Road stated in the Uniform Vehicle code. Bicycle lanes on one-way streets 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). In unique situations, it may be appropriate to provide a contra-flow bicycle lane on the left side of a one-way street. Where this occurs, the lane should be marked with a solid, double yellow line and the width of the lane should be increased by 1 foot.



Source: [Guide for the Development of Bicycle Facilities](#), AASHTO, 1991

Figure 26

Bicycle Lane Markings

a. Lane Widths

Under ideal conditions, the minimum bicycle lane width is 5 feet (1.5 m). However, certain edge conditions dictate additional desirable bicycle lane width. To examine the width requirements for bicycle lanes, Figures 27, 28 and 29 show three usual locations for such facilities in relation to the roadway. Figure 27 depicts bicycle lanes on an urban curbed street where a parking lane is provided. The minimum bicycle lane width for this location is 5 feet (1.5 m). If parking volume is substantial or turnover is high, an additional 1 or 2 feet (0.3 or 0.6 m) of width is desirable for safe bicycle operation. Bicycle lanes should always be placed between the parking lane and the motor vehicle lanes. Bicycle lanes between the curb and the parking lane can create obstacles for bicyclists and eliminate a bicyclist's ability to avoid a car door as it is opened, therefore, this placement should not be considered.



Figure 27

Bicycle Lanes on an Urban Curbed Street

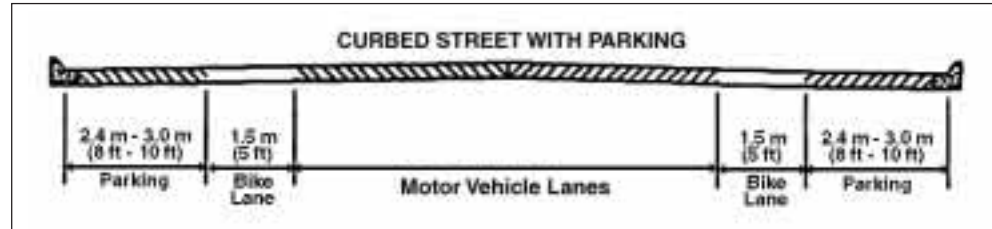


Figure 28 depicts bicycle lanes along the outer portions of an urban curbed street where parking is prohibited.

Bicyclists do not generally ride near a curb because of the possibility of debris, of hitting a pedal on the curb, of an uneven longitudinal joint, or of a steeper cross slope. Bicycle lanes in this location should have a minimum width of 5 feet (1.5 m) from the curb face. If the longitudinal joint between the gutter pan and the roadway surface is uneven and falls within 5 feet (1.5 m) of the curb face, a minimum of 4 feet (1.2 m) should be provided between the joint and the motor vehicle lanes.

Figure 28

Bicycle Lanes along the Outer Portions of an Urban Curbed Street

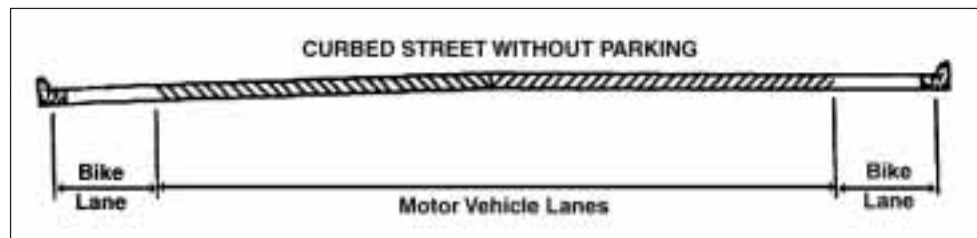
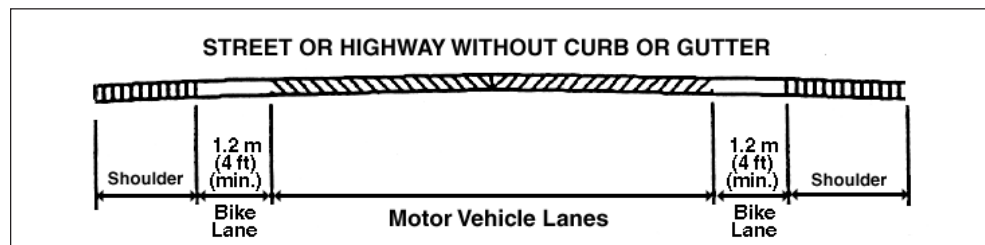


Figure 29 depicts bicycle lanes on a highway not adjacent to the curb. Bicycle lanes should be located between the motor vehicle lanes and the roadway shoulders. In this situation bicycle lanes may have a minimum width of 4 feet (1.2 m), since the shoulder can provide additional maneuvering width. A width of 5 feet (1.5 m) or greater is preferable; additional widths are desirable where substantial truck traffic is present, or where vehicle speeds exceed 40 mph. In certain situations it may be appropriate to designate the full shoulder as the bike lane.

Figure 29

Bicycle Lanes on Highway Without a Curb or Gutter



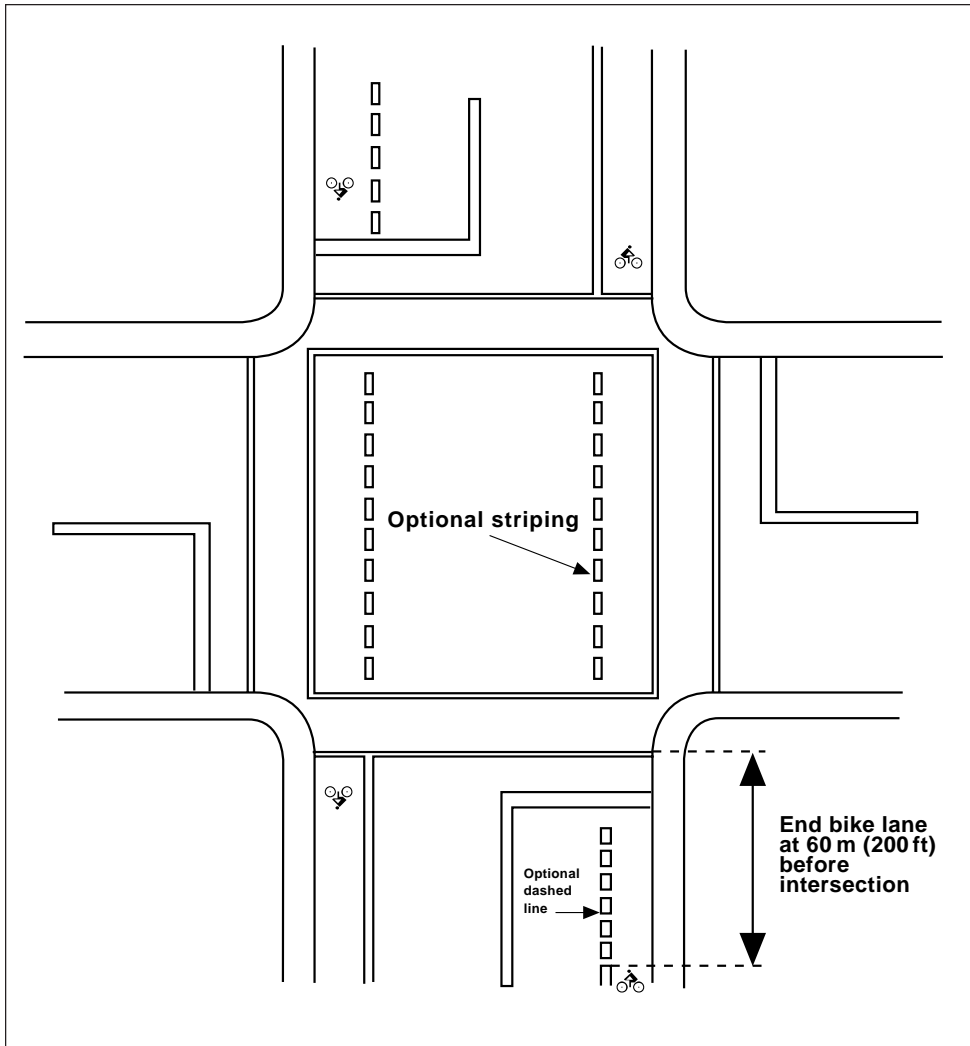
Source: Adapted from *Guide for the Development of Bicycle Facilities*, AASHTO, 1991



b. Intersections

Bicycle lanes tend to complicate both bicycle and motor vehicle turning movements at intersections. Because they encourage bicyclists to keep to the right and motorists to keep to the left, 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 from the left side of the bicycle lane. Both maneuvers are contrary to established Rules of the Road and result in conflicts.

Design treatment for bicycle lanes at simple intersections is shown in Figure 30. On a two lane highway, the edge line along the bike lane should end approximately 60 meters (200 feet) from the intersection to allow left turning bicyclists and right turning motorists to “weave.”



Source: Adapted from *Technical Handbook of Bikeway Design*, Velo, Quebec, 1992

Figure 30

Bicycle Lanes on 2 Lane Roadways Without Turn Lanes



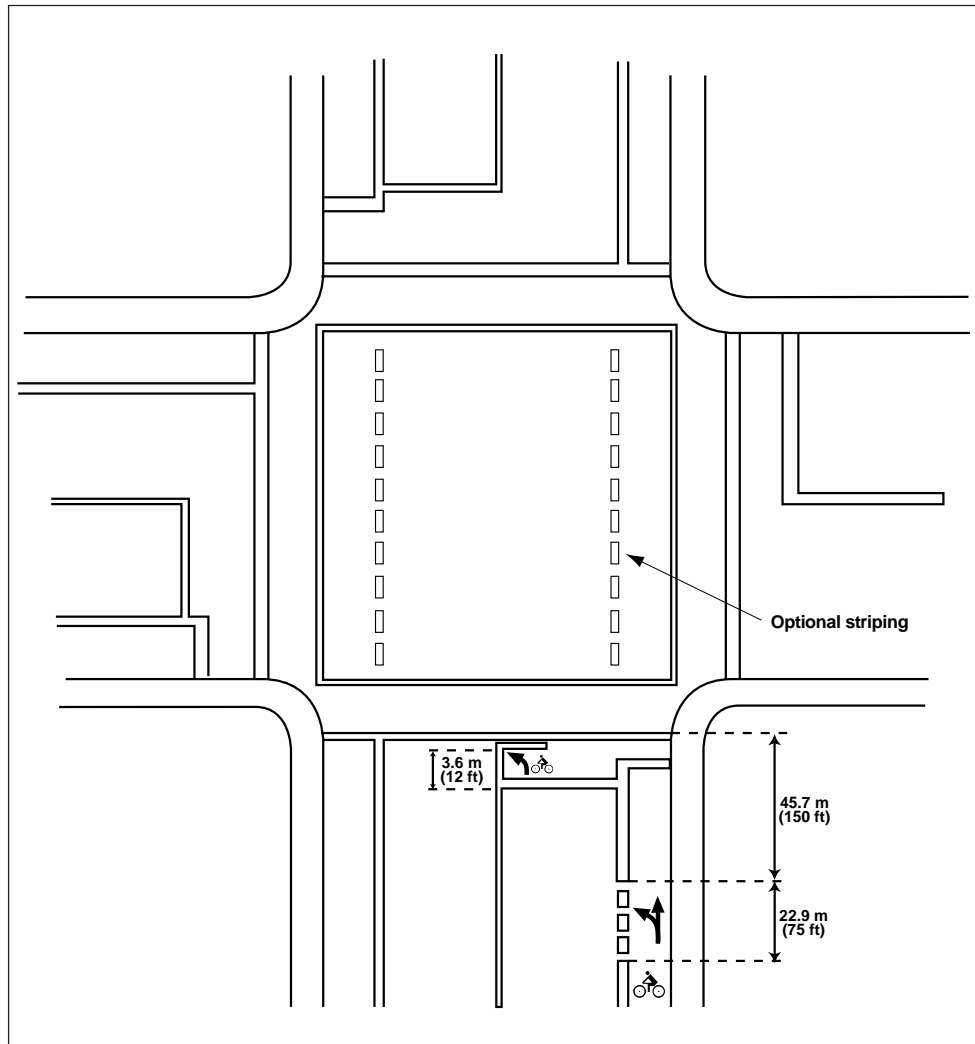
Where high volumes of bicycle traffic exist and primacy is given to bicyclists, a bicycle queuing area should be considered at the intersection as shown in Figure 31. At these intersections, the stop line for vehicles is set back to allow bicyclists to move to the front of a lane of vehicular traffic to make a left turn or proceed through the intersection.

