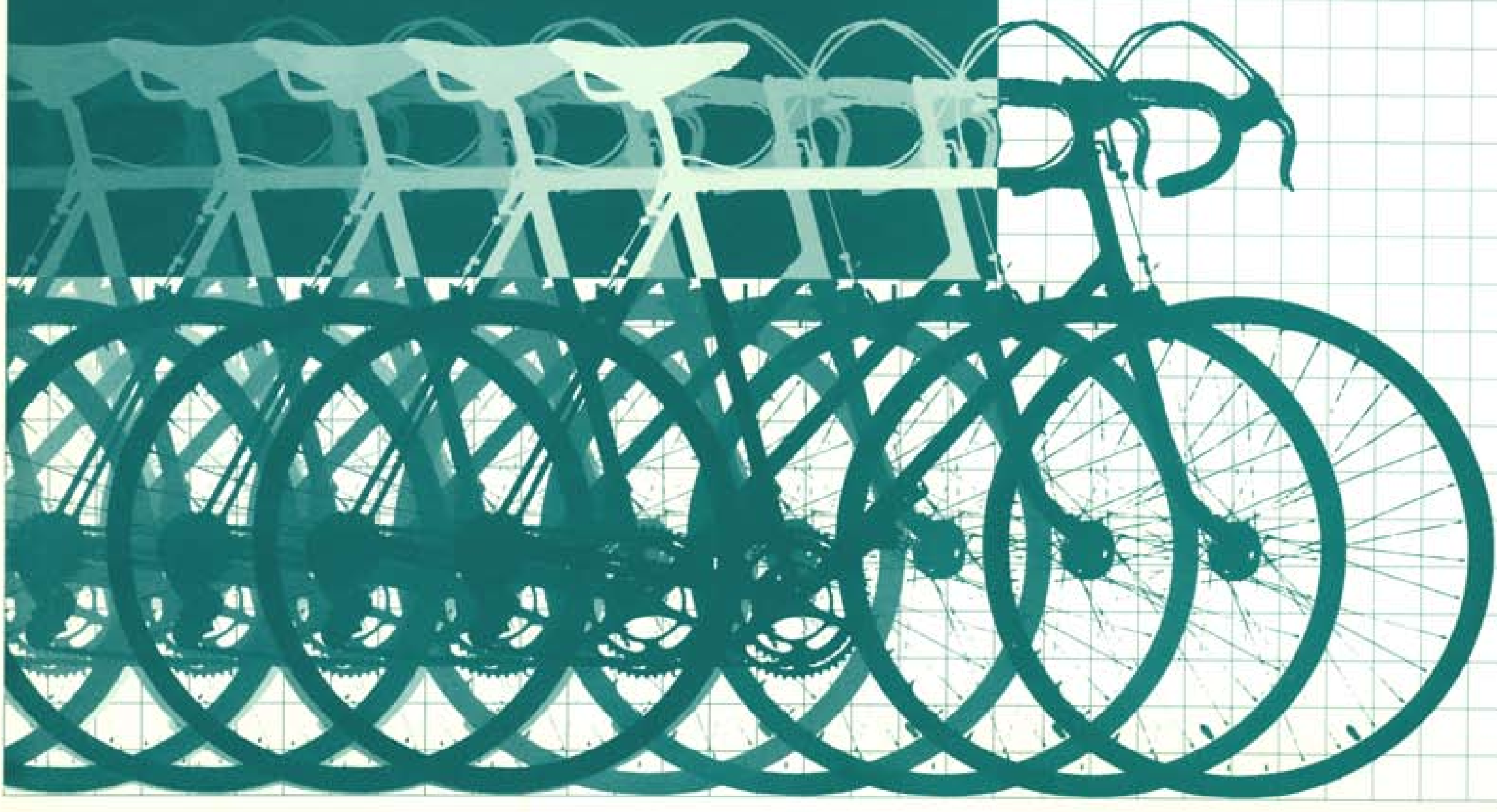
North Carolina Bicycle Facilities Planning And Design Guidelines

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION



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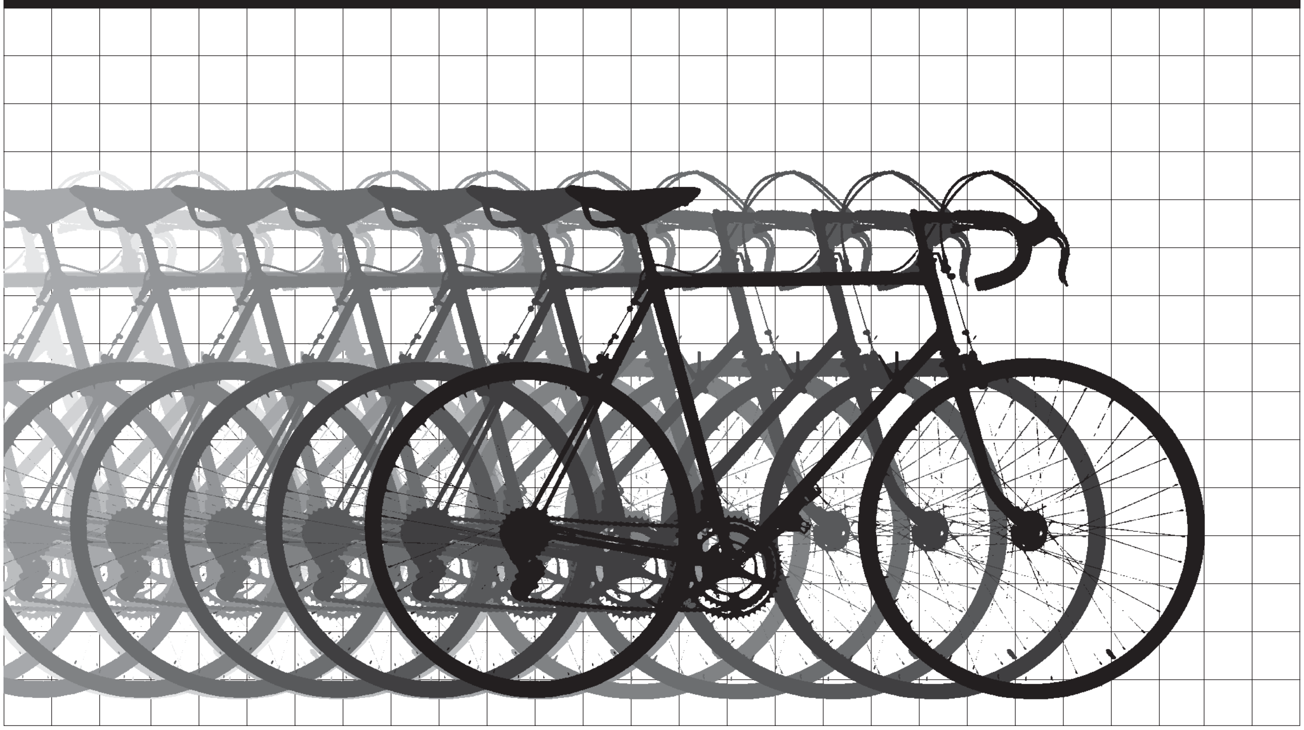

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This manual draws heavily upon several copyrighted publications of the American Association of State Highway and Transportation Officials (AASHTO), including the AASHTO Guide for the Development of New Bicycle Facilities (1981) and the AASHTO Guide for the Development of Bicycle Facilities (1991). The 1991 Guide updated and superseded the 1981 Guide, which is no longer available. Also drawn upon are the AASHTO Standard Specifications for Highway Bridges, Fourteenth Edition (1989), the AASHTO Roadside Design Guide (1989), and the AASHTO Maintenance Manual (1987). Permission to utilize material taken from and based upon these publications has been granted by AASHTO to the North Carolina Department of Transportation, solely for the purpose of publishing this manual. Information on how to obtain copies of these publications can be obtained by writing to: AASHTO, 444 N. Capitol St. NW, Suite 249, Washington D.C. 20001.

Parts of the manual are also based upon the Arizona Bicycle Facilities Planning & Design Guidelines (1988), the North Carolina Roadway Design Manual (1984), the Manual on Uniform Traffic Control Devices (1988), the Highway Capacity Manual (1985), and the Motor Vehicle Laws of North Carolina (1985).

North Carolina Bicycle Facilities Planning And Design Guidelines

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1 Introduction

Bicycling is a popular means of travel and recreation for a variety of people.

History

The bicycle has been around in some form since the early 1800s, when Baron von Drais of Germany developed his "Draisienne," a two-wheeled device with a saddle and a steering handlebar, but no pedals. During the 19th century, such features as pneumatic tires, gearing, pedals, and brakes were added to the point where the bicycle of the late 1800s looked much like the bicycle of today.

As breakthroughs in mass production techniques drove bicycle prices down and the bicycle became more popular, a major problem arose. The roads of the day were, for the most part, dirt trails. In foul weather, these became quagmires and bicyclists found riding difficult, if not impossible.

This problem led bicyclists to create and lead the "Good Roads Movement." One major thrust of this campaign was to build short stretches of all-weather paved roads around the country, demonstrating how such roads would improve transportation in America.

As the automobile's popularity grew during the first part of this century, the bicycle' s popularity declined, eventually becoming little more than a child's toy. However, since the late 1960s, adult bicycle use has grown dramatically. Today, millions of Americans use the bicycle to fulfill their transportation, recreational, fitness and utilitarian needs.

Planning for bicycle transportation

Since the early 1970s, agencies have worked to accommodate the growing number of bicyclists in their roadway planning and engineering. While early attempts were experimental in nature, over the years, designers have begun assembling an accepted body of field experience and theoretical knowledge. Although many questions remain to be answered, much has been learned.

Some examples of changes seen in the bicycle planning and engineering field in recent years are as follows:

- Early designers believed a 1.5 m (5 ft) wide two-way path was sufficient; today's two-way paths are at least 3.0 m (10 ft) wide.
- Early designers tried to separate bicycle and motor vehicle traffic; today, designers know that separation can increase crash rates when bicyclists and motorists surprise each other at intersections.
- Early curve design formulas gave a radius of less than 15 m (50 ft) for a 48 km/h (30 mph) curve; today's formula gives a radius of 75 m (250 ft).

Each year, cities throughout North Carolina request more and improved bicycle facilities. Many are actively developing networks of bicycle improvements and producing bicycle route maps.

The state has shown its support for bicycling through the Bicycle and Bikeway Act of 1974, which states that it is "in the public interest, health, safety and welfare for the state to encourage and provide for the efficient and safe use of the bicycle" and that "bikeways are a bona fide highway purpose, subject to the same rights and responsibilities, and eligible for the same considerations as other highway purposes and functions" [GS §136-71-8]. The state also sponsors one of the most active bicycle programs in the nation.

At the national level, the U.S. Department of Transportation under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), is more involved in bicycle planning and engineering projects than ever before. Among other provisions, ISTEA requires states and local agencies to include bicycle considerations in their overall transportation planning processes.

Definitions

The following terms are used throughout this manual. References from North Carolina General Statutes are included where applicable.

BICYCLE: A non-motorized vehicle with two or three wheels tandem, a steering handle, one or two saddle seats and pedals by which the vehicle is propelled [GS §20-171.1].

BICYCLE FACILITIES: A general term denoting improvements and provisions to accommodate or encourage bicycling, including parking facilities, maps, all bikeways and shared roadways.

BICYCLE LANE (BIKE LANE): A portion of a roadway which has been designated by striping, signing, and pavement markings for the preferential or exclusive use of bicyclists.

BICYCLE PATH (BIKE PATH): A bikeway physically separated from motorized vehicular traffic and either within the highway right-of-way or within an independent right-of-way.

BICYCLE ROUTE (BIKE ROUTE): A segment of a system of bikeways designated by the jurisdiction having authority with appropriate directional and informational markers, with or without a specific bicycle route number.

BIKEWAY: A thoroughfare suitable for bicycles – may either exist within the right-of-way of other modes of transportation, such as highways, or along a separate and independent corridor [GS 136-71.7].

HIGHWAY: The entire width between property or right-of-way lines of every way or place of whatever nature, when any part thereof is open to the use of the public as a matter of right for the purposes of vehicular traffic. The terms "highway" and "street" and their cognates are synonymous [GS §20-4.01 (13)].

RIGHT-OF-WAY: A general term denoting land, property, or interest therein, usually in a strip, acquired for or devoted to transportation purposes.

RIGHT OF WAY: The right of one vehicle or pedestrian to proceed in a lawful manner in preference to another vehicle or pedestrian.

ROADWAY: That portion of a highway improved, designed or ordinarily used for vehicular travel, exclusive of the shoulder. In the event a highway includes two or more separate roadways the term "roadway" as used herein shall refer to any such roadway separately but not to all such roadways collectively [GS §20-4.01 (38)].