Design treatment at multi-lane intersections is more complex. Figure 32 presents examples of details on pavement markings for bicycle lanes approaching motorist right-turn-only lanes. Where there are numerous left turning bicyclists, a separate turning lane, as indicated in the MUTCD should be considered. The design of bicycle lanes should also include appropriate signing at intersections to reduce the number of conflicts. General guidance for pavement marking of bicycle lanes is contained in the MUTCD.

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

Figure 31

Optional Bicycle Queuing Area at Intersection with High Volumes

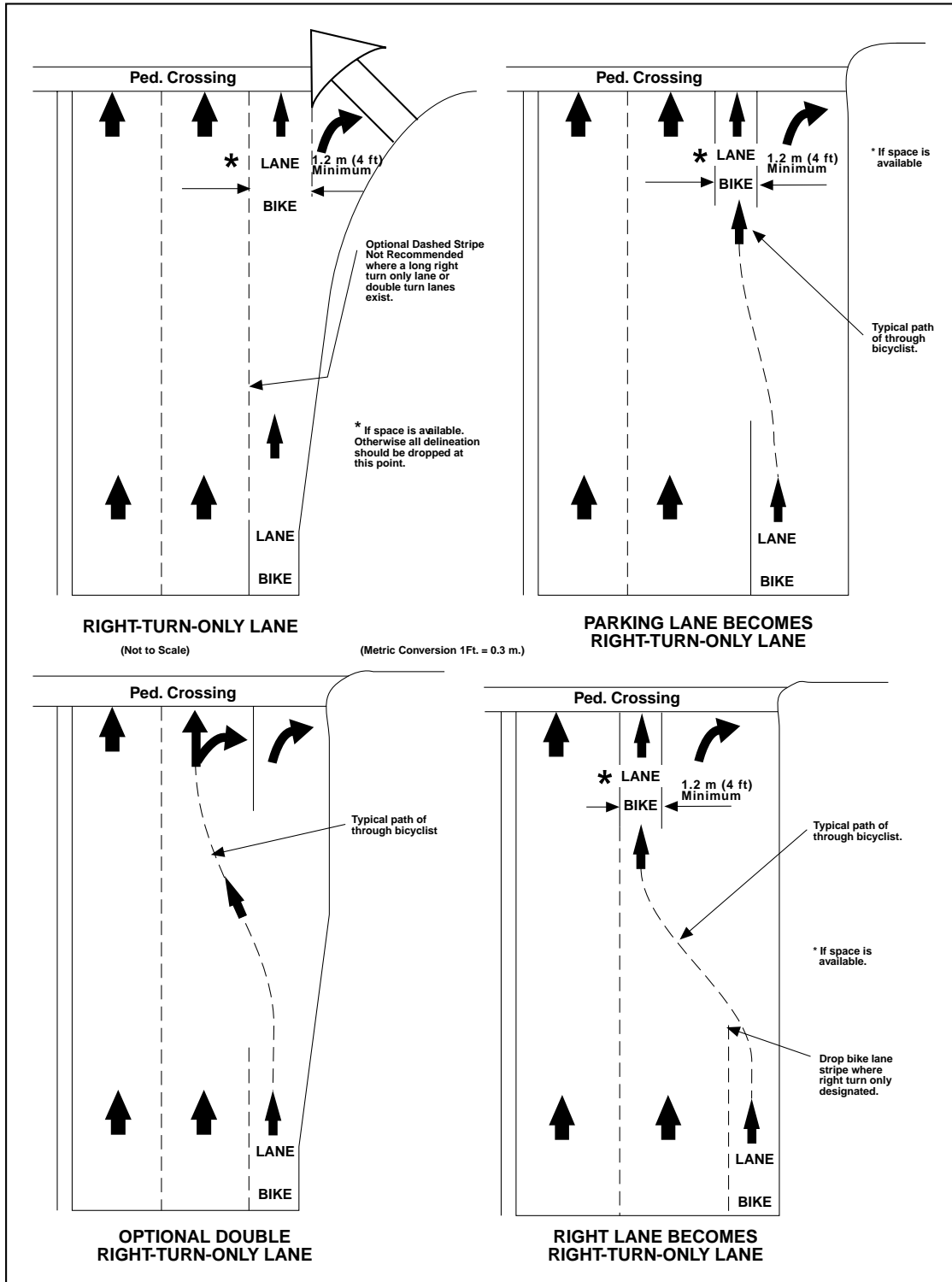


Source: Adapted from *Technical Handbook of Bikeway Design*, Velo, Quebec, 1992



Figure 32

Bicycle Lanes Approaching Motorist Right-Turn-Only Lanes



Source: *Guide for the Development of Bicycle Facilities*, AASHTO, 1991



c. Signing and Striping Requirements

Signing should be in accordance with MUTCD and is shown in Figure 33. Bicycle lanes should be well-marked and signed to ensure clear understanding of the presence and purpose of the facility by both bicyclists and motorists. The MUTCD specifies standard signing for bicycle lanes. According to MUTCD, “the R3-16 sign should be used in advance of the beginning of a marked designated bicycle lane to call attention to the lane and to the possible presence of bicyclists. The R3-16 and R3-17 signs should be used only in conjunction with the Preferential Lane symbol pavement marking and erected at periodic intervals along the designated bicycle lane and in the vicinity of locations where the preferential lane symbol is used.”

According to MUTCD, where it is necessary to restrict parking, standing, or stopping in a designated bicycle lane, appropriate signs as described in MUTCD may be used, or signs R7-9 or R7-9a shall be used.

Bicycle lane stripes should be solid, 150mm to 200mm (6 to 8 inches)

wide white lines. Care should be taken to use pavement striping that is skid resistant. Thermoplastic tape and painted markings can become slippery and cause the cyclist to fall. Impregnated grit, non-skid, preformed tape is an acceptable striping material.

It is very important to re-apply bicycle lane markings when they begin to fade, since faded bicycle lane markings can lead to confusion by motorists and bicyclists. If necessary, re-application of bicycle lane stripes should be placed on a more frequent schedule than regular roadway re-striping projects. Old markings should be removed prior to re-striping if new layers of marking materials would otherwise create raised areas that would be hazardous to bicyclists.

Preferential bicycle lane symbols should be installed on the pavement in bicycle lanes. Symbols should be installed at regular intervals (no more than 107 meters (350 feet) between symbols), immediately after intersections, and at areas where bicycle lanes begin. Pavement letters that spell “ONLY BIKE,” and arrows are optional.

Figure 33

MUTCD Bicycle Lane Signs



Source: *Manual on Uniform Traffic Control Devices*, FHWA, 1988



3. Suitability Factors for Locating Bikeways on Highways

The suitability of a highway facility for bicycling is influenced by a number of factors. These factors can generally be classified in the following categories:

- Land Use and Location Factors
 - Physical Constraint Factors
 - Traffic Operations Factors
- a. **Land use and location factors** represent the most significant category affecting suitability. Since bicycle trips are generally shorter than trips made by other modes, there must be a manageable distance between origins and destinations such as between residential areas and places of employment. There are certain key land uses which are especially likely to generate bicycle traffic if good bicycle facilities are available. These consist of, but are not limited to transit centers, schools, employment centers with nearby residential areas, recreation areas and mixed use cities, towns and villages.
 - b. **Physical constraint factors** consist of highway geometric or physical obstacles to bicycling which are difficult or costly to remedy. For example, a roadway may be suitable because of location factors but not suitable because of the existence of physical constraints to bicycling such as a narrow bridge, insufficient ROW or intersections with restricted lane widths, as a result of lane channelization. The feasibility of ameliorating these physical constraints must be weighed in deciding the designation of bikeways.
 - c. **Traffic operations factors** include traffic volume, speed, the number of curb cuts or conflict points along the highway, sight distance, and bicycle and pedestrian sensitive traffic control devices. Experienced bicyclists will use highways despite limiting traffic operational factors. However, less confident bicyclists will perceive such highways as unsafe and intimidating. These highway facilities should be designed or improved to accommodate bicyclists through the shared use of roadways. However, they are inappropriate for designation as bikeways.

Other safety issues such as maintenance and pavement repair are also important considerations in the designation of bikeways but do not affect the planning aspects of suitable facilities.

4. Design Guidelines for Bikeways on Highways

Bicycle lanes are usually more suitable in urban settings on roads with high traffic volumes and speeds. Bicycle routes are often used in urban settings to guide bicyclists along alternate or parallel routes that avoid major obstacles or which have more desirable traffic operational factors.

In rural settings, bicycle lanes are not usually necessary to designate preferential use. On higher volume roadways, wide shoulders offer bicyclists a safe and comfortable riding area. On low volume roadways, bicyclists prefer the appearance of a narrow, low speed country road.

Table 2 recommends the type of bikeway and pavement width for various traffic conditions.

For locations where pavement widths do not meet the following criteria, the NJDOT Bicycle/Pedestrian Advocate should be notified, and can assist in the decision making process.

Where physical obstructions exist that can be removed in the future, the highway facility should be designed to meet bikeway space allocation requirements, and upgraded and designated when the physical constraint is remedied (i.e., bridge is replaced and improved to allow designated facility.)

The final design should be coordinated with the NJDOT Bicycle/Pedestrian Advocate for review and approval prior to construction.



Table 2Bikeway Types
and Pavement
Width**Condition I
AADT 1200* - 2000**

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	BR (SL) 4.2m (14 ft.)	BR (SL) 4.2m (14 ft.)	BR (SL) 3.0m (10 ft.)
50 km/h-65 km/h (31-40 mph)	BL 1.5m (5 ft.)	BL 1.5m (5 ft.)	BR (SH) 1.2m (4 ft.)
65 km/h-80 km/h (41-50 mph)	BL 1.8m (6 ft.)	BL 1.5m (5 ft.)	BR (SH) 1.8m (6 ft.)
>80 km/h (50 mph)	N/A	BL 1.8m (6 ft.)	BR (SH) 1.8m (6 ft.)

KEY: BR (SL) = shared lane, BR (SH) = shoulder, BL = bike lane

* For volumes less than 1200 AADT a shared lane is acceptable where adequate sight distance exists.

**Condition II
AADT 2000 - 10,000**

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	BR (SL) 4.2m (14 ft.)	BR (SL) 4.2m (14 ft.)	BR (SH) 1.2m (4 ft.)
50 km/h-65 km/h (31-40 mph)	BL 1.5m (5 ft.)	BL 1.5m (5 ft.)	BR (SH) 1.2m (4 ft.)
65 km/h-80 km/h (41-50 mph)	BL 1.8m (6 ft.)	BL 1.8m (6 ft.)	BR (SH) 1.8m (6 ft.)
>80 km/h (50 mph)	N/A	BL 1.8m (6 ft.)	BR (SH) 2.4m (8 ft.)

KEY: BR (SH) = shoulder, BR (SL) = shared lane, BL = bike lane

**Condition III
AADT Over 10,000**

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	BR (SL) 1.5m (5 ft.)	BR (SL) 1.5m (5 ft.)	BR (SH) 1.2m (4 ft.)
50 km/h-65 km/h (31-40 mph)	BL 1.8m (6 ft.)	BL 1.5m (5 ft.)	BR (SH) 1.8m (6 ft.)
65 km/h-80 km/h (41-50 mph)	BL 1.8m (6 ft.)	BL 1.8m (6 ft.)	BR (SH) 1.8m (6 ft.)
>80 km/h (50 mph)	N/A	BL 1.8m (6 ft.)	BR (SH) 2.4m (8 ft.)

KEY: BR (SH)=shoulder BL=bike lane



5. Integrating Bikeways Into The Highway Planning Process

Planning for bicycle facilities on highways should begin at the very earliest stage of project development on all sizes and types of highway projects. Even the smallest highway reconstruction project could result in a missed opportunity if bicyclists are not taken into consideration at the initiation of the project.

At the municipal level, planners should address these highway planning issues in the comprehensive context of the circulation element in the municipal master plan, as provided for in the New Jersey Municipal Land Use Law, N.J.S.A. 40:55D-28.b.(4).

The following procedure offers the planner and designer guidance in determining the need for bikeways during the usual phases of project development.

a. Needs Assessment

The first step in the planning process for any transportation project is the assessment of needs. Existing and planned land use, current and projected traffic levels, and the special needs of the area population are examined. There are circumstances in which a portion of the transportation need might be served by non-motorized means, as well as locations where existing bicycle demand would be better served by improved facilities. A series of questions with respect to land use and location factors are presented to assist in recognizing the potential for non-motorized travel and evaluating the needs of bicyclists at the State level.

- Does the highway serve an activity center which could generate bicycle trips?
- Is the highway facility included on a county or municipal bicycle master plan?
- Will the highway facility provide continuity with or between existing bicycle facilities?
- Is the highway facility located on a roadway which is part of a mapped bike route or utilized regularly by local bicycle clubs?
- Does the highway facility pass within 3.2 kilometers (two miles) of a transit station?
- Does the highway facility pass within 3.2 kilometers (two miles) of a high school or college?
- Does the highway facility pass within 0.8 kilometers (1/2 mile) of an elementary school or middle school?
- Does the highway facility pass through an employment center? If so, is there a significant residential area within a 4.8 kilometer (3 mile) radius?
- Does the highway facility provide access to a recreation area or otherwise serve a recreation purpose?

If any one of these criteria produces a significantly positive response, the highway facility has the potential of attracting less experienced bicycle riders and/or large numbers of advanced riders. As a result, it should be considered as potentially suitable for designation as a bikeway. If none of the above criteria is met, the project should be designed to meet minimum bicycle compatible roadway criteria.

The planner should include a description of the potential significance of the highway facility as a bicycle facility in the project initiation or scoping document that will be forwarded to the project designer. If the planner determines that the project is potentially suitable for



designation as a bikeway, the nature of potential bicycle use should be addressed, including factors affecting roadway design such as highway truck volumes or intersections.

b. Preliminary Engineering

Highway facilities which have been determined through the needs assessment process to be potentially suitable for bikeways should be analyzed to determine physical constraints which may limit the type of facility which could be provided.

The following factors should be considered:

- Does sufficient ROW exist or can additional ROW be acquired to allocate the required space for a bikeway?
- If physical impediments or restrictions exist, can they be avoided or removed to allow the required pavement to provide a bikeway?
- Do bridges allow for bicycle access in accordance with bikeway standards?
- Can travel or parking lanes be reduced in width or eliminated to allow space for bikeways?

If the answer to these questions is positive, a bikeway should be recommended at the completion of the preliminary engineering phase for the following situations:

- Transportation facilities or segments that connect bicycle traffic generators within 8.0 kilometers (5 miles) of each other.
- Segments of transportation facilities that provide continuity with existing bicycle facilities.

If physical constraint factors that preclude allocation of space and designation of bikeways exist, and cannot be avoided or remedied, these factors should be reported to the project manager in the final design phase.

c. Final Design and Facility Selection

When the needs assessment and preliminary design indicate the need for bikeways, the designer should consider traffic operations factors in determining the actual design treatment for the bikeway. The following should be considered in the design of the highway and bicycle facility:

- What are the existing and projected traffic volumes and speeds?
- Does parking exist? Can parking be restricted or removed to allow better sight distances?
- Are intersections/conflict points excessive? Can intersections/conflict points be reduced along roadways in accordance with the New Jersey Highway Access Management Code?
- Can turn lanes at intersections be designed to allow space for bicyclists?
- Can sections with insufficient sight distance or highway geometrics be changed?
- Can traffic operations be changed or “calmed” to allow space for bikeways?



Chapter 4

Bicycle Paths

Bicycle paths consist of multiple use paths or trails, separated from motorized vehicular traffic, on which bicycle travel is anticipated and permitted. Bicycle paths may be located within a highway right-of-way or on an independent right-of-way. Because of their expense, bicycle paths seldom are constructed for the exclusive use of bicyclists, but instead must be shared with other users.

Bicycle paths can serve a variety of purposes. They can provide 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. Bicycle paths can be located along abandoned railroad rights of way, the banks of rivers, and other similar areas. Bicycle paths can also provide bicycle access to areas that are otherwise served only by limited access highways closed to bicycles. Appropriate locations can be identified during the planning process. Examples of bicycle paths are shown in Figure 34 and Figure 35.

All bicyclists can find bicycle paths inviting places to ride. In addition, since paths augment the roadway system, they can extend circulation options for bicyclists, making trips feasible which might not be feasible if bicyclists had to depend exclusively on roadways. Basic bicyclists and children, however, especially appreciate the freedom from conflicts with motor vehicles which off-road paths promise.

Provision of a bicycle path should not be used as a rationale for prohibiting use of parallel roadways by bicyclists nor as an excuse for not designing such roadways to be compatible with bicycle use. Because of conflicts created by intense usage, differing speed and riding skills of bicyclists and conflicts between users, multiple use recreational paths may often be inappropriate facilities for experienced bicycle riders. In fact, many conflicts on popular multiple use paths can be avoided by encouraging more experienced bicyclists to use parallel roadways.



Figure 34

Example of Bicycle Path

Source: *Guide for the Development of Bicycle Facilities*, AASHTO, 1991

1. Planning Issues in Designating Bicycle Paths

a. Shared Use of Multiple Use Paths

As indicated, off-road paths are rarely constructed for the exclusive use of bicyclists, but instead must be shared with other non-motorized users (or, in some instances, with specialized motorized uses such as snowmobiles, off-road motorcycles and similar vehicles).

Just as conflicts can occur between bicycles and pedestrians on sidewalks, or between motor vehicles and bicycles on highways not constructed to compatible standards, heavy use of trails and other multiple use paths can create conflicts between different user groups. Among bicyclists, basic riders and young children who travel at speeds below 15 km/h (9 mph) will conflict with more advanced riders travelling at speeds greater than 20



km/h (12 mph). Pedestrians, in-line skaters and bicyclists, both basic and advanced, will wish to travel at substantially different speeds. So long as the volume of users is low, the

Figure 35

Example of
Bicycle Path



Source: *Guide for the Development of Bicycle Facilities*, AASHTO, 1991

conflicts between different groups can be kept manageable. However, even moderate volumes may result in substantial deterioration in level of service and can expose users to substantial safety risks. Conflicts between users are especially likely to occur on regionally significant recreational trails which attract a broad diversity of users.

b. Regulation of Multiple Use Paths

The types of conflicts on multiple use paths have increased substantially in recent years with the increased popularity of mountain bikes and in-line skating. Methods of addressing these conflicts include providing alternative facilities for different groups, prohibiting certain modes, restricting different modes to specific hours of operation, providing wider facilities or marking wide paths to regulate the flow of traffic. Examples of all of these types of actions can be witnessed along boardwalks in New Jersey where conflicts between different user groups can be especially severe.

c. Incompatible Multiple Use of Paths or Trails

Joint use of paths or trails by bicycles and horses or mountain bikes and hikers pose special problems which in general should be avoided. Horses startle easily and may kick out suddenly if a bicyclist is perceived to be a danger. Furthermore, the surface requirements of a bicycle path are incompatible with the requirements of a bridle path: bicycles function best on hard surfaces, horses best on soft surfaces. A compromise surface to accommodate both would result in a less than adequate surface for both. As a result, where either horseback activity or bicycle activity is anticipated to be high, separate trails are required. Mountain bikes and horses may safely share the use of gravel or dirt trails provided that adequate passing widths are available, the volume of traffic by both modes is low and sight distances permit horses and bicyclists to anticipate and prepare for possible conflicts.

The popularity of mountain bikes has created an increasing problem on hiking trails which have minimal surface improvement and are narrow in width. The speed differential between a mountain bike and a hiker can be substantial. Narrow trails in woods can substantially limit sight distance for mountain bikes and cause riders to either crash into hikers or have near misses. Mountain bike use of hiking trails also results in substantial erosion problems. As a result, use of mountain bikes should be restricted to wider dirt roads and lanes which have adequate sight distance as well as drainage improvements sufficient to protect against trail erosion.

d. Linkage Paths

Conflicts between different users of multiple use paths occur primarily on heavily used recreational trails or in the immediate vicinity of a major pedestrian trip generator. Neigh-



neighborhood paths and community trails which are used much less intensively will seldom result in conflicts and can be safely shared by a variety of users. Construction of linkages between adjoining residential developments, between schools and neighborhoods or between shopping areas and surrounding streets can substantially expand the circulation opportunities for both pedestrians and bicyclists.

Because such linkage paths are usually short and lightly used, they can almost always be safely shared by different users even if the path's width is minimal. A designer of such a linkage path needs to anticipate the probability of conflicts when designing such a facility. A short path, less than 120 meters (400 feet) in length, in a suburban neighborhood, can usually be constructed to a width of only 1.5 meters (5 feet) provided that adequate sight distance is available to allow a bicyclist to stop when encountering a pedestrian or an opposing bicyclist. This assumes that the probability of encountering a conflicting pedestrian or bicyclist is too small to justify providing the added width needed to pass.

Linkage paths should be required to be constructed when developments are being planned or have been constructed in such a fashion that reasonable pedestrian or bicycle travel is frustrated as a result of a constrained roadway network. Policy for linkages can be defined in the land use element of municipal master plans, in the circulation element of municipal master plans, and on the official map as provided in the Municipal Land Use Law. NJDOT's companion manual, Pedestrian Compatible Planning and Design Guidelines provides additional planning and design guidance regarding the construction of linkage paths.

e. Bicycle Use of Sidewalks

Identifying a sidewalk as a bicycle path is undesirable for a variety of reasons. *Sidewalks are typically designed for pedestrian speed and maneuverability and are not safe for higher speed bicycle use. Conflicts are common between pedestrians traveling at low speeds (or exiting stores, parked cars, etc.) and bicycles, as are conflicts with fixed objects (e.g., parking meters, utility poles, sign posts, bus benches, trees, fire hydrants, mail boxes, etc.). Walkers, joggers, skateboarders, and roller skaters can, and often do, change their speed and direction almost instantaneously, leaving bicycles insufficient time to react to avoid collisions.*

Similarly, pedestrians often have difficulty predicting the direction an oncoming bicyclist will take. At intersections, motorists are often not looking for bicyclists (who are traveling at higher speeds than pedestrians) entering the crosswalk area, particularly when motorists are making a turn. Sight distance is often impaired by buildings, walls, property fences, and shrubs along sidewalks, especially at driveways.

In residential areas, young children can be anticipated to ride bicycles, tricycles, scooters and other riding toys on sidewalks. This type of use is an acceptable exception to the general finding that use of sidewalks by bicyclists is undesirable. Sidewalks in residential areas generally have low pedestrian volumes and are accepted as extended play areas for children. Pedestrians anticipate and usually enjoy encounters with young children who are playing in the sidewalk. This type of bicycle use of the sidewalk is generally acceptable, and provides young children who do not have the judgement or skill to ride in the street an opportunity to develop their riding skills.

f. Bicycle Paths Adjacent to Roadways

Two-way bicycle paths located immediately adjacent to a roadway are not generally recommended for the following reasons:



- (1) They require one direction of bicycle traffic to ride against motor vehicle traffic, contrary to normal Rules of the Road.
- (2) *When the bicycle path ends, bicyclists going against traffic will tend to continue to travel on the wrong side of the street. Likewise, bicyclists approaching a bicycle path often travel on the wrong side of the street in getting to the path. Wrong-way travel by bicyclists is a major cause of bicycle/automobile accidents and should be discouraged at every opportunity.*
- (3) *At intersections, motorists entering or crossing the roadway often will not notice bicyclists coming from their right, as they are not expecting contra-flow vehicles. Even bicyclists coming from the left often go unnoticed, especially when sight distances are poor.*
- (4) *When constructed in narrow roadway right of way, the shoulder is often sacrificed, thereby decreasing safety for motorists and bicyclists using the roadway.*
- (5) *Many bicyclists will use the roadway instead of the bicycle path because they have found the roadway to be safer, more convenient, or better maintained. Bicyclists using the roadway are often subjected to harassment by motorists who feel that in all cases bicyclists should be on the path instead.*
- (6) *Bicyclists using the bicycle path generally are required to stop or yield at all cross streets and driveways, while bicyclists using the roadway usually have priority over cross traffic, because they have the same right of way as motorists.*
- (7) *Stopped cross street motor vehicle traffic or vehicles exiting side streets or driveways may block the path crossing.*
- (8) *Because of the closeness of motor vehicles to opposing bicycle traffic, barriers are often necessary to keep motor vehicles out of bicycle paths and bicyclists out of traffic lanes. These barriers can represent an obstruction to bicycles and motorists, can complicate maintenance of the facility, and can cause other problems as well.*

For the above reasons, bicycle lanes, or shared roadways should generally be used to accommodate bicycle traffic along highway corridors rather than providing a bicycle path immediately adjacent to the highway.