SHARED ROADWAY: Any roadway upon which a bicycle lane is not designated and which may be legally used by bicycles regardless of whether such facility is specifically designated as a bikeway.

SHOULDER: That part of a highway which is contiguous to the regularly traveled portion of the highway and is on the same level as the highway; the shoulder may be pavement, gravel or earth.

SIDEWALK: The portion of a highway designed for preferential or exclusive use by pedestrians.

STREET: A highway as defined in subdivision (13) [see above]. The terms "highway" and "street" and their cognates are synonymous [GS §20-4.01 (46)].

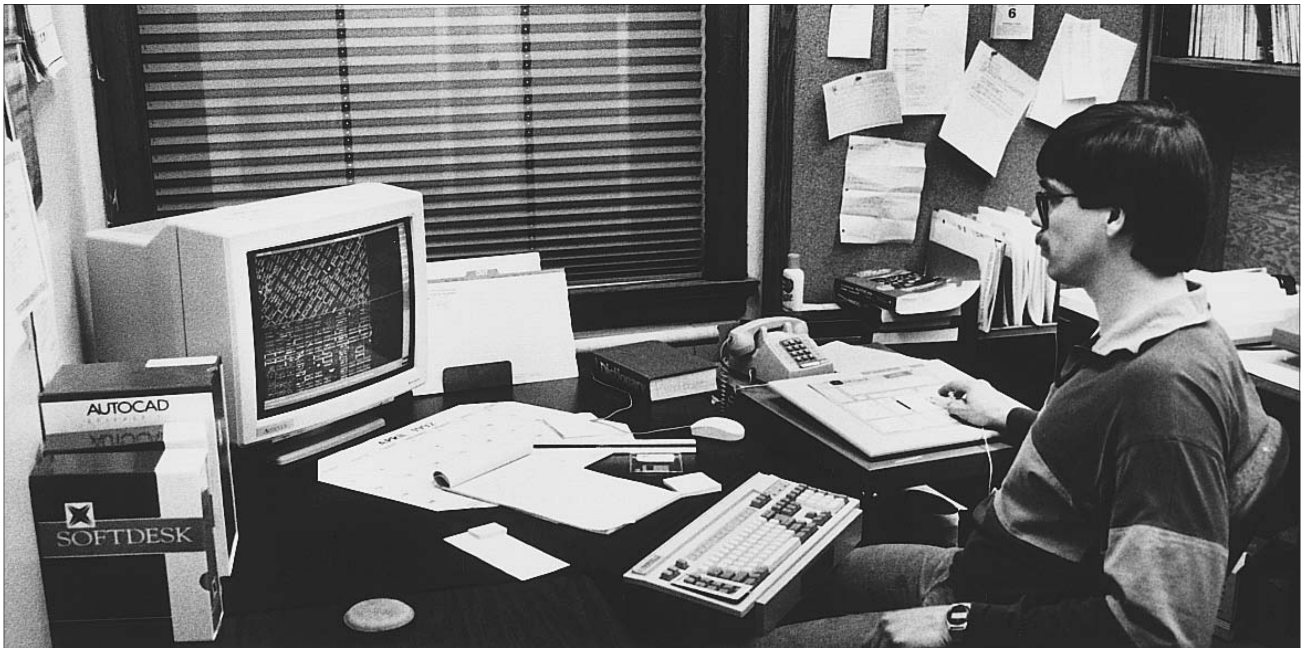
Purpose and scope

The purpose of this set of planning and design guidelines is to inform engineers, planners and other transportation officials of the planning and design considerations which are recommended for good bicycle facility design.

The information contained in this manual is a distillation of much of what has been learned in the past 20 years. The intention is to help designers avoid repeating mistakes made in the past.

These guidelines provide a uniform set of the most current planning and design considerations available for safe and effective bicycle facilities development, construction and maintenance.

2 Planning For Bicycle Use



Planning for bicycle use involves learning about and responding to the expressed needs and desires of bicycling and non-bicycling residents.

Introduction: the planning process

Planning for bicycle use involves learning about and responding to the expressed needs and desires of residents by encouraging a healthy, environmentally-beneficial activity - bicycle riding. The potential benefits of bicycling to the community include reductions in transportation-related energy use, traffic congestion, improved air quality and public health.

The process of planning for bicycle use can be simple or complex depending on the needs and scale of the community. But whatever the scope, the following steps are suggested when planning for bicycle use.

(1.) Develop goals and objectives
(2.) Develop the planning framework
(3.) Analyze local conditions
(4.) Develop the problem statement
(5.) Generate solution ideas
(6.) Develop overall plan and select solutions
(7.) Implement projects
(8.) Evaluate results and revise

Step 1: Develop goals and objectives

The first step in planning for bicycle use is to develop the agency's goals and objectives for bicycling. These should be as specific and measurable as possible. Measurable, specific goals can be achieved more readily than vague, general goals.

Potential goals and objectives: The agency's overall goal may be to encourage increased use of the bicycle for utilitarian and recreational purposes. More specific sub-goals would include ones similar to those listed below, but more detailed objectives giving performance measures and approximate time frames.

Goal 1. Hazard elimination: Identify bicycling hazards on all streets in the community and work for their elimination.

Goal 2. Barrier elimination: Identify barriers to bicycling on all streets in the community and work for their elimination.

Goal 3. Behavior improvement: Identify the most important bicycling and motoring behavioral problems, in terms of bike safety, and work to correct them.

Goal 4. Institutional enhancements: Identify governmental policies (e.g. parking ordinances) which may be changed to enhance bicycle use and add appropriate "pro-bicycling" language.

Step 2: Develop planning framework

Comprehensive bicycle planning: Comprehensive bicycle planning encompasses four areas: engineering, education, enforcement and encouragement (Figure 2-1). In this manual, bicycle facility improvements are discussed as they relate to engineering. However, it is important that local agencies develop cooperative strategies in all four areas to implement a truly comprehensive program.

An incomplete program can result in unachieved goals. For example, if an engineering agency provides bicycle facilities, which attract new bicyclists, but the police fail to enforce basic bicycle traffic laws (e.g., using lights at night, riding with traffic, obeying stop signs), there may be more people riding unlawfully and, possibly, more bicycle crashes. Creating a bicycle advisory committee with representatives from all involved agencies, as well as members of the public, can be one very good way of developing such a comprehensive approach.

Integration with other plans: Planning for bicycle transportation also should be integrated into the overall transportation planning process. Often an improvement which enhances bicycle travel will also benefit other modes of travel. For example, wide outside lanes, added to a roadway to provide extra space for bicyclists, also benefit motorists by maintaining capacity in the curb lane.

Similarly, highway improvements, through appropriate planning and design, can enhance bicycle travel. For example, paved shoulders added to rural highways for the pupose of reducing motor vehicle accidents and maintenance can significantly improve those roads for bicycling.

Other plans, such as open space plans, outdoor recreation plans and land use plans , should address bicycle concerns as well. For example, uniform (and spread-out) land uses tend to increase distances between home, work and shopping, and make bicycling less feasible for many trips. Also, parking ordinances may include bicycle parking requirements. Virtually every plan can or may affect bicycle transportation in some manner and, therefore, should address bicycle concerns.

Step 3: Analyze local conditions

Successfully planning for bicycle transportation requires developing an understanding of current conditions and future needs. The two primary aspects to consider are user characteristics and environmental conditions.

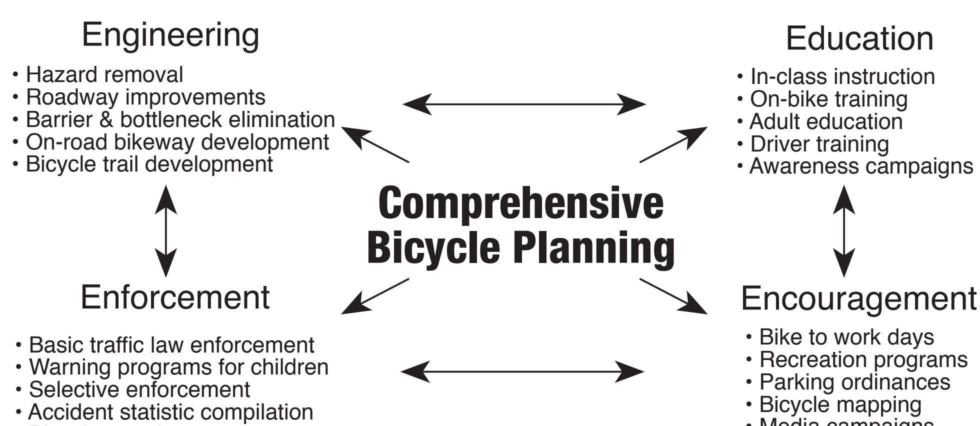


Figure 2-1: A model for comprehensive bicycle planning, encompassing the areas of engineering, education, enforcement and encouragement.

User characteristics:

Since satisfying the needs and desires of the users is the primary goal of bicycle planning, planners must learn as much as possible about the different groups who ride. Four main approaches are useful in gathering the necessary data: surveys, bicycle counts, behavioral observations and crash studies.

User surveys: User surveys give information on bicyclists' and non-bicyclists' attitudes, demographic characteristics and, to some extent, behavior. Demographic data of interest would include respondents' ages, sex, education, occupation and patterns of bicycle ownership.

Attitude data would include perceptions of cycling problems and interest in new opportunities for bicycle use. Behavior data would include factors like current levels of bicycle use, bicycling purposes, distances traveled and helmet and headlight use.

Since surveys must be carefully crafted if they are to be valid, it is important to get expert help. However, such assistance need not be expensive. For example, a local university professor may agree to give such a project to his or her students. Other opportunities for collecting affordable survey data may involve collaborating with similar agencies or public interest groups. Sharing costs will reduce the amount spent by each participant.

Three primary approaches for surveying bicyclists are telephone surveys, mail surveys and face-to-face surveys.

Telephone surveys: Telephone surveys involve calling a random sample of residents and asking a set of standardized questions. Phone surveys have the advantage of involving an operator in a central location, and they are relatively fast to conduct. This helps keep the costs down. However, phone interviewers get no visual clues by which to judge the answers, and getting a representative sample may be difficult depending on phone ownership patterns. Also, it is difficult to spend much time with the person being interviewed.

Mail surveys: Mail surveys involve distributing a printed survey form to a sample of residents and asking respondents to return the survey when completed. Mail surveys involve relatively low costs and provide a geographical distribution of residents. They are easy for respondents to complete and time is less of a factor. Standardization is a benefit, in terms of collecting statistics. However, it is difficult to ask open-ended questions which may need follow-up. In addition, response rates are generally low.

Face-to-face surveys: Face-to-face surveys involve personally asking respondents a set of questions. This approach is a good way to get answers to complex questions, since it allows the interviewer to ask probing follow-up questions. However, face-to-face surveys are time consuming, and uncontrolled factors, like the personal interaction with the interviewer and differences between the approaches of multiple interviewers, may affect the results.

Bicycle counts: Doing bicycle counts will help to determine baseline levels of current use. By identifying locations with high or low use, it is possible to determine where bicycle improvements are most likely to fill an existing need. At the same time, bicycle counts will not identify latent demand. Such information is best gathered through user surveys.

The first step is to identify key corridors for bicycle travel. Since there is likely to be little data on the subject, locations should be chosen based on intuition and a general feel for where bicyclists are likely to be found (e.g., near universities and schools, passing over key bridges, etc.). Within these corridors, one should identify locations where the most useful data may be gathered. For example, it may be important to know if bicyclists generally turn or go straight through a particular intersection. Next, it is important to decide on a time for counting. If recreational use is important, evening and weekend hours will be important. If utilitarian riding is important, commute times (for work and school) will be important.

Records of the bicycle counts should be kept in a safe place where they may be found in future years. The value of routine bicycle counts lies primarily in their ability to show change over time. Increases in bicycle use in a particular corridor from one year to the next may suggest that improvements implemented have met with users' approval, for example. Conversely, decreases in use may reflect a worsening bicycling environment.

For this reason, it is important to consider counts as part of an evaluation system. They should be performed on a routine basis, at least annually but preferably several times per year.

There are two primary counting techniques: manual counts and mechanical counts. The appropriate counting technique will depend on the available labor, equipment and the location of interest. Manual counts are best done at intersections, allowing counters to keep track of bicycle traffic on more than one street. Turn movements can also be recorded. Manual counts, however, are labor-intensive.

Mechanical counts are best done away from the influence of intersections. As a result, turning movements are not as easily recorded. However, labor is not a problem; this approach is quite useful for an agency that has the equipment. Specific tips on using each method follow.