An exception to this general rule consists of situations where an off-road path intended for bicycle use must be located adjacent to a roadway for a relatively short distance. In order to maintain continuity of the trail section, it may be preferable in this situation to locate the path adjacent to the roadway. An example of this situation would consist of the joint use of a roadway's bridge by a trail. In such situations, physical separation of the path from the roadway must be provided as discussed later in this chapter.

2. Design of Paths for Bicycle Use

a. Width and Clearance

The paved width and the operating width required for a bicycle path are primary design considerations. Figure 36 depicts a bicycle path. Under most conditions, recommended paved width for a two-directional bicycle path is 10 feet (3 m). In some instances, however, a minimum of 8 feet (2.4 m) can be adequate. This minimum should be used only where the following conditions prevail: (1) bicycle traffic is expected to be low, even on peak days or during peak hours; (2) pedestrian use of the facility is not expected to be more than occasional; (3) there will be good horizontal and vertical alignment providing safe and frequent passing opportunities; (4) the path will not be subjected to maintenance vehicle loading conditions that would cause pavement edge damage. Under certain conditions it may be necessary or desirable to increase the width of a bicycle path to 12 feet (3.7 m) or more; for example, because of substantial bicycle volume, probable shared use with joggers and other pedestri-



ans, use by large maintenance vehicles, steep grades, where bicycles will be likely to ride two abreast.

Reduced widths are acceptable on linkage paths. Because of their short length, they seldom allow bicyclists to operate at full speed, and because of low traffic volumes they seldom result in conflicts. However, whenever possible, linkage paths should comply with the minimum width standards presented here.

One directional bike paths are not recommended since they will usually be used as two-way facilities and should be designed accordingly.

A minimum of 2 feet (0.6 m) width graded area should be maintained adjacent to both

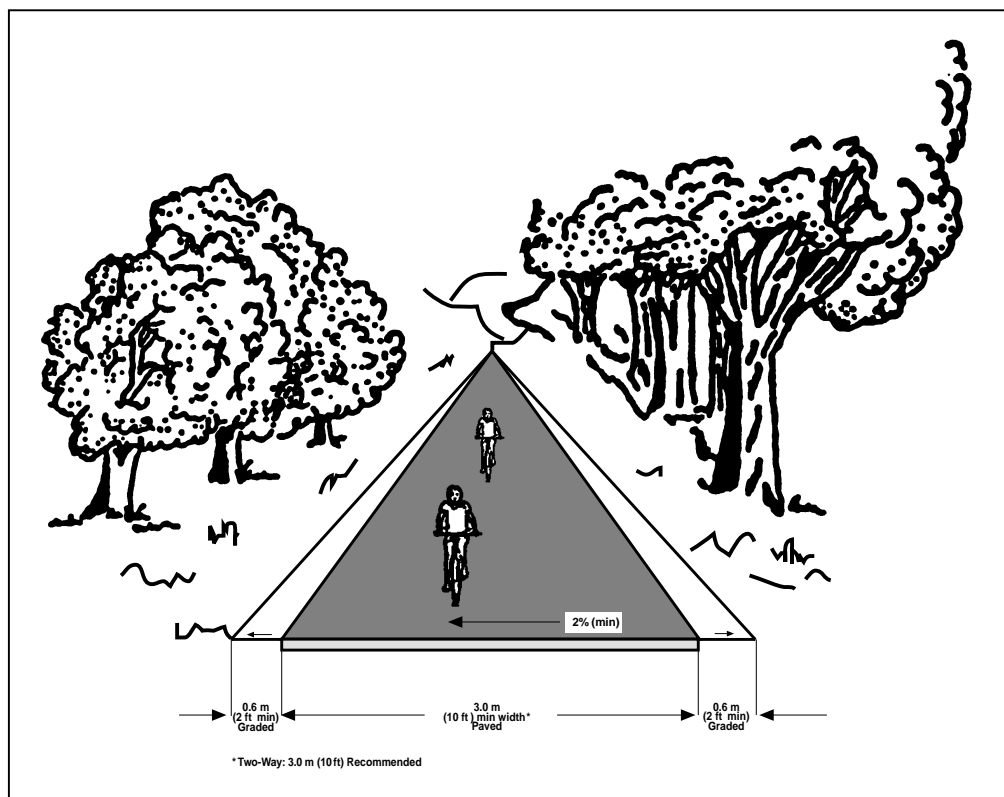


Figure 36

Bicycle Path on Separated Right-of-Way

Source: Adapted from *Guide for the Development of Bicycle Facilities*, AASHTO, 1991

sides of the pavement, however, 3 feet (0.9 m) or more is desirable to provide clearance from trees, poles, walls, fences, guardrail, or other lateral obstructions. A wider graded area on either side of the bicycle path can serve as a separate jogging path.

The vertical clearance to obstructions should be a minimum of 8 feet (2.4 m). However, vertical clearance may need to be greater to permit passage of maintenance vehicles and, in undercrossings and tunnels, a clearance of 10 feet (3 m) is desirable for adequate vertical sky distance.

b. Horizontal Separation from Roadways

Ordinarily, bicycle paths are located where separate right-of-way is available. However, where a bike path is being considered within a roadway right-of-way, a wide separation between a bicycle path and adjacent highway is desirable to confirm both the bicyclist and the motorist that the bicycle path functions as an independent highway for bicycle traffic. In addition to physical separation, landscaping or other visual buffer is desirable. When this is not possible and the distance between the edge of the roadway and the bicycle path is less than 5 feet (1.5 m), a suitable physical divider may be considered. Such dividers serve both to prevent bicyclists from making unwanted move-



ments between the path and the highway shoulder and to reinforce the concept that the bicycle path is an independent facility. Where used, the divider should be a minimum of 4.5 feet (1.4 m) high, to prevent bicyclists from toppling over it, and it should be designed so that it does not become an obstruction or traffic hazard in itself.

c. Design Speed

The speed that a bicyclist travels is dependent on several factors, including the type and condition of the bicycle, the purpose of the trip, the condition and location of the bicycle path, the speed and direction of the wind, and the physical condition of the bicyclist. Bicycle paths should be designed for a selected speed that is at least as high as the preferred speed of the faster bicyclists. In general, a minimum design speed of 20 mph (32 km/h) should be used; however, when the grade exceeds 4 percent, a design speed of 30 mph (48 km/h) is advisable.

On unpaved paths, where bicyclists tend to ride slower, a lower design speed of 15 mph (24 km/h) can be used. Similarly, where the grades dictate, a higher design speed of 25 mph (40 km/h) can be used. Since bicycles have a higher tendency to skid on unpaved surfaces, horizontal curvature design should take into account lower coefficients of friction.

d. Horizontal Alignment and Superelevation

The minimum radius of curvature negotiable by a bicycle is a function of the superelevation rate of the bicycle path surface, the coefficient of friction between the bicycle tires and the bicycle path surface, and the speed of the bicycle. The minimum design radius of curvature can be derived from the following formula:

$$R = \frac{V^2}{15(e+f)}$$

where: R = Minimum radius of curvature (ft)

V = Design Speed (mph)

e = Rate of superelevation

f = Coefficient of friction

For most bicycle path applications the superelevation rate will vary from a minimum 2 percent (the minimum necessary to encourage adequate drainage) to a maximum of approximately 5 percent (beyond which maneuvering difficulties by slow bicycles and adult tricyclist might be expected). The minimum superelevation rate of 2 percent will be adequate for most conditions and will simplify construction.

The coefficient of friction depends upon speed; surface type, roughness, and condition; tire type and condition; whether the surface is wet or dry. Friction factors used for design should be selected based upon the point at which centrifugal force causes the bicyclist to recognize a feeling of discomfort and instinctively act to avoid higher speed. Extrapolating from values used in highway design, design factors for paved bicycle paths can be assumed to vary from 0.30 at 15 mph (24 km/h) to 0.22 at 30 mph (48 km/h). Although there are not data available for unpaved surfaces, it is suggested that friction factors be reduced by 50 percent to allow a sufficient margin of safety.

Based upon a superelevation rate (e) of 2 percent, minimum radii of curvature can be selected from the following table.

When substandard radius curves must be used on bicycle 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.



Design Speed-V (mph) (1 mph=1.6 km/hr)	Friction Factor - f	Minimum Radius - R (Feet) (1'=0.3 m)
20	0.27	95
25	0.25	155
30	0.22	250
35	0.19	390
40	0.17	565

Table 3

e. Grade

Grades on bicycle paths should be kept to a minimum, especially on long inclines. Grades greater than 5 percent are undesirable because the ascents are difficult for many bicyclists to climb and the descents cause some bicyclists to exceed the speeds at which they are competent. Where terrain dictates, grades over 5 percent and less than 500 feet (150 m) long are acceptable when a higher design speed is used and additional width is provided. Grades steeper than 3 percent may not be practical for bicycle paths with crushed stone surfaces.

f. Switchbacks

In areas of extremely steep terrain, a series of “switchbacks” may be the only solution to traversing changes in elevation. At these locations, a grade of 8 percent is acceptable for a distance of no longer than 30 meters (100 feet). Grades steeper than 8 percent will not meet *Americans with Disabilities Act* standards. Pavement width should be a minimum of 3.6 meters (12 feet) wide to allow ascending bicyclists to walk. The “switchbacks,” or turns should be completely visible from the uphill turn. Runouts at the end of each turn should be considered for bicyclists not able to stop. Railing should be installed to discourage shortcuts, and appropriate signing should be placed at the top of the descent.

g. Sight Distance

To provide bicyclists with an opportunity to see and react to the unexpected, a bicycle path should be designed with adequate stopping sight distance. The distance required to bring a bicycle to a full controlled stop is a function of the bicyclist's 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 bicycle.

Figure 37 indicates the minimum stopping sight distance for various design speeds and grades based on a to-

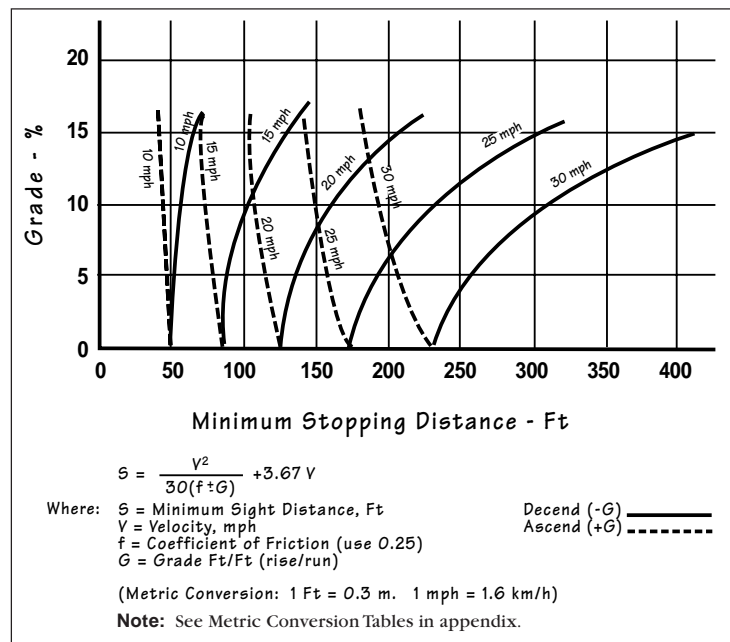


Figure 37
Minimum Stopping Sight Distance



Source: Guide for the Development of Bicycle Facilities, AASHTO, 1991

tal perception and brake reaction time of 2.5 seconds and a coefficient of friction of 0.25 to account for the poor wet weather braking characteristics of many bicycles. For two-way bicycle paths, the sight distance in descending direction, that is, where “G” is negative, will control the design.