Manual counts: Counters should be provided with standard forms with diagrams of the location that identify each movement with a unique number. Clipboards with mechanical counters may make counting easier. Otherwise, staff should tick off the number of bicyclists they see performing each movement. Volunteers can help agencies perform time-intensive manual counts.

Mechanical counts: The location for a mechanical count should be chosen carefully. The best situation is one that allows motor vehicle traffic to flow freely at speeds of 40 km/h (25 mph) or more without enhancing bicycle speed. Significant downhill grades allow bicyclists to approach motor vehicle speeds and, therefore, are not appropriate locations for mechanical counts. However, uphill grades work well.

Counters should be installed in pairs as in a speed study. Sensitivity should be set to detect bicycles. Any traffic moving significantly slower than the rest (e.g., 8 to 25 km/h (5 to 15 mph)) would likely be bicycles.

Behavioral observation: Observing bicyclist behavior and bicyclist-motorist interactions can help identify problems that otherwise would not be noticed. While crash data, for example, can highlight the most serious problems and user comments can report what people say or believe, behavioral observation can show what people actually do. In some cases, observing behavior can help determine priorities for educational programs and awareness campaigns. In others, it may expose quirks in the road network.

Typical behaviors: Common behaviors to consider when setting up observations include use of helmets and other safety equipment, general lane use and lane use when compared with destination at intersections, traffic law compliance and turning maneuvers.

Observation technique: The first step is to decide what behavior is important, using the list given above as a basis. Next, a simple checklist should be developed, presenting the options (e.g., wrong way vs. right way riding) in an easy-to-record fashion. Observers should be able to quickly check off which of the behaviors they see. Each observer should be trained prior to being sent into the field. Adequate training significantly improves the accuracy, reliability and consistency of the data. For more information on field work, see the previous section on bicycle counts.

Crash studies: Determining the major causes and locations of bicycle crashes is an important step in understanding a community's cycling problems.

Police crash reports: Police records are one of the best sources of information on a community's common crash types; however, the majority of bicycle crashes are not reported. Typically, only one serious car-bike crash in five is reported. Of the crashes that do not involve motor vehicles, only one in twenty are reported. As a result, police data can only give an indication of the problem. Even so, police records provide useful information (Stutts 1986).

One enlightening task is to categorize reported crashes according to the crash types developed for the National Highway Traffic Safety Administration. (See the Reference section at the end of this document for further information on crash types.)

Emergency room records: Another source of data on bicycle crashes is the hospital emergency room. In several North Carolina communities, hospitals have cooperated with crash researchers to compile data on the number of bicyclists seriously injured in crashes, their ages and sexes, and the general circumstances surrounding the crash. Collecting hospital data is a good way to determine the overall scope of the problem and learn some of the demographic factors of interest. However, hospital records are not generally a good source of detailed information on crash type. Police records are better for this purpose. To learn more about emergency room studies, see the reports listed in the Reference section.

Surveys: Contacting bicycle users is another way to get general information on local crash problems. Such information as the seriousness of injury, general type and location of crash (e.g., bike-bike, bike-car), bicyclist demographics, and time and day of crash may be gathered in this way. In order to accomplish several goals at once, a crash survey may be part of a more general bicycle user survey (see page 7).

Crash study implications: Information gathered through bicycle crash studies can help structure an agency's bicycle program in several ways. The two most important topics for analysis are as follows:

Bicycle crash locations: Through the three approaches listed above, it is possible to develop a map of bicycle crash locations. These locations should be investigated to identify any physical hazards which may contribute to accidents.

Behavioral factors: Bicyclist and motorist behavioral problems are the leading factors in most crashes. The studies may help isolate key errors, which may become the focus of education and public awareness programs.

Environmental conditions inventory:

In order to plan effectively for bicycle use, it is important to gain a detailed understanding of local environmental conditions. Local bicycle clubs may be a good source of information when inventorying local bicycle conditions.

Developing a map or set of maps of such conditions is a key ingredient in the bicycle planning process. The most important conditions fall into three main categories: barriers, hazards and bicycle traffic generators. Because locating these features can be a time-consuming and staff-intensive process, it is best to solicit information from the community. There are several ways to accomplish this goal.

Volunteer recruitment: A relatively small group of cycling volunteers can help conduct an environmental conditions inventory. By breaking the community into districts and giving a map of each one to a volunteer, one can make the task more manageable. Volunteers should use the lists of barriers and hazards on the following pages and should be briefed, as a group, on how to record their observations.

Public meetings: A series of public meetings can help staff identify key problems. By bringing a set of maps and encouraging attendees to note barriers or hazards of greatest concern, it is possible to collect a lot of data in a short period of time. Another approach is to attend regularly scheduled meetings of neighborhood associations. These may not bring in as much bicycling expertise as specially scheduled bike meetings, however.

Hang tags and postcards: In some communities, bicyclists are encouraged to note barriers or hazards on mailback postcards distributed through bicycle shops and other high-traffic locations. In other cases, hang tag surveys are hung from bike handlebars and cyclists are encouraged to send these back.

Surveys: See *User Surveys* (page 7) for information concerning how to conduct a survey.

Barrier identification: Since for most people bicycle trips tend to be shorter than motoring trips, physical features can act as barriers to bicycle travel. A 5 km (3 mi) detour to get around a railroad track, for example, may be an annoyance for those driving cars but may deter people from using bicycles for what would otherwise be a relatively short trip.

Identifying and eliminating such barriers can open up major portions of the road network for bicycle use. However, the cost of bicycle bridges and other such facilities should be weighed against the accompanying benefits. Identifying barriers is a simple process of noting such features on a map.

Common barriers: Common bicycle traffic barriers include limited access freeways and expressways; shopping centers; rivers, creeks, canals and lakes; dead-end streets and cul de sacs; linear parks; mountains and ravines; railroads and transit lines; and utility rights-of-way.

Hazard identification: Hazards on existing highways should be considered for their effects on bicycling. A hazard is a condition that has the potential to cause a bicycle crash. The vast majority of serious bicycle crashes are single-bike accidents in which the bicyclist either hits a stationary object or loses control due to surface problems or operator error.

The most common bicycling hazards fall into three primary categories: surface hazards, geometric hazards and operating hazards.

Surface hazards: Surface hazards involve problems with the roadway or pathway surface. The most important ones are listed below.

Unsafe drainage grates or utility covers: Parallel bar grates can catch wheels while grates and covers that are not flush with the roadway surface can damage a wheel or cause a fall.

Debris: Gravel, sand, glass and other debris tend to accumulate in certain areas (e.g., near the right edge of the roadway or at intersections). Such debris may cause loss of control. A bicyclist may experience a crash when swerving to avoid such conditions.

Rough shoulder or rumble strips: Rumble strips laid down on rural highway shoulders are intended to alert sleepy or unattentive drivers, but their roughness can cause bicyclists to lose control and crash. For this reason, bicyclists will often choose to ride in the travel lane to avoid them.

Rough pavement: Rough pavement can be a serious impediment to bicycling. Rough pavement includes potholes, ravelled edges and cracks (especially those going the direction of travel).

Excessive drop-offs at the gutter pan: Multiple overlays on curb and gutter sections can cause a pavement build-up and subsequent drop-off at the point where the pavement meets the gutter pan. This can result in a hazard to bicyclists.

Bridge expansion joints: Some bridge expansion joints are unlevel and can cause wheel damage when bicyclists pass over them.

Metal grate bridge decks: Some bridge deck designs can cause bicyclists difficulty in controlling their bicycles due to the unevenness of their surface.

Railroad crossings: On diagonal railroad crossings, the gap next to the rail can trap bicycle wheels, causing a fall. Rough crossings can cause wheel damage or falls.

Geometric hazards: Geometric hazards involve characteristics of the roadways other than the surface.

Narrow lanes or structures: Narrow lanes (i.e., less than 3.6 m to 4.2 m (12 ft to 14 ft) in width) make it difficult for motorists to pass bicyclists safely without shifting to adjacent lanes. On multi-lane roads or structures, motorists can shift into the adjacent same-direction lane, which is a relatively safe maneuver. However, on two-lane facilities, motorists must shift into the on-coming travel lane, a potentially dangerous situation. Often, they will try to stay in the lane and squeeze past the bicyclist instead.

High volume driveways: High volume commercial driveways, like those at fast food restaurants, can be more hazardous than less-used commercial driveways or residential driveways.

Sight obstructions: Sight restrictions like shrubs, fences or parked cars near intersections are significant factors in many car/bike crashes.

Traffic signals not bike-responsive: Many demand-actuated signal systems were designed and installed without attention to their effects on bicyclists. As a result, bicyclists may find it impossible to get a green light.

Operating hazards: Operating hazards involve specific characteristics of other traffic. The most important are listed below.

High speed traffic: High traffic speeds are often associated with a greater threat of fatal crashes. They are most hazardous when combined with high traffic volumes, high percentages of truck traffic, and narrow lane and shoulder widths.

High volume traffic: High volumes of motorized traffic serve as a deterrent to bicycling and may lead to more car-bike crashes. They also increase the stress levels on bicycle users.

High volumes of truck or RV traffic: On high-speed roads, trucks generate buffeting winds that can push bicyclists off to the right and then pull them back to the left. If the traffic lanes are narrow and there is no ridable shoulder, the presence of significant volumes of truck traffic can be a deterrent to safe and comfortable bicycle use. Also, on scenic narrow roads that are popular with tourists, RV side mirrors can strike bicyclists' heads.

Curbside auto parking: Short-term parking generally causes more problems than long-term parking because of the number of motorists entering and exiting the spaces and their cars. Diagonal parking is particularly troublesome for bicyclists, because motorists may often back well out into the travel lane in order to look for approaching traffic.

Bicycle Traffic Generators: Bicycle traffic tends to occur where residential areas are accessible to people's likely destinations. For most people, average bicycle trip lengths are under 8 km (5 mi), and, for this reason, isolated destinations will not attract much bicycle traffic. Areas near bicycle traffic generators should be reviewed to identify existing or potential bicycle travel.

Common bicycle traffic generators include major employment centers, downtown shopping areas, schools and universities, college residential areas, sports and recreation complexes and parks.

Step 4: Develop the problem statement

The information gathered in the previous step can be combined into a comprehensive statement of the problem. This statement includes two primary parts: a set of environmental conditions maps and accompanying descriptions of hazards, barriers, etc.; and a report outlining the non-physical situation. These documents give the basis upon which to judge potential problem solutions.

Environmental conditions maps: One map would show major barriers and hazardous sites. A larger map would show more detail on specific problems like non-responsive traffic signals and drainage grates. The accompanying description would discuss details not possible to show on the maps, including such features as site plans of particular intersections and photos of unique hazards.

Non-physical conditions report: This document would discuss findings of user surveys, behavioral observations, crash studies and bicycle counts.

Step 5: Generate solution ideas

Once a comprehensive list of problems has been assembled, it is possible to identify potential solutions by focusing on the problems one at a time. In many cases, the solutions are standard ideas; however, it is possible that analysis has identified some truly unique local situations.

In such cases, having a clear understanding of the standard options and a commitment to evaluating results will allow the designer to create a unique solution that both works and does not contribute to other problems.

The following is a list of potential solutions to some common problems.

Roadway improvements: Roadway improvements can solve many bicycling problems. The following ideas are explained in further detail in the subsequent chapters.

Replace unsafe drainage grates or utility covers: Parallel bar grates can be replaced with bicycle-safe models, and covers that are not flush with the surface of the roadway can be adjusted.

Sweep debris: A map may be developed showing the most serious locations. This map could help guide the maintenance department's work.

Remove shoulder rumble strips: Where not needed, rumble strips may be removed. Where they are needed, they may be located in such a manner as to present the minimal hazard for bicyclists.

Improve rough pavements: Bad stretches of pavement may be repaired or resurfaced.

Eliminate excessive drop-offs at the gutter pan: Excessive drop-offs can be eliminated by feathering out the asphalt at the point where the pavement edge meets the gutter pan during resurfacing. Consideration can also be given to milling the old pavement surface to prevent the build-up.

Repair bridge expansion joints: Rough or uneven bridge expansion joints should be inspected and repaired.

Improve diagonal railroad crossings: Diagonal railroad crossing problems may be solved by paving an apron which would allow bicyclists to cross at 90 degrees, by installing a flangeway filler next to the track, or by providing warning signs or markings.

Improve rough railroad crossings: Installing rubberized crossings can eliminate roughness and reduce long-term maintenance costs.

Remark or widen narrow lanes: In some cases, it is possible to widen outside lanes by remarking an existing street. In other cases, it may require reconstruction. Either way, wide lanes give bicyclists more room to maneuver in high-volume traffic.

Provide smoothly paved shoulders: Paving full-depth shoulders on high-speed rural-type roads gives cyclists more leeway and a less stressful ride.

Consolidate high-volume driveways: It may be possible to reduce the number of commercial driveways, to the benefit of passing motorists and bicyclists alike.

Remove sight obstructions: Sight restrictions should be removed through sight triangle ordinances and a routine program of sight obstruction elimination.

Replace non-responsive traffic signal detectors: Some existing signals can be adjusted to detect bicycles. In other cases, signal detector loops may be replaced with bicycle-responsive models.

Eliminate curbside auto parking: In some cases, it may be possible to eliminate on-street parking. In other cases, widening the outside travel lane will make it easier for bicyclists to ride farther away from the parked cars.

Special bicycle facilities: Special bicycle facilities may solve particular problems or provide opportunities for non-cyclists to try bicycling in a less-threatening environment. Examples include the following:

Bicycle routes: Identifying bicycle routes with signs may be a way to help bicyclists get to particular destinations, avoid high-stress corridors or ride on scenic but little-known roads.

Bike lanes: Bicycle lanes can delineate a portion of the available roadway for bicycle traffic. In so doing, they may reduce the sense of danger among inexperienced bicyclists.

Bicycle paths: Separate bicycle paths can help bicyclists get around a barrier or difficult traffic situation. They also may provide an enjoyable recreational experience.

Bicycle bridges: Bridges may be constructed that allow bicyclists to get over a river or other linear barrier.

Other options: Other physical improvements can provide support for bicycling as well.

Bicycle parking: Since every bicycle trip has a destination, bike parking facilities are a necessary adjunct to physical improvements. Parking should be provided at major traffic generators (e.g., shops and schools) and at mass transit stations to encourage intermodal travel.

Bicycle/transit connections: A number of communities have found that encouraging bicycling to transit stations results in increased transit use. Some, for example, have provided secure bicycle parking, while others have developed systems for allowing bicycles on trains or buses.

Non-physical improvements: Non-physical improvements should be an integral part of any overall plan for bicycling. The following are options that may be considered.

Bicycle maps: Bicycle maps provide an excellent way to let bicyclists know about route options and large-scale hazards. Often, safety and access information is included on the back.

Bicyclist training: Bicyclist education and training include many options, from developing community awareness through public service announcements to training adults and youngsters in on-road sessions.

Bicycle enforcement: Enforcement of traffic laws is basic to a comprehensive bicycle program. Some communities have implemented on-bike patrols, while others have focused on "selective enforcement" procedures. Selective enforcement involves looking closely at the community's bicycle accident picture and emphasizing those violations that lead directly to the most crashes.

Encouragement projects: Encouragement may include such things as "bike to work week," during which people are encouraged to ride their bicycles for utilitarian trips. It may include recreational rides for families, publicity campaigns or bicycle maps. Each of these options can encourage people to get on their bikes and ride.

Step 6: Select solutions and develop a plan

Developing an overall plan for bicycle transportation in a community is a process of matching the goals and objectives identified in Step 1 with the problems discovered in Step 3 and the solutions identified in Step 5, in light of the community's fiscal limitations.

The ideas in the plan should help solve the problems in order to achieve the goals in a timely fashion. Assembling cost information is an important part of developing the plan. When determining costs, it is best to consult local technical staff who will implement the projects. They also can point out cost-saving opportunities which otherwise might be missed.

The result will be an action plan which identifies those actions which can be easily accomplished and those which require major investment.

Step 7: Implement projects

Implementing the plan involves work on three related but distinct tasks: policy development, long-range planning and short-range planning.

Policy development: The first task may involve the agency in reviewing and altering ordinances and policies that affect routine functions; an example would be the adoption of a bicycle-safe drain grate standard. Policies in the areas of transportation, construction, zoning, parking and law enforcement are particularly important to review.

Long-range planning: The second task involves scheduling long-term investments that solve major problems or provide major opportunities; examples would be the development of a special barrier-breaking bicycle bridge or planning a lengthy bicycle path.

These projects may be identified in a bicycle plan, but many should be worked into the project priority lists in other related plans, for example, the community's transportation and recreation plans. Quite possibly, other unrelated projects planned for the near future, with some modifications, can solve bicycle problems as well.

Some projects (e.g., a trail network) may be implemented on a phased basis. In this way, it is not only possible to pay the costs over a period of years, but later phases may be altered based on the experience of the earlier ones. As an example, one community found that their 2.4 m (8 ft) wide bicycle paths were getting far more use than they had expected. Subsequent segments were paved to a 3.6 m (12 ft) width.

Other projects, such as a major bike bridge, must be accomplished in one step. However, it may be necessary for an agency to set aside funds until it can afford to build the entire project.

Short-range planning: The third task involves scheduling short-term, mostly small-scale improvements; examples of these might include fixing potholes on a particular street or installing a warning sign. Many of the items identified in the hazard inventory fall under the category of short-term planning. Typically, they may be completed in one or two years.

Often, these improvements may be accomplished with as little as a maintenance work order. In some cases, however, where many small projects are needed, setting up an annual "bicycle spot improvement" budget and a schedule for completion will be necessary.

Step 8: Evaluate results and revise

Evaluating the success of an agency's bicycle plan is an ongoing function very similar to the process of problem identification described in Step 3. It requires paying attention to changes in crash causes, bicycle use, and user satisfaction and making adjustments based on the results. Looking at bicycle crash reports, doing annual bicycle counts and observations, and user surveys allow an agency to determine whether the situation is improving and the goals of the program are being met.

Evaluation also requires watching for bicycle-related problems during an agency's routine maintenance procedures.

The remaining chapters of this manual offer detailed guidelines on how to accommodate bicyclists in transportation projects and recreational corridors.

3 Design Factors

An example of a bicycle-pedestrian bridge.

Planners and engineers have a wide range of options to enhance bicycle transportation. On the one hand, improvements can be simple, inexpensive and involve minimal design consideration. An example might be approving a change in bicycle-safe drainage grates used on local road projects. On the other hand, improvements can involve substantial allocations of funds, detailed design, and multi-year commitments to phased development. An example might be an extensive community-wide bicycle path network.

In order to adequately design for bicyclists, particularly when approaching large-scale projects, one must have a basic understanding of how bicycles operate. Most designers have an understanding of motor vehicle operation, but few have studied bicycle operation closely.

Bicycle and bicyclist characteristics

The physical space occupied by a bicycle is relatively modest. Generally, bicycles are between 600 mm and 750 mm (24 in and 30 in) wide from one end of the handlebars to the other. An adult tricycle or a bicycle trailer, on the other hand, is approximately 0.8 m to 1 m (32 in to 40 in) wide. The length of a bicycle is approximately 1.75 m (70 in); with a trailer, the length grows to 2.55 m to 2.75 m (102 in to 110 in). In determining the design of off-road facilities, the width is more critical than the length.

The height of an adult bicyclist on a bicycle is given as 2.3 m (88 in). This height takes into consideration the possibility that the bicyclist may be riding while standing up. Generally, adult riders are between 1.5 m and 1.8 m (60 in and 72 in) high while riding on the saddle.

While these dimensions give the physical space occupied by the bicycle and rider, the bicycle in motion requires additional space. One must also consider clearances and maneuvering allowances between the bicycle and static or moving obstructions. The following are typical clearances used in determining widths of bicycle facilities:

Typical clearances:

Maneuvering allowances:

To edge of pavement	0.3 m (1.0 ft)
Between bikes	0.8 m (2.5 ft)
Between bikes and peds	0.8 m (2.5 ft)

Lateral clearances:

To parked cars	0.6 m (2.0 ft)
To curb drop-off	0.6 m (2.0 ft)
To utility poles, trees, and hydrants	0.6 m (2.0 ft)
To soft shoulder	0.45 m (1.5 ft)
To sloped drop-off	0.3 m (1.0 ft)

Vertical clearance:

To overhead obstruction	0.6 m (2.0 ft)

Source: Bikeway Planning Criteria and Guidelines; ITTE, 1972

In determining design speeds, it is important to consider the average speeds of typical bicyclists, as well as other likely users. Studies have shown that the average speed of bicyclists is 16 km/h (10 mph). However, these studies may not account for the growing number of riders, whose speeds may easily exceed 32 km/h (20 mph).

An important consideration in setting bicycle path curve radii, particularly those on downgrades is the effect of speed on turning ability. When traveling at average speeds, a bicyclist cannot turn the handlebars more than a few degrees to either side without losing control.

Further, while bicyclists can lean into turns, few riders are comfortable leaning at angles above five to ten degrees. To do so puts the inexperienced rider at risk of either sliding out or hitting the inside pedal on the pavement. As a result of these factors, bike path curve radii should be designed in a conservative manner.

Another critical characteristic is stopping distance. Due to differences in brake type and quality and rider skill, stopping distances for bicyclists traveling at the same speed may vary dramatically. Some bicycles are equipped with coaster brakes attached to the rear wheel hub; others use caliper brakes that act on both wheels. Further differences are found between high quality caliper brakes with special brake pads and inexpensive ones equipped with relatively slick pads.

In addition, wet weather seriously reduces the effectiveness of most bike brakes. According to *Pedal Cycle Braking Performance: Effects of Brake Block and Rim Design* (Watt, TRRL 1980), some common bicycle brakes take over four times as far to stop in the rain as they do under dry conditions. Further, bikes equipped with aluminum alloy rims stop between twice and four times as quickly in the rain as similar bikes equipped with steel rims.

Complicating all these factors are the varying abilities of the riders themselves. Skilled bicyclists can stop far more quickly than can unskilled riders.

As a result, stopping sight distances are important factors to consider, particularly when designing curves and intersections on separate trail systems.

Design options

The rest of this manual describes specific design features and approaches for accommodating bicyclists both on- and off-road. The topics include:

- Roadway improvements
- Bicycle lanes
- Bicycle routes
- Bicycle paths
- Supplemental facilities
- Operation and maintenance

4 Roadway Improvements

Bicycles will be ridden on all highways where they are permitted. As a result, all new highways, except those where bicyclists legally will be prohibited, should be designed and constructed under the assumption that they will be used by bicyclists. Bicycle-safe design practices, as described in this guide, should be followed to avoid costly retrofit improvements. Roadway conditions should be examined and, where necessary, such improvements as safe drainage grates and railroad crossings, smooth pavements and traffic signals responsive to bicycles should be provided.

Drainage grates

Drainage grate inlets and utility covers can be serious hazards to bicyclists. Unsafe grates can divert a cyclist's front wheel, causing a crash. Parallel bar drainage grate inlets are the most hazardous because they can trap the front wheel of a bicycle causing loss of steering control and the bar spacing is such that they can allow narrow bicycle wheels to drop into the grates, resulting in damage to the bicycle wheel and frame and/or injury to the bicyclist.

Grate cover replacement and retrofit: Unsafe grate covers should be replaced with either Type E, F or G standard grate covers as shown in Figure 4-1. For more complete details, refer to the *North Carolina Department of Transportation Roadway Design Manual, and Roadway Standard Drawings Manual*, std. no. 840.03.

Identifying a hazardous grate with a pavement marking, as indicated in the *Manual on Uniform Traffic Control Devices* (MUTCD), is generally unacceptable, especially with parallel bar grate inlets. Because of the serious consequences of a bicyclist's missing the pavement marking in the dark or being forced over such a grate inlet by other traffic, these grates should replaced as soon after they are identified as practicable.

Grates and resurfacing: Because bicycles are more sensitive than motor vehicles to pavement irregularities, during construction appurtenances should not be left projecting above the pavement surface.