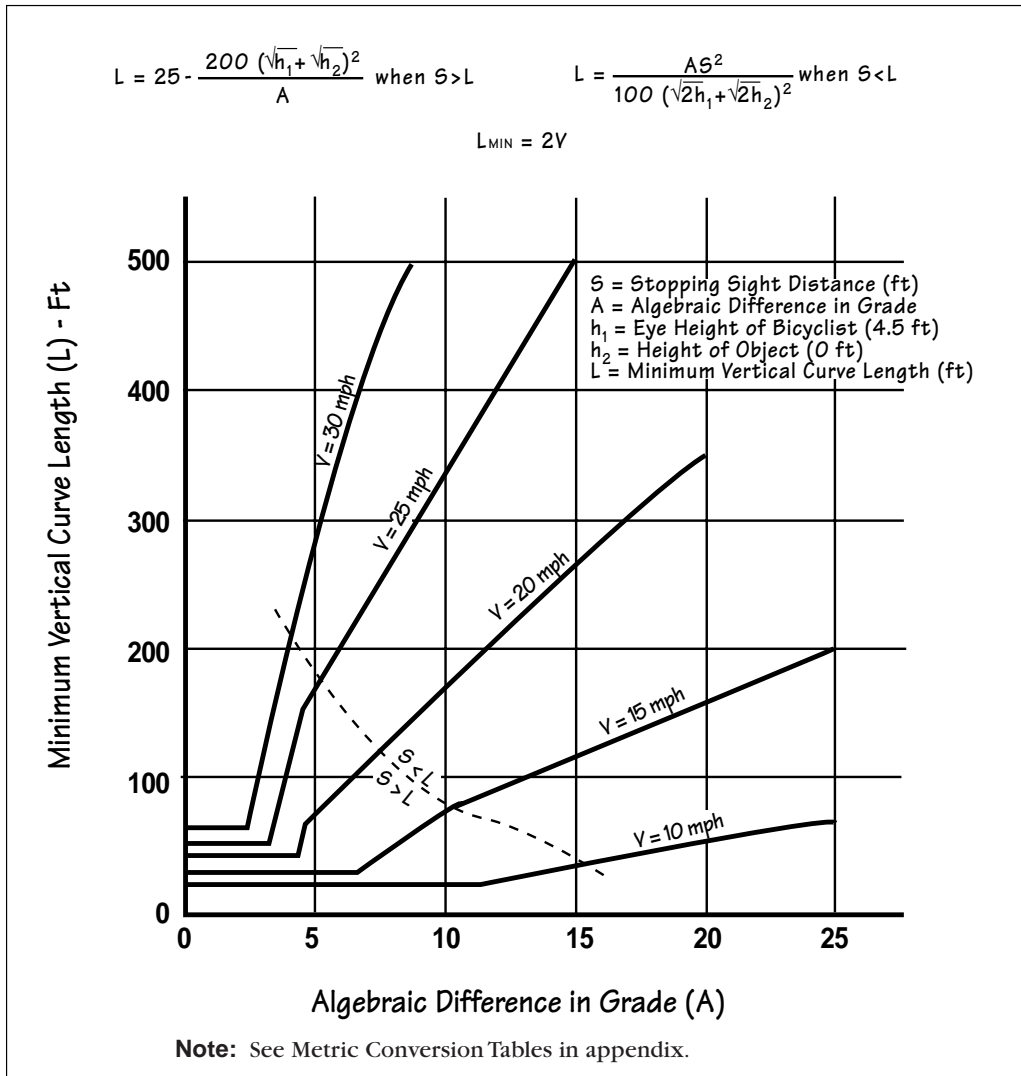
Figure 38 is used to select the minimum length of vertical curve necessary to provide minimum stopping distance at various speeds on crest vertical curves. The eye height of the bicyclist is assumed to be 4.5' (1.4 m) and the object height is assumed to be zero to recognize that impediments to bicycle travel exist at pavement level.

Figure 39 indicates the minimum clearance that should be used to line of sight obstructions for horizontal curves. The lateral clearance is obtained by entering Figure 39 with the stopping sight distance from Figure 37 and the proposed horizontal radius of curvature.

Bicyclists frequently ride abreast of each other on bicycle paths and, on narrow bicycle 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 accident, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distance for bicyclists traveling in opposite directions around the curve. Where this is not possible or feasible, consideration should be given to widening the path through the curve, installing a yellow center stripe, installing a curve ahead warning sign in accordance with the MUTCD, or some combination of these alternatives.

Figure 38

Minimum Length of Vertical Curves



Source: Guide for the Development of Bicycle Facilities, AASHTO, 1991

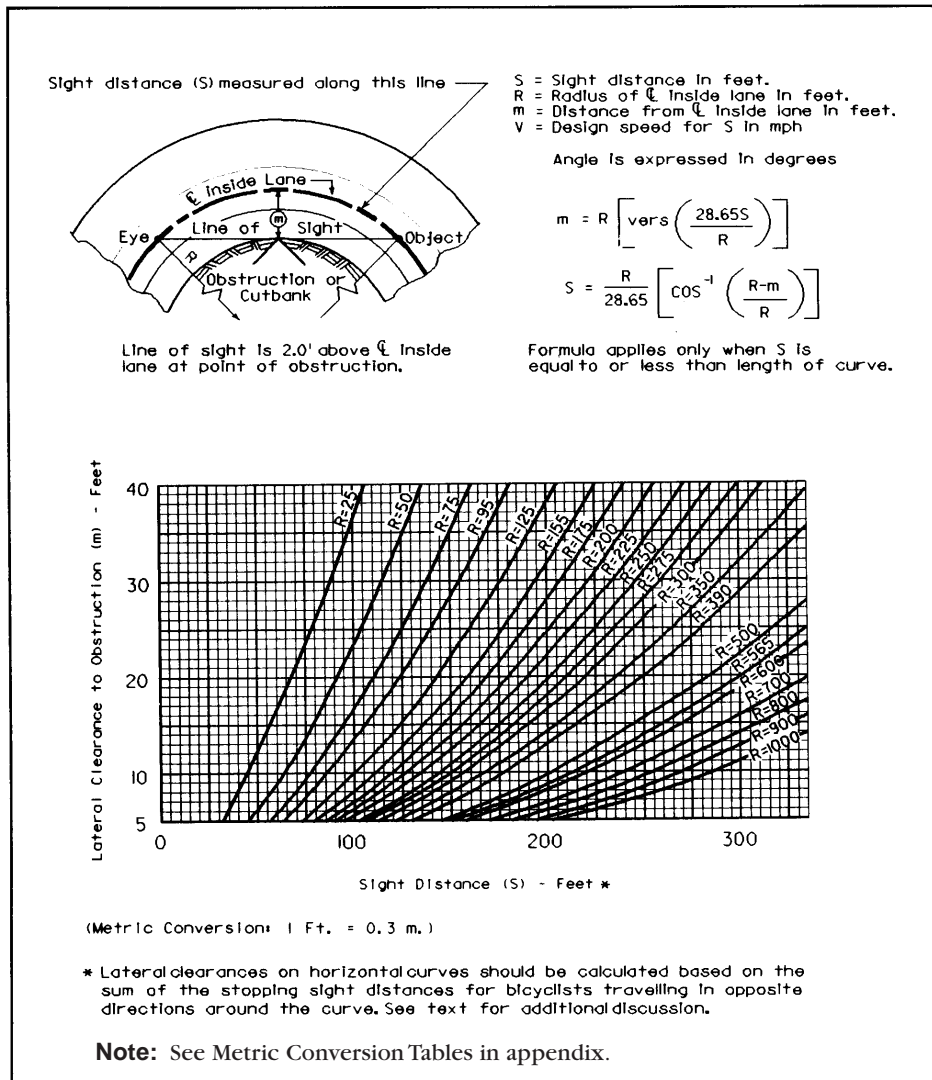


Figure 39
Minimum Lateral Clearances on Horizontal Curves

Source: *Guide for the Development of Bicycle Facilities*, AASHTO, 1991

h. Intersections

Intersections with roadways are important considerations in bicycle path design. If alternate locations for a bicycle path are available, the one with the most favorable intersection conditions should be selected. For crossings of 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 crossing highway, providing for turning movements must be considered.

When intersections occur at grade, a major consideration is the establishment of right of way. The type of traffic control to be used (signal, stop sign, yield sign, etc.), and location, should be provided in accordance with the MUTCD (see Figure 40).

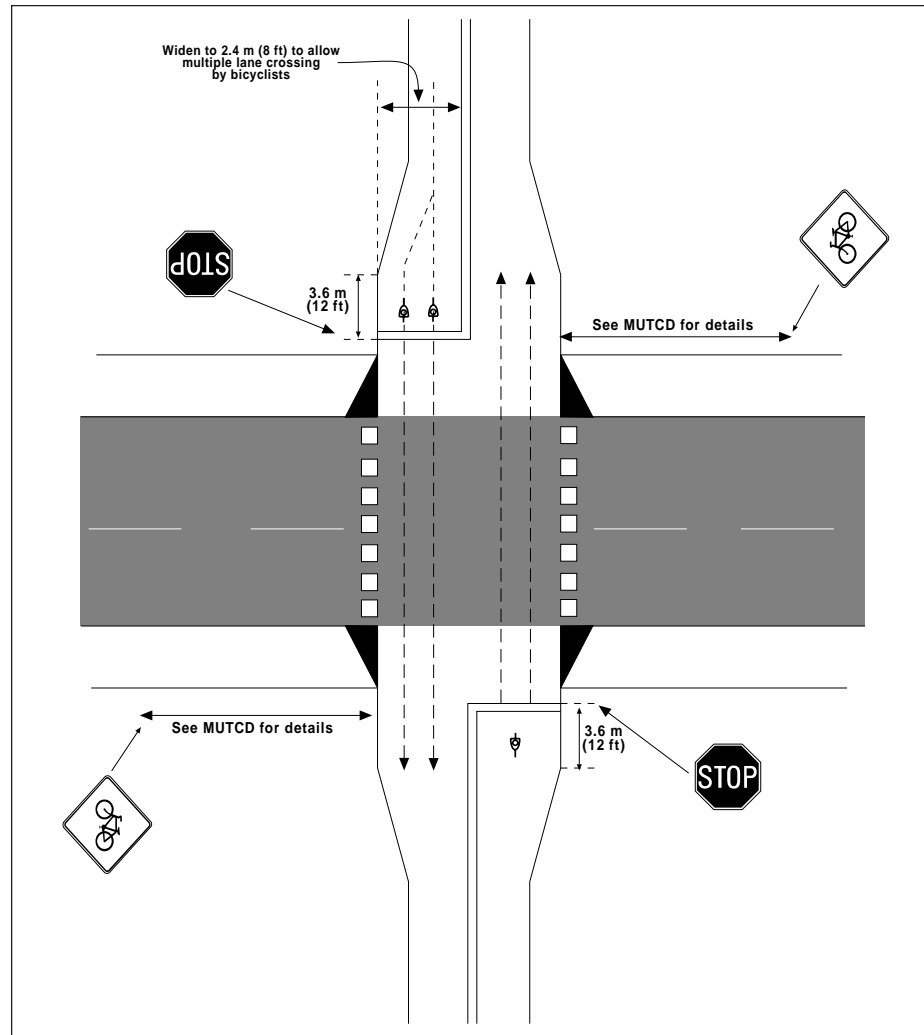
Sign type, size and location should also be in accordance with the MUTCD. Care should be taken to ensure that bicycle path signs are located so that motorists are not confused by them and that roadway signs are placed so that bicyclists are not confused by them.

Other means of alerting bicyclists of a highway crossing include grade changes or changing surfaces at the approach (see Figure 41). Devices installed to prohibit motorists from entering the bike path can also assist with alerting bicyclists to crossings.



Figure 40

Intersection of Bicycle Path
and 2 Lane Roadway



Source: Adapted from *Technical Handbook of Bikeway Design*, Velo, Quebec, 1992

It is preferable that the crossing of a bicycle path and a highway be at a location 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. Where physical constraints prohibit such independent intersections, the crossings may be at or adjacent to the pedestrian crossing. 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. 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.

When bicycle 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 a safe merging or diverging situation. Appropriate signing is necessary to warn and direct both bicyclists and motorists regarding these transition areas.

Bicycle path intersections and approaches should be on relatively flat grades. Stopping sight distances at intersections should be checked and ad-



equate warning should be given to permit bicyclists to stop before reaching the intersection, especially on downgrades.

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

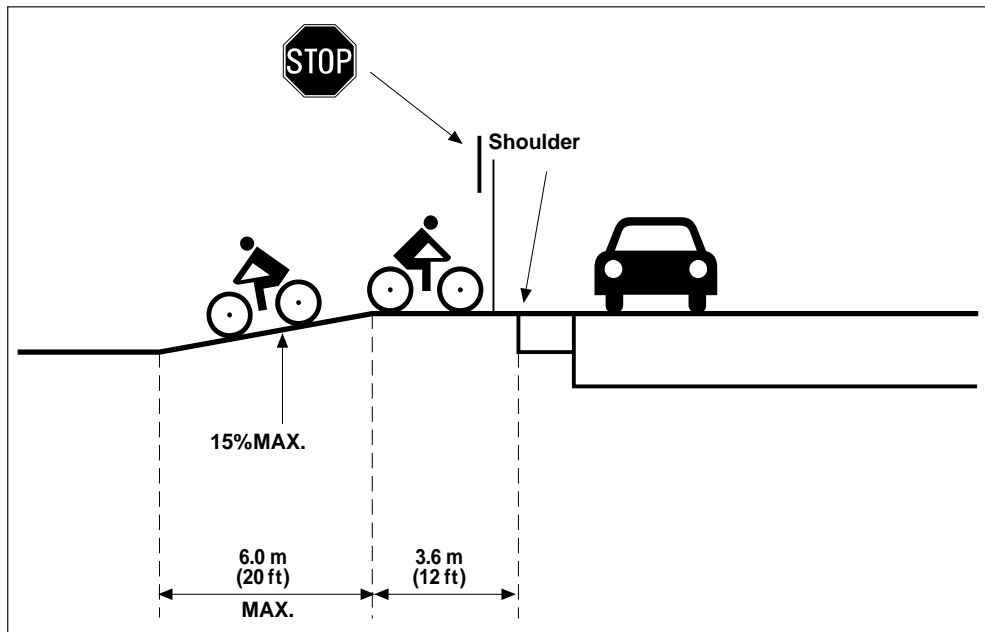


Figure 41

Highway Crossing Marked by Grade Change

Source: Adapted from *Technical Handbook of Bikeway Design*, Velo, Quebec, 1992

i. Signing and Marking

Adequate signing and marking are essential on bicycle paths, especially to alert bicyclists to potential conflicts and to convey regulatory messages to both bicyclists and motorists at highway intersections. In addition, guide signing, such as to indicate 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.

A designer should consider a 4 inch (10 cm) wide yellow centerline stripe to separate opposite directions of travel. This is particularly beneficial in the following circumstances: (1) for heavy volumes of bicycles; (2) on curves with restricted sight distances; and (3) on unlighted paths where nighttime riding is expected. Edge lines can also be very beneficial where nighttime bicycle traffic is expected.

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.

j. Pavement Structure

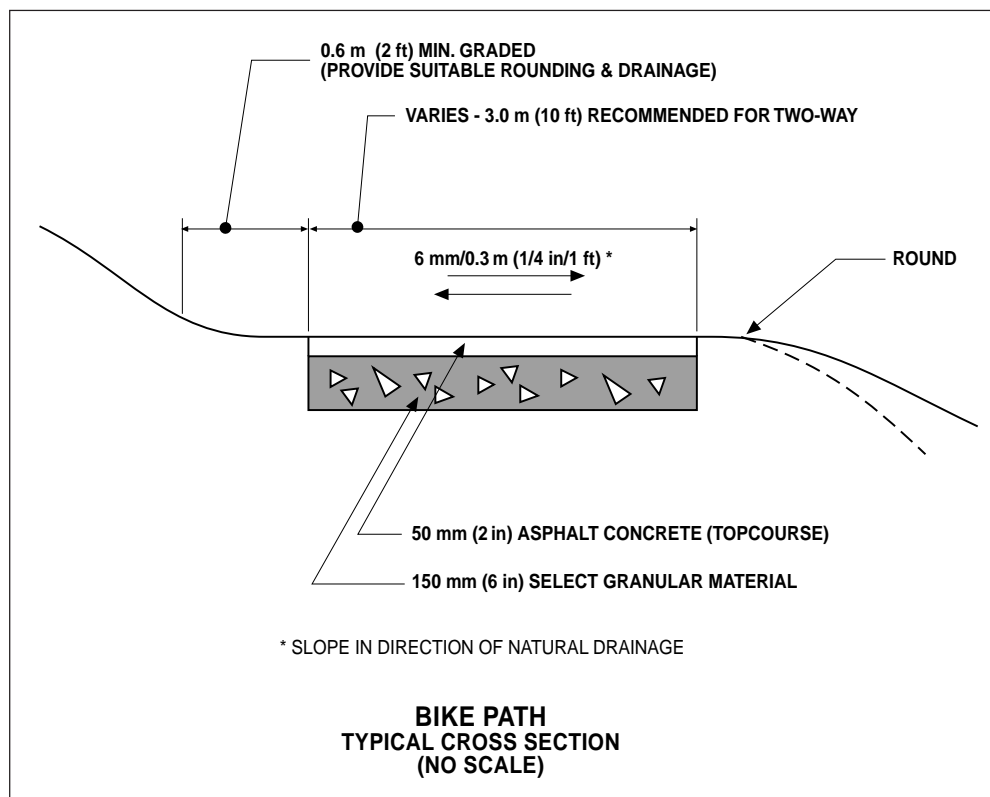
Under most circumstances, a 50 millimeter (2 inch) thick asphaltic concrete top course placed on a 150 millimeter (6 inch) thick select granular subbase is suitable for a bikeway pavement structure as shown in Figure 42. Where unsatisfactory soils



Table 4

Trail Surface Synopsis		
SURFACE MATERIAL	ADVANTAGES	DISADVANTAGES
Soil cement	Uses natural materials, more durable than native soils, smoother surface, low cost.	Surface wears unevenly, not a stable all-weather surface, erodes, difficult to achieve correct mix.
Granular stone	Soft but firm surface, natural material, moderate cost, smooth surface, accommodates multiple use.	Surface can rut or erode with heavy rainfall, regular maintenance to keep consistent surface, replenishing stones may be a long-term expense, not for steep slopes.
Asphalt	Hard surface, supports most types of use, all weather, does not erode, accommodates most users simultaneously, low maintenance.	High installation cost, costly to repair, not a natural surface, freeze/thaw can crack surface, heavy construction vehicles need access.
Concrete	Hardest surface, easy to form to site conditions, supports multiple use, lowest maintenance, resists freeze/thaw, best cold weather surface.	High installation cost, costly to repair, not a natural looking surface, construction vehicles will need access to the trail corridor.
Native soil	Natural material, lowest cost, low maintenance, can be altered for future improvements, easiest for volunteers to build and maintain.	Dusty, ruts when wet, not an all-weather surface, can be uneven and bumpy, limited use, not accessible.
Wood chips	Soft, spongy surface - good for walking, moderate cost, natural material.	Decomposes under high temperature and moisture, requires constant replenishment, not typically accessible, limited availability.
Recycled materials	Good use of recyclable materials, surface can vary depending on materials.	High purchase and installation cost, life expectancy unknown.



**Figure 42**Bikeway Pavement
StructureSource: Adapted from *Highway Design Manual*, New York State Department of Transportation

can be anticipated, a soil investigation should be conducted to determine the load carrying capabilities of the native soil and the need for any special provisions.

In addition, there are several principles that should be followed to recognize some basic differences between the operating characteristics of bicycles and those of motor vehicles. While loads on bicycle paths will be substantially less than highway loads, paths should be designed to sustain without damage wheel loads of occasional emergency, patrol, maintenance, and other motor vehicles that are expected to use or cross the path.

Conditions where additional pavement structure may be necessary are flood plains, and locations where shallow root systems will upheave a thin pavement section.

Special consideration should be given to the location of motor vehicle wheel loads on the path. When motor vehicles are driven on bicycle 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 operating width of the path, adequate edge support should be provided. Edge support can be either in the form of stabilized shoulders or in constructing 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 and second, the additional construction cost can be less than for constructing shoulders because the separate construction operation is eliminated.

It is important to construct and maintain a smooth riding surface on bicycle paths. Bicycle path pavements should be machine laid; root barriers should be used where necessary to prevent vegetation from erupting through the pavement; and, on portland cement concrete pavements, transverse joints, necessary to control cracking, should be sawcut to provide a smooth ride. On the other hand, 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.

In areas where climates are extreme, the effects of freeze-thaw cycles should be anticipated in the design phase. At unpaved highway or driveway crossings of bicycle 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.

When a bike path is part of a multi-use trail facility, alternative pavement structure may be appropriate. Particularly because of today's wide profile tires found on hybrid and all-terrain bikes, more bicycles are able to use this surface.

k. Structures

An overpass, underpass, small bridge, drainage facility or facility on a highway bridge may be necessary to provide continuity to a bicycle path. An example of a small bridge structure used to provide bicycle continuity is shown in Figure 43. A bicycle facility on a highway structure is shown in Figure 44.

Figure 43

Bridge Structure to Provide Bicycle Path Continuity



Source: *Guide for the Development of Bicycle Facilities*, AASHTO, 1991

A bicycle facility on a highway structure is shown in Figure 44.

On new structures, the minimum clear width should be the same as the approach paved bicycle path; and the desirable clear width should include the minimum 2 foot (0.6 m) wide clear areas. Carrying the clear areas across the structures has two advantages. First, it provides a minimum horizontal shy distance from the railing or barrier; and 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 bicycle paths. Similarly, vertical clearance may be dictated by occasional motor vehicles using the path. Where practical,

a vertical clearance of 10' (3 m) is desirable for adequate vertical shy distance.

Railings, fences, or barriers on both sides of a bicycle path structure should be a minimum of 4.5' (1.4 m) high. Smooth rub rails should be attached to the barriers at handlebar height of 3.5' (1.1 m).

Bridges designed exclusively for bicycle 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 bicycle 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 bicycle path across the bridge on one side. This should be done where (1) the bridge facility will connect to a bicycle path at both ends; (2) sufficient width exists on that side of the bridge or can be obtained by widening or restriping lanes; and (3) provisions are made to physically separate bicycle traffic from motor vehicle traffic as discussed above.

A second option is to provide either wide curb lanes or bicycle lanes over the bridge. This may be advisable where (1) the bicycle path transitions into bicycle lanes at one end of the bridge; and (2) sufficient width exists or can be obtained by widening or restriping.

A third option is to use existing sidewalks as one-way or two-way facilities. This may be advisable where (1) conflicts between bicyclists and pedestrians will not exceed tolerable limits; and (2) the existing sidewalks are adequately wide. Under certain conditions, the bicyclist may be required to dismount and cross the structure as a pedestrian.

Because of the large number of variables involved in retrofitting bicycle facilities onto existing bridges, compromises in desirable design criteria are often inevitable. Therefore, the width to be provided is best determined by the designer, on a case-by-case basis, after thoroughly considering all the variables.