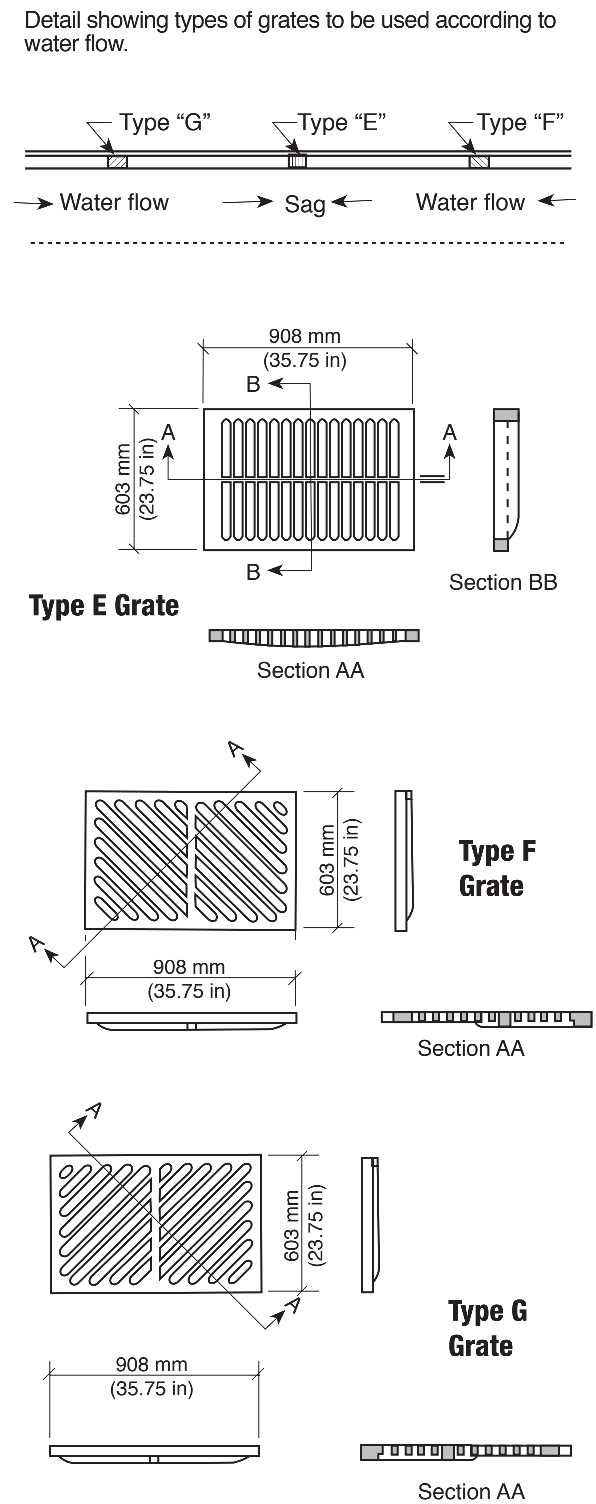


Figure 4-1: Bicycle-safe drainage grates approved by the North Carolina Department of Transportation.

Repeated resurfacings without adjusting the utility cover neck flange or drainage grate frames result in the covers being sunken below the pavement surface, a hazardous condition to bicycle traffic. Therefore, all manholes, inlets, lampholes and water valve boxes should be brought to grade by either lowering or raising as required in all new construction, reconstruction and resurfacing projects.

When a new roadway is designed, all grates and covers should be bicycle safe. Gutters designed for flow to curb-opening inlets are not considered ridable because of the warping of the gutter for drainage. Such warping may result in adverse handling effects.

Railroad crossings

For bicycle traffic, there are two main problems with at-grade railroad crossings. First, if the tracks cross the roadway at less than 45 degrees, a bicyclist's front wheel may be diverted by the rail or trapped in the flangeway, causing loss of steering control. Second, a rough crossing – regardless of angle – may cause wheel damage or may cause a bicyclist to crash.

Angled crossings: When railroad tracks cross highways or bikeways at-grade, they should do so as close to a right angle as possible. If this is not possible, consideration should be given to the following options:

(1.) As shown in Figure 4-2, widening the approaching roadway, bike lane or shoulder will allow the bicyclist to cross at approximately 90 degrees without veering into the path of overtaking traffic. The minimum amount of widening should be 1.8 m (6 ft); however, 2.4 m (8 ft) is desirable, depending on the amount of available right-of-way. Adequate tapers should be provided.

(2.) On low-speed, lightly-travelled railroad tracks, commercially available flangeway fillers can eliminate the gap next to the rail (see Figure 4-3). The filler normally fills the gap between the inside railbed and the rail. When a train wheel rolls over it, the flangeway filler compresses. This solution, however, is not acceptable for high-speed rail lines, as the filler will not compress fast enough **and the train may derail.**

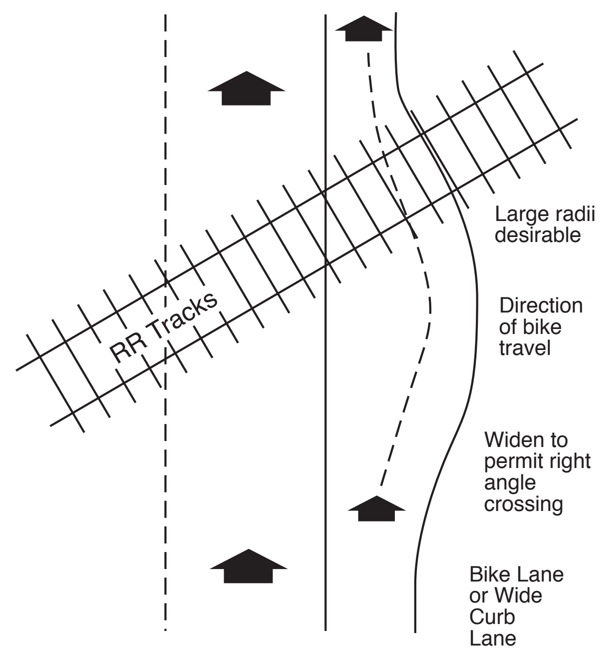


Figure 4-2: Flared roadway permits bicyclists to cross angled railroad crossing at or near 90 degrees.

Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

(3.) In some cases, abandoned tracks can be removed, completely eliminating the problem.

(4.) If no other solution is available, warning signs and pavement markings should be installed in accordance with the MUTCD. While there is no approved sign for this specific situation, a W11-1 warning sign with an appropriate subplate message (e.g., BIKES CROSS AT RIGHT ANGLE) may provide sufficient warning for bicyclists.

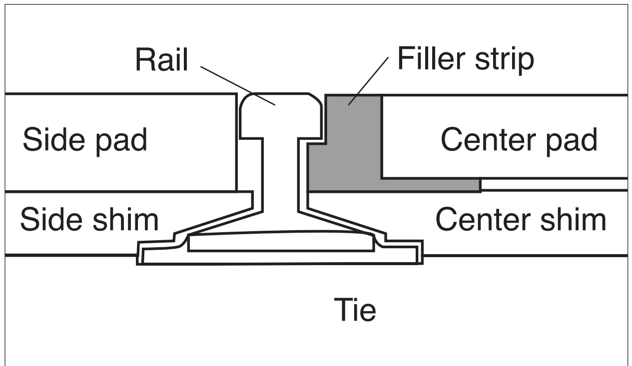


Figure 4-3: Cross section of rubberized railroad crossing with flangeway filler strip for low-speed angle crossings.

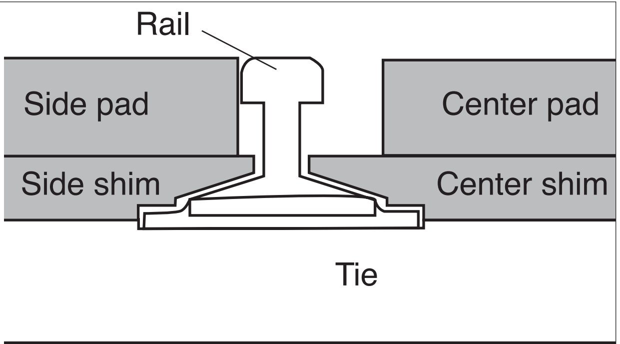


Figure 4-4: Cross section of rubberized railroad crossing for rough perpendicular crossings.

Rough perpendicular crossings: Rough and uneven timber or paved perpendicular crossings can cause control problems and equipment damage for bicyclists. Regular maintenance and replacement, if necessary, can solve the problem. However, in some cases the best long-term solution is to install a rubberized crossing (see Figure 4-4). Such crossings generally consist of a concrete base with a rubberized surface. While these are relatively expensive to install, there are significant savings in long-term maintenance costs because of their stability.

Pavement quality

Pavement surface irregularities can do more than cause an unpleasant ride. While automobile suspensions can compensate for surface roughness and potholes, and wide tires can span cracks, bicycles, with their narrow tires and lack of suspension, have difficulty handling such hazards. Gaps between pavement slabs or drop-offs at overlays parallel to the direction of travel can trap a bicycle wheel and cause loss of control. Holes and bumps can cause bicyclists to swerve into the path of motor vehicle traffic. To the extent practicable, pavement surfaces should be free of irregularities.

The right lane or shoulder generally should be uniform in width. While skilled bicyclists guide off the lane stripe and ride a predictable straight line, many riders will move right or left depending on the width of the lane or presence of shoulders. A road which varies widely in width will encourage such unpredictable behavior.

On older pavements it may be necessary to fill joints, adjust utility covers or, in extreme cases, overlay the pavement to make it suitable for bicycling. See *Drainage Grates* (page 21) for guidance on grates and utility covers.

When new pavement overlays are added to curb and gutter sections, the new asphalt should be feathered to allow the new surface to meet the gutter pan smoothly. Failure to feather the new overlay into the existing pavement can result in a hazardous longitudinal lip at the edge of the new asphalt. In some cases, the old pavement may need to be milled. Generally, paving over a concrete gutter is not satisfactory for several reasons: (1) the joint line will probably come through the new asphalt, causing a longitudinal crack, (2) paving to the curb may affect the drainage and lower the effective height of the curb.

Chip sealing a road extends the life of the pavement at relatively low cost. However, the process can cause bicyclists serious problems. When applying chip seal coats to existing streets, removal of excess gravel at the earliest possible convenience is important. Since passing motor traffic sweeps the gravel off to the side of the road, the gravel tends to collect in piles high enough to cause bicyclists to crash. For this reason, bicyclists will often ride in the area cleared by motorists' tires. Also, chip sealing tends to roughen the surface and is not the preferred treatment for roads where bicycle traffic is to be encouraged.

Slurry seal, on the other hand, can provide a smooth surface to a previously rough shoulder or lane. While it should only be applied to sound pavement, it is an inexpensive treatment for improving the surface for bicyclists. As with chip sealing, any extra material should be removed as soon as possible.

Traffic control devices

Bicycles should be considered in the selection and provision of traffic control devices. While most traffic signs apply equally to motorists and to bicyclists, bicyclists have special needs in two primary areas: (1) signal timing and actuation and (2) bicycle-related signing and marking.

Traffic signal timing: Bicycles should be considered in the timing of traffic signal cycles and in the choice of a traffic detection system. An average bicyclist can cross an intersection under the same signal phasing arrangement as a motor vehicle. However, on multi-lane streets, clearance intervals should be long enough to allow bicyclists to cross. If necessary, an all-around-red-clearance interval may be used. To check the clearance interval, use a bicyclist's speed of 16 km/h (10 mph) and a perception/reaction/ braking time of 2.5 seconds.

Signal actuation: Detectors for traffic-actuated signals should be sensitive to bicycles and should be located in the bicyclist's expected path, including left turn lanes. The preferred options for loop detectors are as follows (see Figure 4-5):

(1) In shared roadway situations, where the exact location of the bicycle cannot be easily predicted, the diagonal quadrupole loop is best, since it is bicycle-sensitive over its entire width while being relatively immune to false calls caused by motor vehicles in adjacent lanes.

(2) In bicycle lane or bicycle path situations, where the location of the bicycle can be easily predicted, a quadrupole detector works well. The quadrupole loop is highly sensitive over the center wires, less sensitive over the outer wires and relatively insensitive to motor vehicles in adjacent lanes.

(3) Standard loops are the least desirable for sensing bicycles. These loops are square or rectangular in shape and are most sensitive over the wires that form the outer boundary of the loop. While some are sensitive enough directly over the wires to detect bicycles, the bicyclist must know just where to stop, and why it's important to stop there.

For this reason, standard loops are the least desirable and should be used only in locations where bicycle traffic is not expected. Some standard loop/amplifier combinations cannot be adjusted to reliably detect bicycles without detecting motor vehicles in adjacent traffic lanes. These loops should be replaced with bicycle-sensitive models.

In special cases, pedestrian activated buttons may be mounted near the curb for bicycle use. This approach may be useful where a bicycle path crosses a highway, for example.