Source: *Guide for the Development of Bicycle Facilities*, AASHTO, 1991

Figure 44

Bicycle Facility on a Highway Structure

I. Drainage

The recommended minimum pavement cross slope of 2 percent 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 bicycle 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 in such a way that no undue obstacles are presented to bicyclists. Where necessary, catch basins with drains should be provided to carry the intercepted water under the path. Drainage grates and manhole covers should be located outside of the travel path of bicyclists. To assist in draining the area adjacent to the bicycle path, the design should include considerations for preserving the natural ground cover. Seeding, mulching, and sodding of adjacent slopes, swales, and other erodible areas should be included in the design plans.



m. Lighting

Fixed-source lighting reduces conflicts along the paths and at intersections. In addition, lighting allows the bicyclist to see the bicycle path direction, surface conditions, and obstacles. Lighting for bicycle paths is important and should be considered where riding at night is expected, such as bicycle paths serving college students or commuters, and at highway intersections. Lighting should also be considered through underpasses or tunnels, and when nighttime security could be a problem. Depending on the location, average maintained horizontal illumination levels of 0.5 foot candle (5 lux) to 2 foot-candles (22 lux) should be considered. Light standards (poles) should meet the recommended horizontal and vertical clearances. Luminaries and standards should be at a scale appropriate for a pedestrian or bicycle path.

n. Barriers to Motor Vehicle Traffic

Bicycle paths often need some type of physical barrier at highway intersections and pedestrian-load bridges to prevent unauthorized motor vehicles from using the facilities. Provisions can be made for a lockable, removable post to permit entrance by authorized vehicles. The post should be permanently reflectorized for nighttime visibility and painted a bright color for improved daytime visibility. When more than one post is used, a 5-foot (1.5 m) spacing is desirable. Wider spacing can allow entry to motor vehicles, while narrower spacing might prevent entry by adult tricycles and bicycles with trailers.

An alternate method of restricting entry of motor vehicles is to split the entry way into two 5 feet (1.5 m) sections separated by low landscaping. Emergency vehicles can still enter if necessary by straddling the landscape. The higher maintenance costs associated with landscaping should be acknowledged, however, before this alternative method is selected.



Chapter 5

Supplemental Facilities

Supplemental and ancillary support facilities for bicycles are important improvements for promoting increased bicycling transportation. Improvements such as bicycle parking at trip origins and destinations and rest areas along bicycle paths increase access and convenience to various locations.

Supplemental facilities can be developed in conjunction with bicycle compatible roadway improvements at key destinations such as transit centers, park and ride lots, shopping centers, downtown commercial areas, employment centers, schools and other public places. The 1991 AASHTO Guide for the Development of Bicycle Facilities recommends:

- promotion of bicycle parking facilities,
- provisions for interfacing bicycle travel with transit (bike-on-bus/rail),
- provisions for rest areas along bicycle paths, and
- development of bicycle maps.

1. Bicycle Parking and Storage Facilities

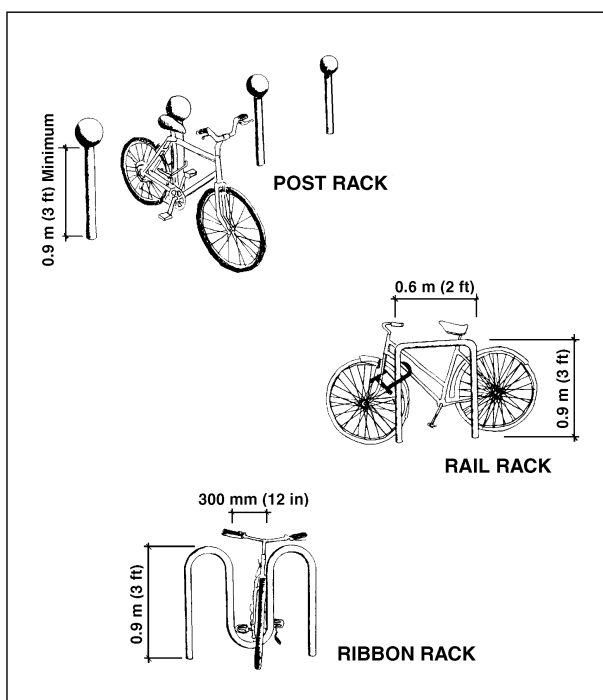
Use of a bicycle for personal transportation requires that the rider be able to park his or her bike. All facilities which provide parking to the public should provide parking for bicycles at the rate of one bicycle parking space per 10 automobile parking spaces for the first 100 parking stalls and one bicycle space for every 20 beyond that.

Guidelines for selecting and siting bicycle parking facilities may vary based on consideration of equipment types, location, and facility program administration and maintenance. Factors to be considered in all instances include the facility's compatibility with the type of site, security, ease of use, durability (weather and vandalism), accessibility and attractiveness.

a. Equipment Types

Bicycle racks and bicycle lockers are the basic equipment types. Different designs and manufacturers are readily available. Bicycle racks generally meet short-term parking needs. They are convenient for brief stops at shopping centers, libraries, post offices and other locations and are simple to use. Typical rack types are shown in Figure 45.

Bicycle lockers are suited for locations that must accommodate long-term bicycle storage needs such as at transit centers, park and ride lots, schools, employment centers and multifamily residential developments.



Source: *Trails for the Twenty-First Century*, 1993

Figure 45

Bicycle Rack Types

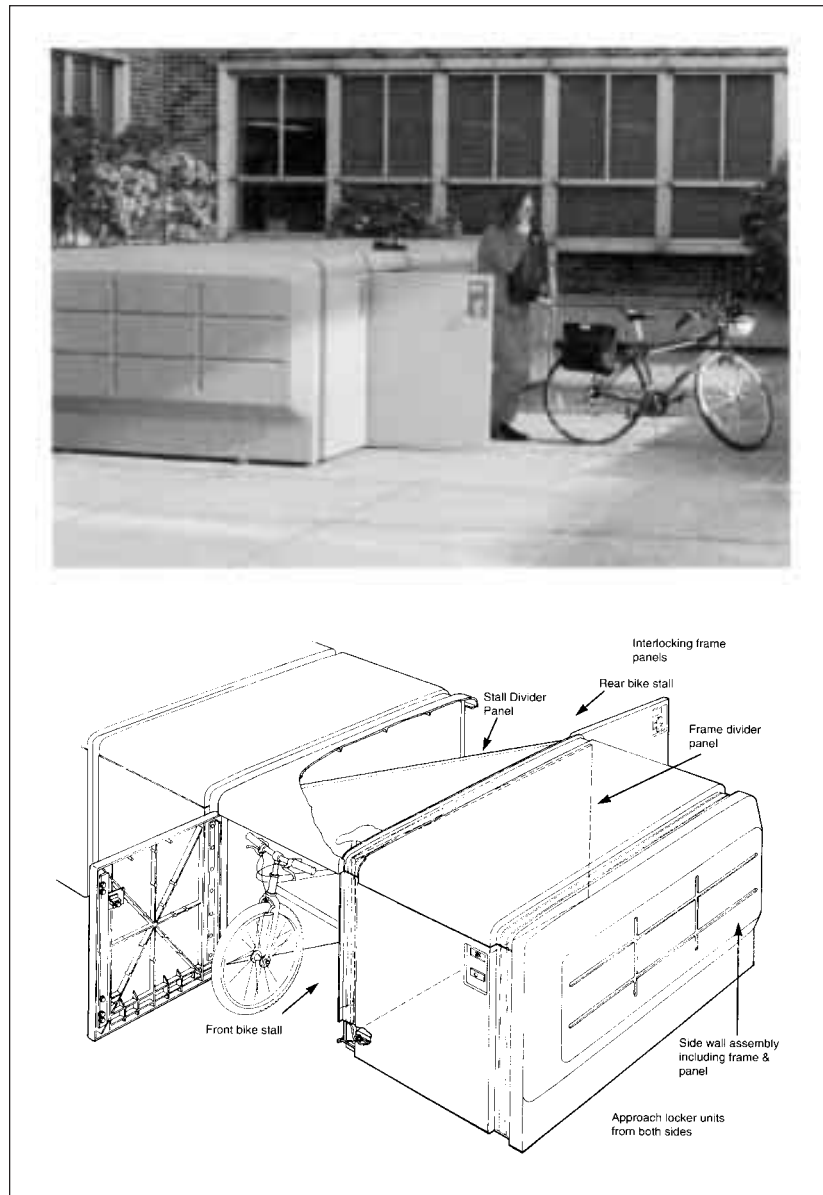


They are typically used by commuters and offer secure storage space and protection for accessories. Lockers usually require a rental or lease program and/or key distribution system and must be monitored and maintained. Locker designs include options for double-sided access with interior partitions and can be purchased in different type groupings and numbers of units (see Figure 46).

In some cases, a combination of both lockers for long-term storage and racks for quick, easy access should be provided at the same location to meet the needs of different types of users.

Figure 46

Bicycle Lockers



Source: Cycle Safe, Inc.

b. Location and Siting of Facilities

Short-term parking facilities, generally bicycle racks, should be highly visible and easily accessible and should be provided at entrances to destinations like libraries, downtown commercial areas, post offices, parks and other public spaces. Wherever possible, bicycle racks should be located under a shelter.



Long-term facilities such as bicycle lockers should be located in secure, easily monitored locations. At transit centers lockers should be placed near boarding locations and be separated from motor vehicle parking areas. Lockers at employment centers should be located near building entrances. In all cases, access to bicycle lockers should be convenient but must not interfere with pedestrian flow or traffic.

Siting of parking facilities should be coordinated with bicycle compatible routes or bikeways that lead to the location. Retrofit of existing motor vehicle parking lots or garages may also offer opportunities to create safe and convenient locations for bicycle storage facilities. Other design elements to consider are the installation of signs that instruct users how to use and operate the parking facility. Appropriate signage directing bicyclists to parking areas, curb ramps, lighting and overhead canopies should be considered in the design of the bicycle parking facility.

c. Facility Operation and Maintenance

Programs for operation and maintenance of bicycle parking facilities vary, depending on equipment types and locations. Bicycle racks generally require minimal maintenance and are easily operated by users. No advance rental or lease system is required. Bicycle lockers are usually leased or rented for longer time periods. A management program for leasing and key distribution must be established. For example, often transit agencies contract out to local jurisdictions or businesses at the station area to administer the locker operations. The transit agency generally provides, installs and services or maintains the units. There are also other variations in administrative programs which offer different degrees of involvement by either the transit agency or local jurisdictions.

Bicycle parking facility programs should also consider provisions for showers and lockers at employment destinations to encourage more commuters.

2. Bicycle-on-Transit

Provisions for bicycles on buses or rail can include racks on buses or on-board areas on either buses or trains.

Guidelines for considering such programs and facilities depend on service area characteristics and equipment types. In urban areas, high transit ridership and limited space on trains often limits the carrying capacity for bicycles. However, there are locations with service area characteristics that are favorable for such programs. These include transit systems with off-peak, reverse commuters where adequate space for bicycles is available; destinations and routes associated with recreation areas, shore areas, hotels and tourism where demand is higher; colleges and university settings; and air quality attainment areas which often can qualify for funding for such projects.

3. Shelters/Rest Areas/Comfort Stations

Support facilities on bicycle paths or multi-purpose trails are improvements that promote bicycle use. On long, uninterrupted bicycle paths amenities should include minor and major comfort stops. Minor facilities may include shade shelters or informational maps. Major facilities should provide restrooms, water or other conveniences.

Shelters at minor facilities can include roofed structures with protected seats. They should be set back from bicycle path traffic, located away from obstructions that can obscure visibility and



Figure 47

Typical Shelter

Source: *Trails for the Twenty-First Century*, 1993

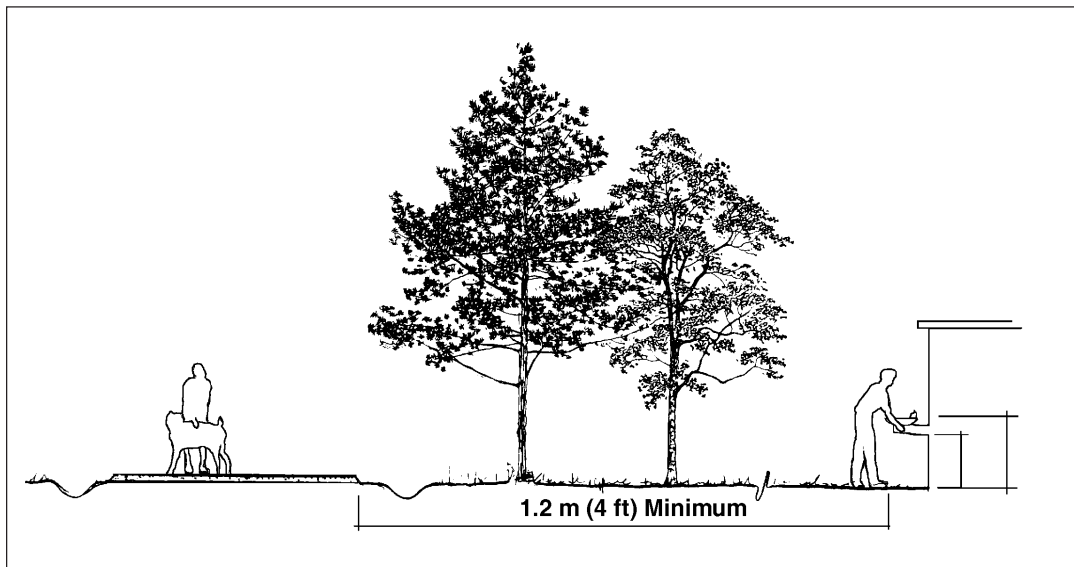
cause safety concerns, and positioned to ensure protection from prevailing winds (see Figure 47).

Facilities can be located at access points of the bicycle path that help link the path to communities and surrounding land uses and destinations such as transit centers, parks, and parking areas. Full-service shelters and rest areas should meet local design

and ADA standards relating to water and sewage utility connections and restroom accessibility. Water services can include drinking fountains designed with spigots to fill water bottles (see Figure 48).

Figure 48

Rest Area Facilities

Source: *Trails for the Twenty-First Century*, 1993

Chapter 6

Operations and Maintenance

1. Operations and Maintenance

The condition of the roadway surface is an important element in both bicycle safety and level of service. In general, due to their high pressure, narrow profile tires, lack of suspension, and need to maintain balance, bicycles require a higher standard of road maintenance than motor vehicles. Potholes, bumps, seams, and debris — which can be of minor annoyance or no consequence whatever to motor vehicles — are potential hazards to bicycle traffic as these obstacles can cause loss of control of the bicycle, or cause the bicyclist to risk conflict with motor vehicle traffic by swerving to avoid the obstacle.

For the above-mentioned reason, the roadway surface on which bicycles normally operate should be maintained free of potholes, bumps, corrugations, seams, unravelled pavement edges, gravel, glass fragments, and any other debris or obstacles that mar a smooth riding surface. The area involved includes the right portion of the outside travel lane plus any additional space. Typically, this portion of the roadway gets less attention as maintenance efforts are concentrated on the portion of the roadway used by motor vehicles.

Maintenance repairs in this area should be carried out with the needs of the bicycle in mind; i.e., they should be done in a workmanlike fashion with particular attention to providing a smooth pavement surface.

The following actions are recommended by the 1991 AASHTO Guide for the Development of Bicycle Facilities as requirements in the operation and maintenance of bicycle facilities.

- Create a smooth surface free of potholes and debris.
- Eliminate dropoffs from pavement edges.
- Inspect pavement conditions - do not allow unravelled pavement edges.
- Inspect signs - making certain that signs do not intrude into bicycle travel space.
- Control growth of trees, shrubs, and vegetation.
- Supply trash and recycling receptacles and be sure they are regularly emptied.
- Mow areas in the vicinity of bike paths.
- Plow snow - do not use deicing agents.
- Enforce and prevent unauthorized motor vehicles from using the path.
- Maintain bicycle and shoulder lane stripings and markings.
- Establish an agency responsible for the control, maintenance, and policing of bicycle facilities.

Maintenance of roadways to accommodate bicycle traffic does not usually require changes in the types of maintenance activities that are carried out; rather it requires changes in the focus of maintenance practices. Where possible, maintenance, repair and litter removal activities should be shifted to include, not to ignore, roadway margins and shoulders.



The use of a shared lane will limit the amount of grit and debris that collects in the bicycle operating (lane sharing) area, as motor vehicle traffic will “sweep” this area clean. When shoulders are assumed to be the appropriate area for bicycle operation, it is essential to regularly sweep the shoulder area. All shoulders should be swept at least monthly. On highways where gravel or other debris can be anticipated to accumulate, more frequent sweeping will be required. This will be especially important on highways carrying a large number of gravel, construction or trash hauling vehicles.



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29. Untermann, Richard K., Accommodating the Pedestrian: Adapting Towns and Neighborhoods for Walking and Bicycling, Van Nostrand Reinhold Co., Seattle, WA, 1984.30.
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Excerpt From the NJDOT Guide to Metrication

CONVERSION FACTORS

GENERAL				
Quantity	From English Units	To Metric Units	Metric Symbol	Multiply By
Length	inch	millimeter	mm	<u>25.4</u>
	foot	millimeter	mm	<u>304.8</u>
	foot	meter	m	<u>0.304 8</u>
	foot (U.S. Survey) *	meter	m	0.304 800 6
	yard	meter	m	<u>0.914 4</u>
	mile	kilometer	km	<u>1.609 344</u>
Area	square inch	square millimeter	mm ²	<u>645.16</u>
	square foot	square meter	m ²	<u>0.092 903</u>
	square yard	square meter	m ²	<u>0.836 127 4</u>
	acre	square meter	m ²	4 046.856
	acre	hectare	ha	0.404 685 6
	square mile	square kilometer	km ²	2.590 000
Volume	fluid ounce	milliliter	ml	29.573 53
	quart	liter	L	0.946 352 9
	gallon	liter	L	3.785 412
	gallon	cubic meter	m ³	0.003 785 412
	cubic inch	cubic millimeter	mm ³	<u>16 387.064</u>
	cubic foot	cubic meter	m ³	0.028 316 85
	cubic yard	cubic meter	m ³	0.764 555
	acre-foot	cubic meter	m ³	1 233.482
Temperature	degree Fahrenheit	degree Celcius	°C	5/9 (*F-32)
Velocity	feet per second	meters per second	m/s	<u>0.304 8</u>
	miles per hour	kilometers per hour	km/h	<u>1.609 344</u>
Rate of application	gallon per square foot	liter per square meter	L/m ²	41.132 19
	gallon per square yard	liter per square meter	L/m ²	4.527 317
	gallon per acre	liter per hectare	L/ha	9.353 925
	gallon per acre	cubic meter per hectare	m ³ /ha	0.009 353 925
	1 000 gallons per acre	cubic meter per hectare	m ³ /ha	9.353 925
Slope	foot per foot	meter per meter	m/m	<u>1.0</u>
	foot per mile	meter per meter	m/m	0.000 189 4
Discharge	cubic foot per second	cubic meter per second	m ³ /s	0.028 316 85

- Underlined factors in the table denote exact numbers.
- Use the number of digits needed for the required accuracy.
- When converting from metric units to English divide by the factor shown (multiply by the inverse).
- Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.
- * U.S. Survey Foot: In 1893, the U.S. foot was legally defined as 1200/3937 meters. In 1959, a refinement was made to bring the foot into agreement with the definition used in other countries, i.e., 0.304 8 meters. At the same time, it was decided that any data in feet derived from and published as a result of geodetic surveys within the U.S. would remain with the old standard, which is named the U.S. Survey foot. The new length is shorter by exactly two parts in a million.



CONVERSION FACTORS

CIVIL AND STRUCTURAL ENGINEERING				
Quantity	From English Units	To Metric Units	Metric Symbol	Multiply By
Mass	ounce	kilogram	kg	0.028 349 52
	pound	kilogram	kg	0.453 592
	ton (2,000 lb)	megagram	Mg	0.907 184
Mass per unit length	pound per inch	kilogram per meter	kg/m	17.857 97
	pound per foot	kilogram per meter	kg/m	1.488 16
Mass per unit area	pound per square foot	kilogram per square meter	kg/m ²	4.882 43
	ton (2,000 lb) per square foot	megagram per square meter	Mg/m ²	9.764 856
Mass density	pound per cubic foot	kilogram per cubic meter	kg/m ³	16.018 46
	pound per cubic yard	kilogram per cubic meter	kg/m ³	0.593 276
	ton (2,000 lb) per cubic yard	megagram per cubic meter	Mg/m ³	1.186 554
Force	pound	newton	N	4.448 222
	kip	kilonewton	kN	4.448 222
	ton (2,000 lb)	kilonewton	kN	8.896 444
Force per unit length	pound per inch	newton per meter	N/m	175.126 8
	pound per foot	newton per meter	N/m	14.593 90
	kip per foot	kilonewton per meter	kN/m	14.593 90
	ton (2,000 lb) per foot	kilonewton per meter	kN/m	28.187 80
Force per unit area, pressure, stress, modulus of elasticity	pound per square inch	kilopascal	kPa	6.894 757
	kip per square inch	megapascal	MPa	6.894 757
	kips per square inch	gigapascal	GPa	0.006 894 757
	pound per square foot	kilopascal	kPa	0.047 880 26
	kip per square foot	megapascal	MPa	0.047 880 26
Bending moment, torque, moment of force	pound inch	newton meter	N · m	0.112 984 8
	pound foot	newton meter	N · m	1.355 818
Moment of mass	pound foot	kilogram meter	kg · m	0.138 255
Moment of inertia	inch to the fourth power	millimeter to the fourth power	mm ⁴	416 231 .
Section modulus	inch cubed	millimeter cubed	mm ³	<u>16 387.064</u>

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- Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.



CONVERSION FACTORS

ELECTRICAL ENGINEERING			
From English Units	To Metric Units	Metric Symbol	Multiply By
abampere	ampere	A	<u>10.</u>
abcoulomb	coulomb	C	<u>10.</u>
abfarad	farad	F	<u>10⁹</u>
abhenry	henry	H	<u>10⁹</u>
abmho	siemens	S	<u>10⁹</u>
abohm	ohm	Ω	<u>10⁻⁹</u>
abvolt	volt	V	<u>10⁻⁸</u>
ampere hour	coulomb	C	<u>3 600.</u>
EMU of capacitance	farad	F	<u>10⁹</u>
EMU of current	ampere	A	<u>10.</u>
EMU of electric potential	volt	V	<u>10⁻⁸</u>
EMU of inductance	henry	H	<u>10⁻⁹</u>
EMU of resistance	ohm	Ω	<u>10⁻⁹</u>
ESU of capacitance	farad	F	1.112 650 × 10 ⁻¹²
ESU of current	ampere	A	3.335 6 × 10 ⁻¹⁰
ESU of electric potential	volt	V	299.79
ESU of inductance	henry	H	8.987 554 × 10 ¹¹
ESU of resistance	ohm	Ω	8.987 554 × 10 ¹¹
faraday (based on carbon-12)	coulomb	C	96 487.0
faraday (chemical)	coulomb	C	96 495.7
faraday (physical)	coulomb	C	96 521.9
footcandle	lux	lx	10.763 91
footlambert	candela per square meter	cd/m ²	3.426 259
gamma	tesla	T	<u>10⁻⁹</u>
gauss	tesla	T	<u>10⁻⁴</u>
gilbert	ampere	A	0.795 774 7
horsepower (electric)	watt	W	<u>746.0</u>
kilowatt hour	joule	J	3 600 000.
lumen per square foot	lumen per square meter	lm/m ²	10.763 91
maxwell	weber	Wb	<u>10⁻⁸</u>
mho	siemens	S	<u>1</u>
oersted	ampere per meter	A/m	79.577 47
ohm centimeter	ohm meter	Ω · m	<u>0.01</u>
ohm circular-mil per foot	ohm meter	Ω · m	1.662 426 × 10 ⁻⁹
statampere	ampere	A	3.335 640 × 10 ⁻¹⁰
statcoulomb	coulomb	C	3.335 640 × 10 ⁻¹⁰
statfarad	farad	F	1.112 650 × 10 ⁻¹²
stathenry	henry	H	8.987 554 × 10 ¹¹
statmho	siemens	S	1.112 650 × 10 ⁻¹²
statohm	ohm	Ω	8.987 554 × 10 ¹¹
statvolt	volt	V	299.792 5
unit pole	weber	Wb	1.256 637 × 10 ⁻⁷

Underlined factors in the table denote exact numbers.

Use the number of digits needed for the required accuracy.

When converting from metric units to English divide by the factor shown (multiply by the inverse).

Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.