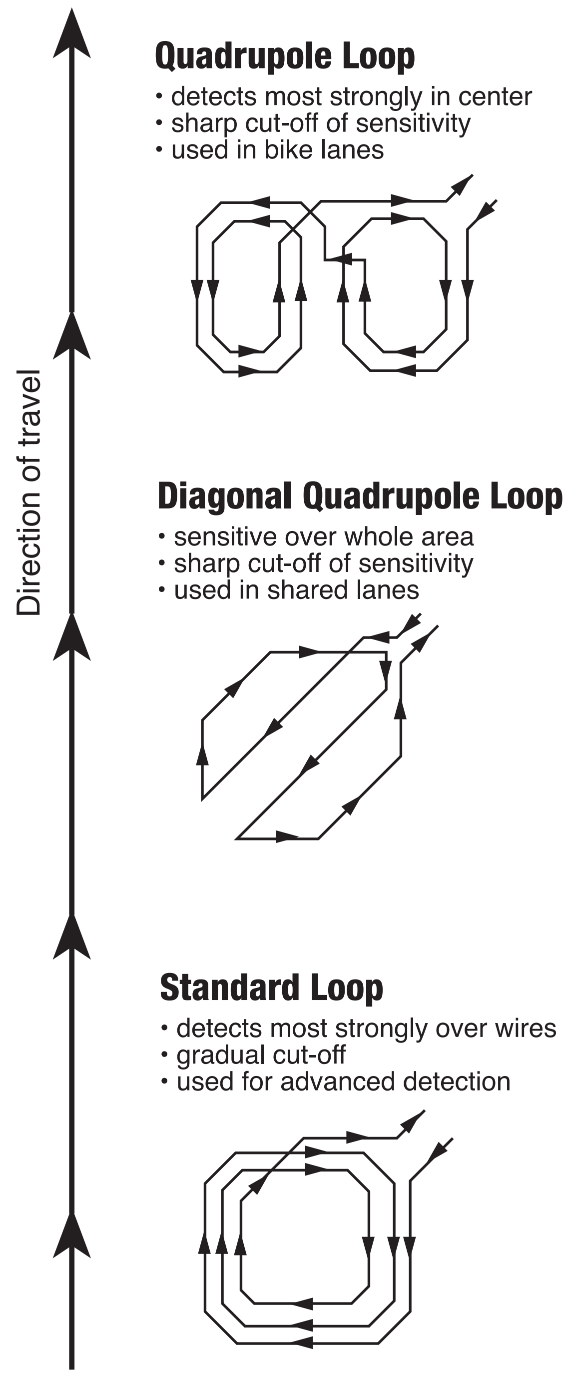


Figure 4-5: Recommended loop types for bicycle detection. In most shared-road situations, the diagonal quadrupole is preferred.

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

However, in most roadway situations, the need for bicyclists to position themselves at intersections according to their destinations (e.g., in left-turn lanes or to the left of a right-turn-only lane) makes such push buttons the least desirable option.

Programmed visibility heads: Where programmed visibility signal heads are used, they should be checked to ensure that they are visible to bicyclists who may be positioned near the right edge of the roadway.

Signing and marking: The following guidance from the MUTCD should be followed when installing signing or marking for bicycles:

"Traffic control devices, whether they are intended for motorists or bicyclists, must adhere to five basic requirements to be able to perform their intended function. They must

1. *Fulfill a need.*
2. *Command attention.*
3. *Convey a clear, simple meaning.*
4. *Command respect of road users.*
5. *Give adequate time for proper response."*

Part IX of the MUTCD, reproduced in Appendix 4, should be consulted for guidance on bicycle signs and pavement markings. Where bicyclists are expected to use different routings than motorists, directional signing should be used to confirm to bicyclists that the special routing leads to their destination. Bike route signs are discussed in Chapter 6, bike lane signs are discussed in Chapter 5, and bike path signs are discussed in Chapter 7, with further details given in Part IX of the MUTCD or in Part IX of the *Traffic Control Devices Handbook*. Other signs used specifically in North Carolina are discussed in Appendix 5.

Structures

Structures like bridges and tunnels can provide key links in any bicycle transportation system. Since they are often expensive to build or modify, structures tend to be replaced less often than sections of roadway by comparison and they tend to be relatively narrow. However, because they often connect networks of local roads on either end, improving a structure, or considering bicyclists' needs in the construction of a new one or renovation of an existing one, can provide significant benefits for bicycle users.

The priority an agency places on providing bicycle-related improvements in any specific case should be based on consideration of the following factors.

Traffic conditions:

Bicycle traffic volume (potential or actual): A structure on a popular bicycling route is a better candidate than one on a road with little or no potential for bicycle use.

Bicycle crash experience: Given that relatively few serious bicycle crashes are reported to the police, a structure with a history of reported bicycle crashes may be the site of many unreported crashes as well. As a result, it should receive close scrutiny.

Motor vehicle traffic volume: A high-volume structure is more likely to need bicycle accommodations than a low-volume one, due to the increased likelihood of conflicts.

Percent of truck and/or RV traffic: A structure with a high percentage of truck and/or RV traffic is more likely to need bicycle accommodations than one with little or no such traffic.

Traffic speed: High traffic speeds (i.e., over 70 km/h (45 mph)) are associated with a significant percentage of bicycling fatalities and structures on such routes need close attention.

Land use and the transportation system:

Proximity to bicycle traffic generators: A structure that serves many nearby residents and connects to popular recreation or commercial areas is likely to attract more bicycle use than one far away from any community.

Alternate routes: If there are no suitable alternate routes, the importance of a particular structure will be greater than if there are numerous options.

Connecting roadways: If the structure connects segments of freeway or expressway, it is less likely to be in demand than one that connects surface streets, like collectors or arterials.

Bicycle accommodations: A structure that connects existing or planned bicycle facilities (e.g., bicycle lanes or routes) is a good candidate for bicycle-related improvements.

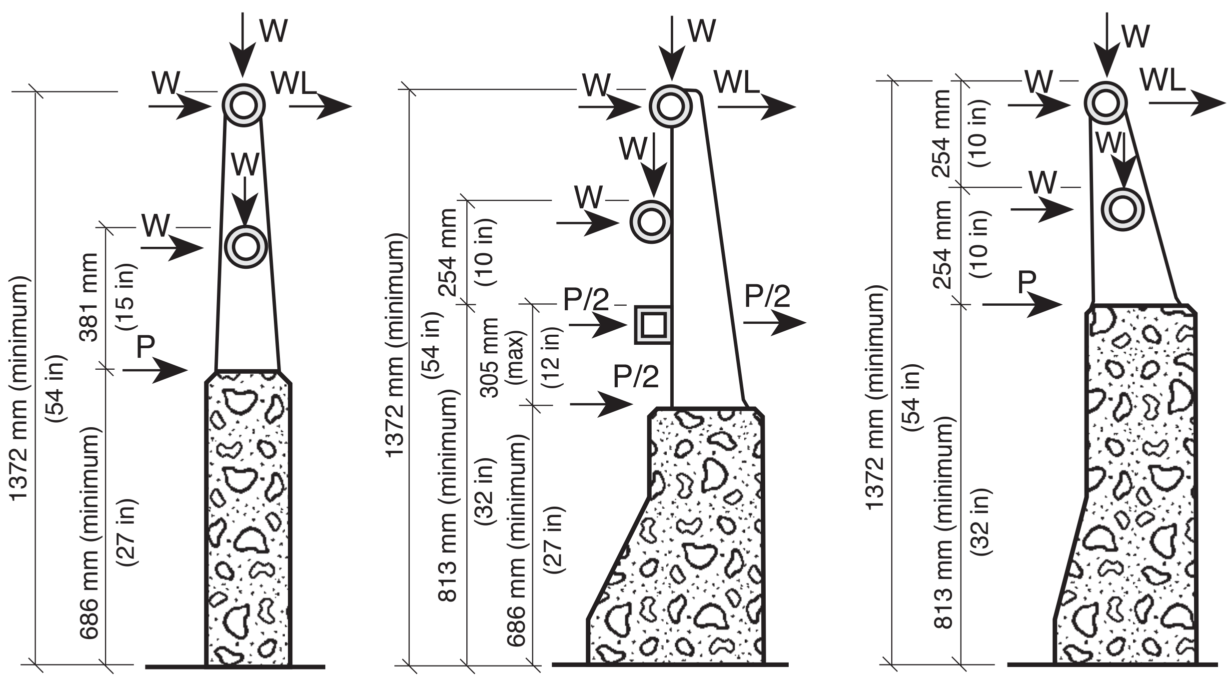
The structure's geometrics:
Elevation: Fixed span bridges that arch high for the passage of ships are less attractive for most bicyclists than are flatter structures. However, on steep structures, the presence of slow-moving bicyclists on the ascent and fast moving bicyclists on the descent must be considered. Wider shoulders to accomodate conditions may be appropriate.

Width: Because passing opportunities are more limited on two-lane structures than on multi-lane structures, the former structures are more likely locations for bicycle/motor vehicle conflicts.

Bridges

Improving a bridge for bicycle use involves analyzing four major areas of concern: (1) static obstructions, (2) surface conditions, (3) bridge deck width, and (4) bridge approaches.

Static obstructions: Bicycle-safe bridge railings (Figure 4-6) shall be used on bridges specifically designed to carry bicycle traffic, and on bridges where specific protection of bicyclists is deemed necessary. Bicycle rails



Notes:
1. Loadings on left are applied to rails.
2. Loads on right are applied to posts.
3. The shapes of rail members are illustrative only. Any material or combination of materials listed in Article 2.7 of Standard Specifications for Highway Bridges (AASHTO, 1989) may be used in any configuration.

Nomenclature:
P = Highway design loading
h = Height of top of top rail above reference surface
L = Post spacing
w = Bicycle loading per unit length of rail

Figure 4-6: Combination traffic and bicycle bridge railings. A railing height of 1372 mm (54 in) will protect bicyclists from toppling over.
Source: AASHTO Standards & Specifications for Highway Bridges, 1989

used on highway bridges shall be in acordance with the latest American Association of State Highway and Transportation Officials (AASHTO) specifications and shall be crash-tested in accordance with Federal Highway Administration (FHWA) guidelines. The minimum height of a railing used to protect a bicyclist shall be 1,372 mm (54 in), measured from the top of the riding surface to the top of the rail. In cases where existing railings are below this height, consideration should be given to retrofitting an additional bicycle railing to the top, bringing the total height to 1,372 mm (54 in).

Guardrails on bridge approaches should be designed with the needs of bicyclists in mind. As a general rule, a roadside barrier should be placed as far from the traveled way as conditions permit. A minimum offset from the edge of the traffic lane or paved shoulder of 1.2 m (4 ft) is desirable. In situations where the slope on the far side of the guardrail is excessive or the hazard serious, or where the shoulder or outside lanes are narrow, consideration should be given to attaching a bicycle-safe railing to the top of the guardrail. This will bring the total height to 1,372 mm (54 in).

Surface conditions: On all bridge decks, special care should be taken to ensure that smooth bicycle-safe expansion joints are used. In cases where joints are uneven, rubberized joint fillers or covers may be considered.

The bridge deck should not pose a hazard for bicyclists. Only bicycle-safe grates and drains should be used. Steel decking on draw bridges or swing bridges can cause steering difficulties for bicyclists. In general, such bridges should not be signed as bicycle facilities without determining the deck's effect on bicycle handling.

The accumulation of roadside debris may cause problems for bicyclists, forcing them to ride farther out from the right edge than many would prefer. Regular maintenance, particularly in the right half of the outside lane and on paved shoulders, is important.

Bridge deck width: Two primary options are available for accommodating bicyclists on highway bridges (see Figure 4-7). First, 1.2 m (4 ft) (minimum) shoulders may be added to each side. Second, a widened outside lane at least 4.2 m (14 ft) wide may be used on each side of curb and gutter sections. In deciding between these options, the primary considerations are traffic speed and volume.

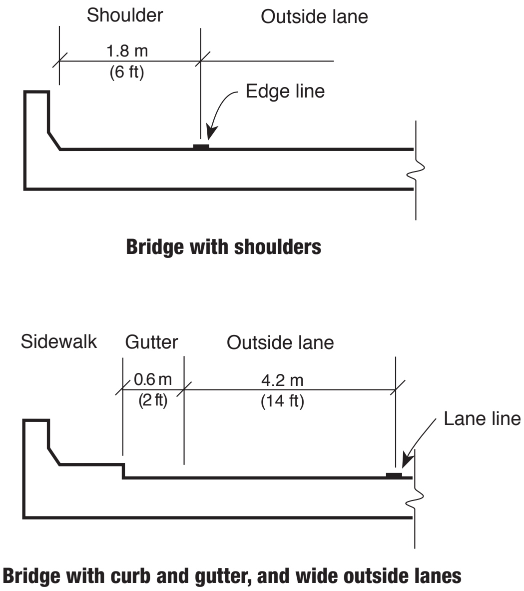


Figure 4-7: Suggested widths for bicycle accommodations on bridges.

On bridges with higher posted speeds, the effects of windblast described in FHWA research (Figure 4-8) may be offset by providing a separation distance between bicyclists and passing vehicles. This is particularly important where a significant percentage of truck or RV traffic is present; in such cases, additional width beyond the recommended 1.2 m (4 ft) of paved shoulder is useful. On bridges with lower posted speeds, windblast effects are not particularly serious, and, hence, widths are determined more by physical clearances.

Bridge approaches: Bicycle provisions, whether shoulders or wide outside lanes, should continue for at least 30 m (100 ft) on either side of the bridge in order to ensure a safe transition. If on- or off-ramps or intersections are present, shoulders or wide outside lanes should continue at least as far as the ramps or intersection.

On lower-speed bridges and ramps, the crossing is similar to that used for turn lanes and the extra width should simply be added to the right-most through lane. On high-speed bridges and ramps, the shoulder striping should not cross over the ramp, but should follow the ramp. Another shoulder stripe should pick up on the far side of the ramp.

If bicycle lanes are used, they should be designed as described in Chapter 5. On low-speed bridges, the bicycle lane stripe should be dropped before the ramp and picked up after, as shown in Figure 5-4(1) and Figure 9-5 in the MUTCD.

Tunnels, underpasses and interchanges

Tunnels, underpasses and interchanges may cause difficulties for bicycle users because of the grades involved, pavement widths and surface, and levels of lighting. Like bridges, these structures tend to be long-term investments and are not replaced or upgraded as often as connecting roadways. For this reason, they may act as barriers for bicycle travel.

Providing adequate width is important for safety, particularly on high-volume roads and highways. When traffic speeds are low, this may be done through the use of wide curb lanes. In high-speed tunnels, the preferred solution is a minimum 1.2 m (4 ft) wide outside shoulder.

Debris can build up at the right edge of the roadway and if the tunnel is not well lighted, bicyclists going from daylight to relative darkness may not immediately see the hazard. For this reason, providing adequate lighting and regular maintenance are important for bicyclists' safety.

If a high-speed tunnel or underpass is particularly narrow or contains a serious sight obstruction, then the structure may not be appropriate for bicycle use. Alternate routes should be investigated. However, there may be some circumstances where

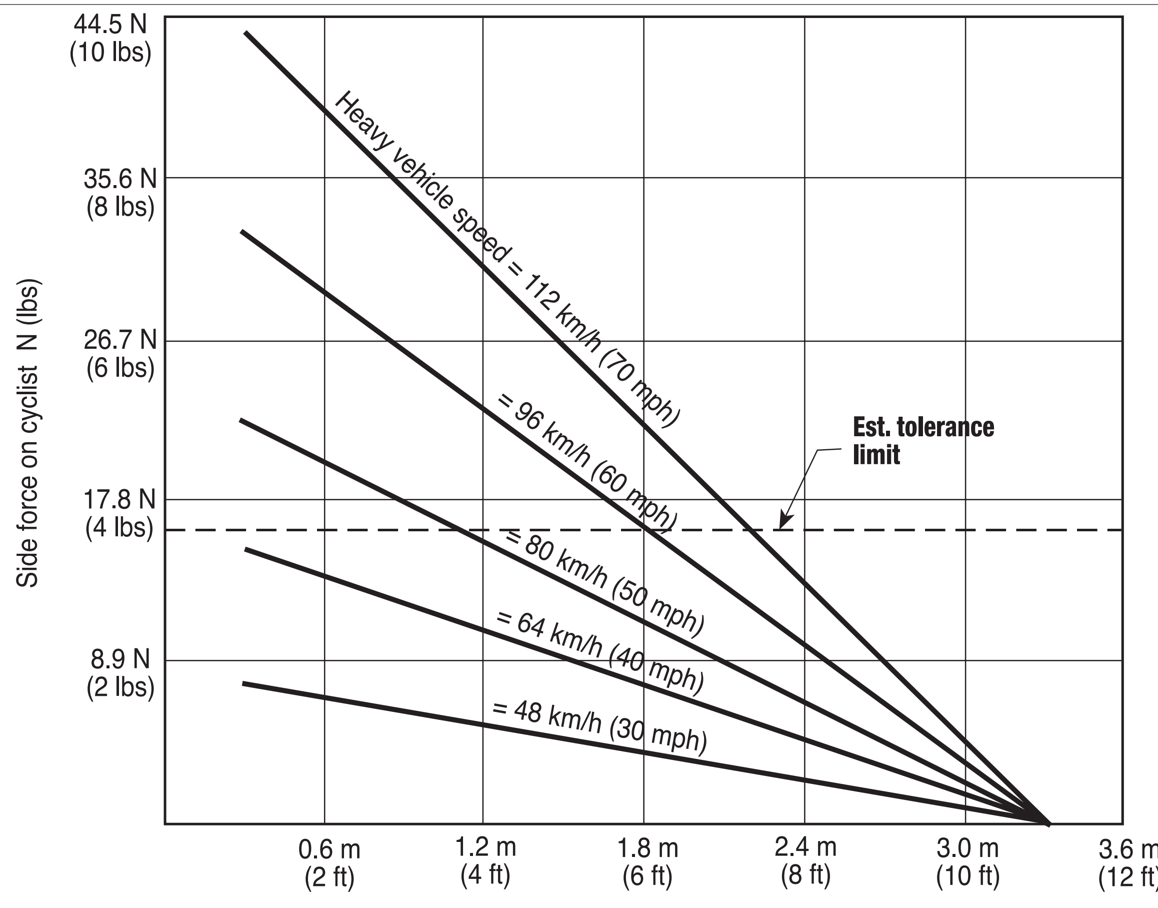


Figure 4-8: Aerodynamic forces caused by heavy motor vehicles passing bicyclists.

Source: A Bikeway Criteria Digest; USDOT Federal Highway Administration, 1977.

bicyclist-actuated flashing lights may be used to warn motorists of the presence of bicyclists in the tunnel or underpass. These lights flash for a given period of time after a bicyclist hits the button, warning motorists of his or her presence ahead.

If the tunnel or underpass is below the normal grade of the connecting roadway, any extra width should be provided on the climbing side of the roadway, since bicyclists will be going slower as they exit.

Shoulders

On urban streets, wide outside through lanes and bicycle lanes are usually preferred over shoulders for bicycle use. In rural areas or on roads with relatively few driveways and intersections, smoothly paved shoulders are preferred by many bicyclists. Shoulders also benefit motor vehicle traffic. Generally, the slope of the roadway should continue across the shoulder.

According to AASHTO's *Policy on Geometric Design of Highways and Streets*, paved or stabilized shoulders provide (1) usable area for vehicles to pull onto during emergency situations, (2) elimination of rutting and dropoff adjacent to the edge of travel lane, (3) adequate cross slope for drainage of roadway, (4) reduced maintenance and (5) lateral support for roadway base and surface course.

Where funding is limited, adding or improving shoulders on uphill sections first will give slow-moving bicyclists needed maneuvering space and decrease conflicts with faster-moving motor vehicle traffic.

Width: If it is intended that bicyclists ride on shoulders, the paved surface must be at least 1.2 m (4 ft) in width (Figure 4-9). If motor vehicle speeds exceed 60 km/h (35 mph); if the percentage of trucks, buses and recreation vehicles is high; or if static obstructions exist at the right side, then additional width is desirable (see Figure 4-8).

Clearances: Clearance from the edge of pavement to the plane of the foreslope of a ditch should be 0.6 m (2 ft) minimum (Figure 4-9). If the slope is greater than 2:1, the clearance should be 0.9 m (3 ft). If a guardrail is provided adjacent to the paved shoulder, a clearance from the edge of pavement of 1.2 m (4 ft) is preferred. Road signs and other vertical obstructions should be offset 1.8 m (6 ft) minimum from edge of pavement.

Pavement quality: Shoulders should be smoothly paved and have adequate strength and stability to support occasional motor vehicle tire loads under all weather conditions without rutting or other surface variations. The thickness of shoulder paving should be based on usual design consideration appropriate for each situation, although full-depth pavement is recommended with few exceptions.

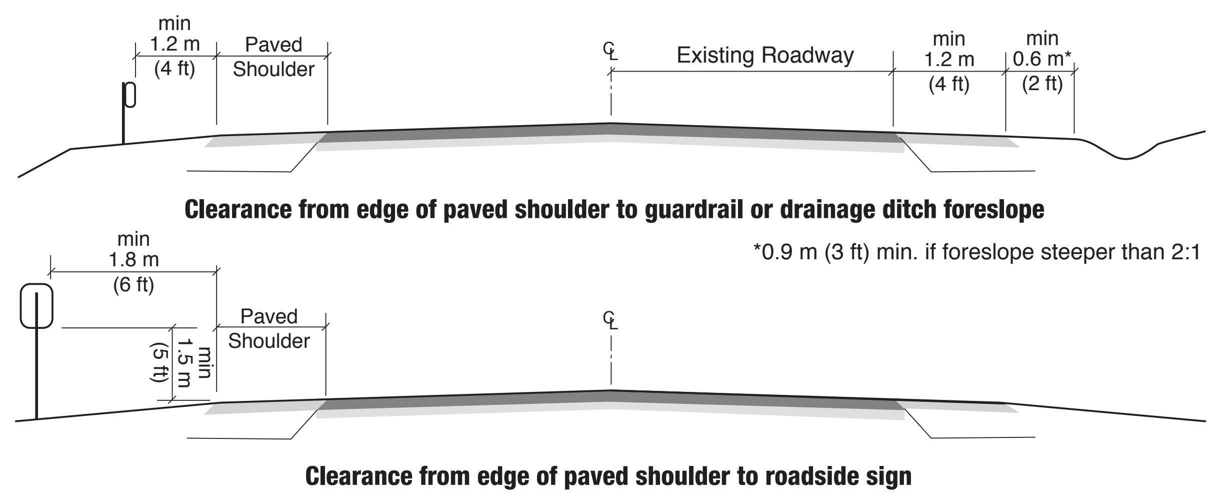


Figure 4-9: Minimum clearances and widths for paved shoulders intended for bicycle travel.

Note: See NCDOT Roadway Design Manual; in some cases values from Section 1-4B will govern.

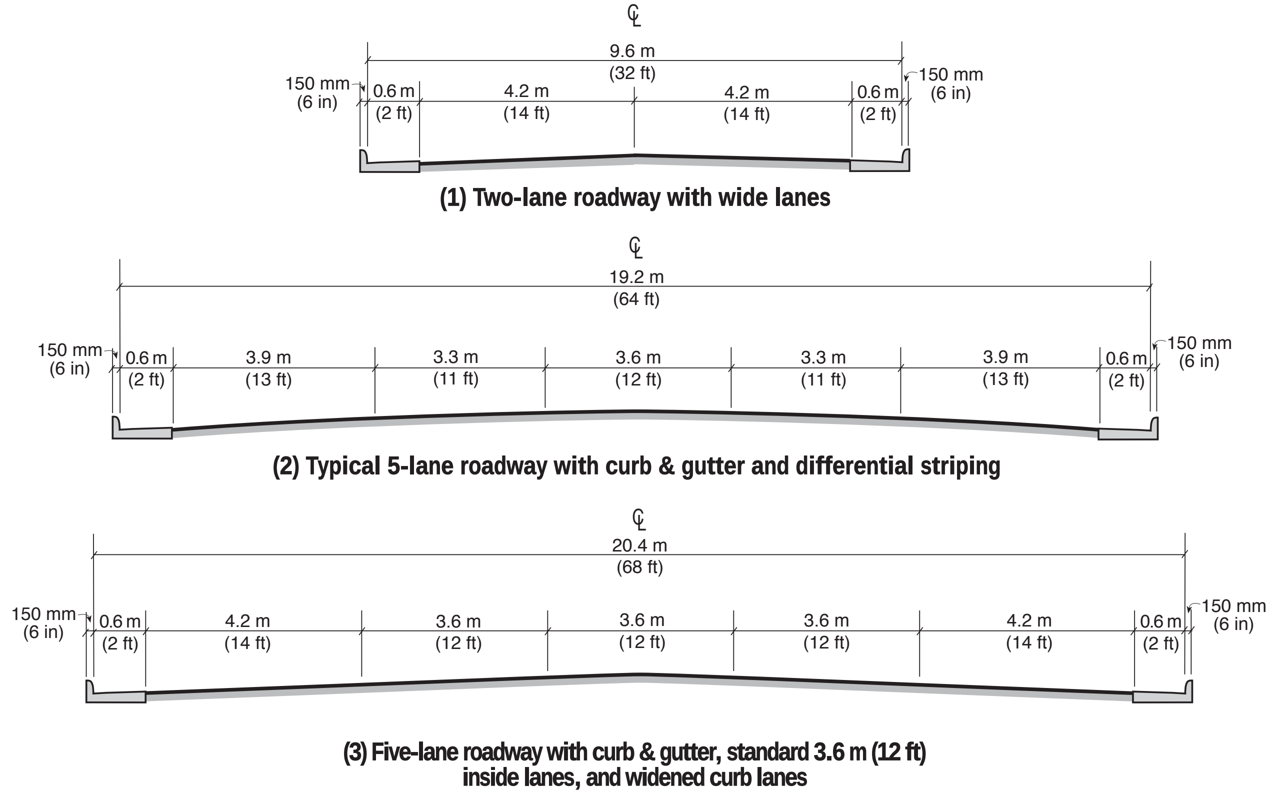


Figure 4-10: Options for creating wide outside lanes for bicycle traffic in different situations.

When it is necessary to add paved shoulders to roadways for bicycle use, paving an asphalt panel 3 m (10 ft) in width is preferred. This eliminates a joint at the edge of the existing pavement and allows the new asphalt to feather into the existing pavement between the motor vehicle wheel tracks. It provides a smooth and visually appealing improvement. White pavement edge lines, 100 mm - 150 mm (4 in to 6 in), should be used to delineate the shoulder from the motor vehicle lanes.

Rumble strips

Rumble strips and other devices designed to alert sleepy motorists can be a danger to bicyclists traveling on shoulders or near the right edge of the roadway. Where bicycle traffic is allowed, asphalt concrete dikes, raised traffic bars or other similar devices should only be considered on shoulders of roads where there is a well-documented safety problem.

In cases where rumble strips are used, additional shoulder width may be provided on the right side of the rumble strip.

Wide outside lanes

The desirable motor vehicle lane width is 3.6 m (12 ft). On roadways without separate bicycle lanes, a right-hand (outside) through lane wider than 3.6 m (12 ft) can better accomodate both bicycles and motor vehicles. The additional width on the outside lane also improves sight distances and provides more maneuvering room for vehicles turning into the roadway. In many cases where there is a wide outside through lane, motorists will not need to change lanes to pass a bicyclist. Thus, on roadways with bicycle traffic, widening the outside lane can have a beneficial effect on capacity.

Width: On roadways that accomodate both bicycles and motor vehicles within the travel lanes, 4.2 m (14 ft) of usable width should be provided on the outside through lanes. Studies have shown that any additional width on outside through lanes is beneficial. In determining the usable width of an outside lane, adjustments need to be made for obstructions. Bicyclists shy away from obstructions such as drainage gates, parked vehicles and longitudinal ridges between the pavement and gutter sections. An extra 0.3 m (1 ft) of "shy distance" should be added for flush or depressed obstructions, such as a joint or soft shoulder. If a raised obstruction, such as a curb and gutter, is present, an extra 0.6 m (2 ft) "shy distance" should be added to the raised face of the curb. If drainage grates are located in the gutter or near the right edge of the roadway, they should not be included in the calculations of usable width.

Some experts have recommended 4.5 m (15 ft) of usable width for an actual "wide outside through lane." However, widths greater than 4.2 m (14 ft) can encourage the operation of two motor vehicles in one lane. This is likely to occur near intersections with heavy turn volumes during periods of peak congestion. Such conditions may reflect a need to consider improvements at the intersection. At intersections with separate right-turn lanes, the outside through lane should be widened to accomodate bicycles.

The additional width for wide outside lanes to accomodate bicycle traffic should be introduced by widening the roadway pavement. However, on multi-lane roadway sections, if the outside lane width cannot be increased by widening the pavement, the lane striping may be shifted to narrow the inside lane(s) while widening the outside lane. No inside lane width should be reduced to less than 3.3 m (11 ft) for this purpose. Narrowing an inside lane from 3.6 m to 3.3 m (12 ft to 11 ft) can reduce the lane's capacity up to 5 percent. When considering this approach, the volume of truck traffic should be taken into account. In general, 3.3 m (11 ft) lanes should not be considered if the truck volumes are greater than 5 percent of the total traffic volume.

Two-lane roadways: A 4.2 m (14 ft) usable lane width is desirable to accommodate both motor vehicles and bicycles within the travel lanes. Figure 4-10 (1) shows the recommended typical section for a two-lane curb and gutter roadway when bicycles share the travel lanes with motor vehicles.

Multi-lane roadways: For curb and gutter roadway sections in urban and suburban areas, with more than one lane in each direction of travel, unequal lane widths with widened outside "curb" lanes are desirable to accommodate bicycles when the following conditions apply;

(1.) Control of access is not provided.

(2.) Motor vehicle traffic is not more than 60 percent (Level of Service C) of the route's capacity. (If greater than 60 percent, alternate bicycle accomodations should be considered, if feasible).

(3.) A minimum width of 3.3 m (11 ft) can be provided on each inside lane.

(4.) Truck traffic is not greater than 5 percent of the total motor vehicle traffic.

Existing facilities: Widening outside lanes to accommodate bicycles can be provided by introducing unequal lane width pavement markings on existing multi-lane facilities. When the above conditions are applicable, unequal lane width pavement markings should be introduced to existing curb and gutter facilities. This is best accomplished when the facility is resurfaced. Figure 4-10 (2) shows the prefered location for unequal lane width pavement markings to accommodate bicycle traffic on an existing five-lane, 19.2 m (64 ft), face-to-face curb and gutter section commonly used in North Carolina.

New facilities: Outside lanes that are 4.2 m (14 ft) wide should be constructed on new multilane curb and gutter facilities when bicycle traffic is anticipated and the above conditions are applicable. Figure 4-10 (3) shows the preferred typical section with appropriate pavement markings to accommodate bicycle traffic on a new curb and gutter roadway.

5 Bicycle Lanes

Bicycle lanes are portions of the roadway designated exclusively or primarily for bicycles.

Introduction

Bicycle lanes may be considered when it is desirable to delineate available road space for preferential use by bicyclists and motorists. 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 *Motor Vehicle Laws of North Carolina.* 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).

While there are no universally accepted objective criteria for determining the need for bicycle lanes, the following factors are important considerations.

Bicycling demand: Simply striping bicycle lanes will not necessarily create bicycle use. Surveys in several cities with active bicycle programs have shown that bike lanes attract existing users to a particular street but do not necessarily attract new bicyclists.

Potential origins and destinations: In order to attract bicyclists, there must be a nearby population of likely users and potential destinations within riding distance. According to most surveys, a 6 km (4 mi) radius defines the maximum bicycle trip for most casual users.

Available alternatives: When considering alternate routes for bicycle lane installation, the designer must remember that most bicyclists will choose the route that best combines direct access with low traffic volumes.

Surrounding land use: Strip development or other areas with many commercial or institutional driveways and, therefore, significant volumes of right-turning traffic, tend to make unsuitable locations for bicycle lanes. In such cases, wide curb lanes may be more appropriate.

Traffic conditions: High volume multi-lane highways with numerous grade separated interchanges, or multi-lane roadways with continuous center-turn lanes and high volumes of motor vehicles make less suitable roads for bicycle lanes. In such cases, bicycle lanes can attract novice or child bicyclists to a potentially hazardous situation.

Geometric conditions: 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. Generally, roads with many complicated intersections (e.g., those with multiple right turn lanes) are more difficult locations to modify for inclusion of bicycle lanes. In these situations, wide curb lanes should be the preferred option for accommodating bicyclists.

Other considerations: Bicycle lanes are not advisable on long, downgrades of 4 percent or more, where bicycle speeds greater than 48 km/h (30 mph) are expected. As grades increase, downhill bicycle speeds will increase, which increases the problem of riding near the edge of the roadway. In such situations, bicycle speeds can approach those of motor vehicles, and experienced bicyclists will generally move into the traffic lanes to increase sight distance and maneuverability. If bike lanes are to be striped, additional width should be provided to accommodate higher bicycle speeds.

Striping bike lanes next to curbs where parking is prohibited only during certain hours must be done only in conjunction with special signing to designate the hours bike lanes are to be effective. This type of bike lane should be considered only if the vast majority of bicycle travel would occur during the hours of the parking prohibition, and only if there is a firm commitment to enforce the parking prohibition. Because of the obvious complications, this type of bike lane is not encouraged for general application.

Figure 5-1 gives several other cautions taken from the Federal Highway Administration's *Safety and Locational Criteria for Bicycle Facilities.*

Bicycle lane delineation

Bicycle lane lines should be solid, 100 mm to 150 mm (4 in to 6 in) wide, and marked with white traffic paint. The width of the lines should match the width of other lines on the particular roadway in question. Thermoplastic and preformed tape can be slippery when wet, causing loss of control for bicyclists, and should, therefore, not be used.

Raised barriers (e.g., raised traffic bars and asphalt concrete dikes) or raised pavement markers should not be used to delineate bicycle lanes. Raised barriers prevent motorists from merging into bike lanes before making right turns, restrict the movement of bicyclists desiring to enter or exit bike lanes and impede routine maintenance.

Bike lane markings should be placed a constant distance from the outside motor vehicle lane. Bike lanes with parking permitted should not be directed toward the curb at intersections or localized areas where parking is prohibited. Such a practice prevents bicyclists from following a straight course. Where transitions from one type of bike lane to another are necessary, smooth tapers should be provided. (See the MUTCD, Section 3B-8 for taper design.)

Principal problems with bike lane applications

- Provision of inadequate lane width or use of unrideable street surface as the bike lane area;
- Abrupt termination of lanes at hazard or constraint situations, creating a facility which leads bicyclists to a trap; also transitions which force awkward bicyclist movements at other termination points;
- Use of non-standard and poorly visible lane demarkation signs and markings which create uncertainties in motorist and bicyclist understanding of lane presence and purpose;
- Lane configuration and lane use ordinances which prevent the bicyclist from establishing proper position with respect to motor vehicle traffic at intersections as well as for mid-block turns into driveways; and
- Lane use ordinances which conflict with reasonable bicyclist desires to leave the lane in order

Bicycle lane surface quality

Bicycle lanes should be paved to the same standards as adjacent traffic lanes. The surface to be used by bicyclists should be smooth, free of potholes, and the pavement edge uniform. For rideability on new construction, the finished surface of bikeways should be smooth and true to the required cross section and grade. The surface should conform to the *NCDOT Standard Specifications for Roads and Structures*, Section 610-13, Surface Requirements. Further, manholes, drainage grates and utility covers should be located outside the bicycle lane. For more advice on pavement quality, see Chapter 4.

Bicycle lane widths

Under ideal conditions, minimum bicycle lane width is 1.2 m (4 ft). However, certain edge conditions dictate additional desirable bicycle lane width. Additional width also is desirable when the width of the adjacent traffic lane is less than 3.6 m (12 ft). This is an important addition because the effective clearance between a bicyclist and adjacent traffic is a function of the combined width of both the bike lane and the adjacent traffic lane.

To examine the width requirements for bicycle lanes, Figure 5.2 shows four usual locations for such facilities in relation to the roadway. Figure 5.2 (1) depicts bicycle lanes on an urban curbed street where a parking lane is provided. The minimum bicycle lane width for this location is 1.5 m (5 ft). Bicycle lanes should always be placed between the parking lane and the motor vehicle lanes. Bicycle lanes between the curb and the parking lane create hazards for bicyclists from opening car doors and poor visibility at intersections and driveways. They also prohibit bicyclists from making left turns; therefore, this placement should never be considered.

Where parking is permitted but a parking lane is not provided, the combination lane, intended for both motor vehicle parking and bicycle use, should be a minimum of 3.6 m (12 ft) wide. Figure 5-2 illustrates this condition. However, if it is likely the combination will be used as an additional motor vehicle lane, it is preferable to designate separate parking and bicycle lanes, as shown in Figure 5-2 (1). In both instances, if parking volume is substantial or turnover is high, an additional 0.3 m to 0.6 m (1 ft or 2 ft) width is desirable for safe bicycle operation.

Figure 5-2 (3) depicts bicycle lanes along the outer portions of an urban-type curbed street where parking is prohibited. Bicyclists do not generally ride near a curb because of the possibilities of riding through debris, over an uneven longitudinal joint, or along a steep cross-slope, or of hitting a pedal on the curb. Bicycle lanes in this location should have a minimum width of six feet from the curb face.

Figure 5-2 (4) depicts bicycle lanes on a highway without curb or gutter. Bicycle lanes should be located between the motor vehicle lanes and unpaved shoulders. Bicycle lanes may have a minimum width of 1.2 m (4 ft), although a width of 1.5 m (5 ft) or greater is preferable. Additional width is desirable where substantial truck traffic is present, where prevailing winds are a factor, on grades, or where motor vehicle speeds exceed 56 km/h (35 mph).

Bicycle lane intersection design

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 lane to the left of the bicycle lane. Both maneuvers are contrary to established rules of the road and result in conflicts. Common movements of motorists and bicyclists are shown in Figure 5-3.

At intersections, bicyclists proceeding straight through and motorists turning right must cross paths. Marking and signing configurations which encourage these crossings through merging in advance of the intersection are generally preferable to those that force the crossing in the immediate vicinity of the intersection. To a lesser extent, the same is true for left-turning bicyclists. However, in this maneuver, the rules of the road allow bicyclists to make either a “vehicular style” left turn (where the bicyclist merges left to the same lane used for motor vehicle left turns) or a “pedestrian style” left turn

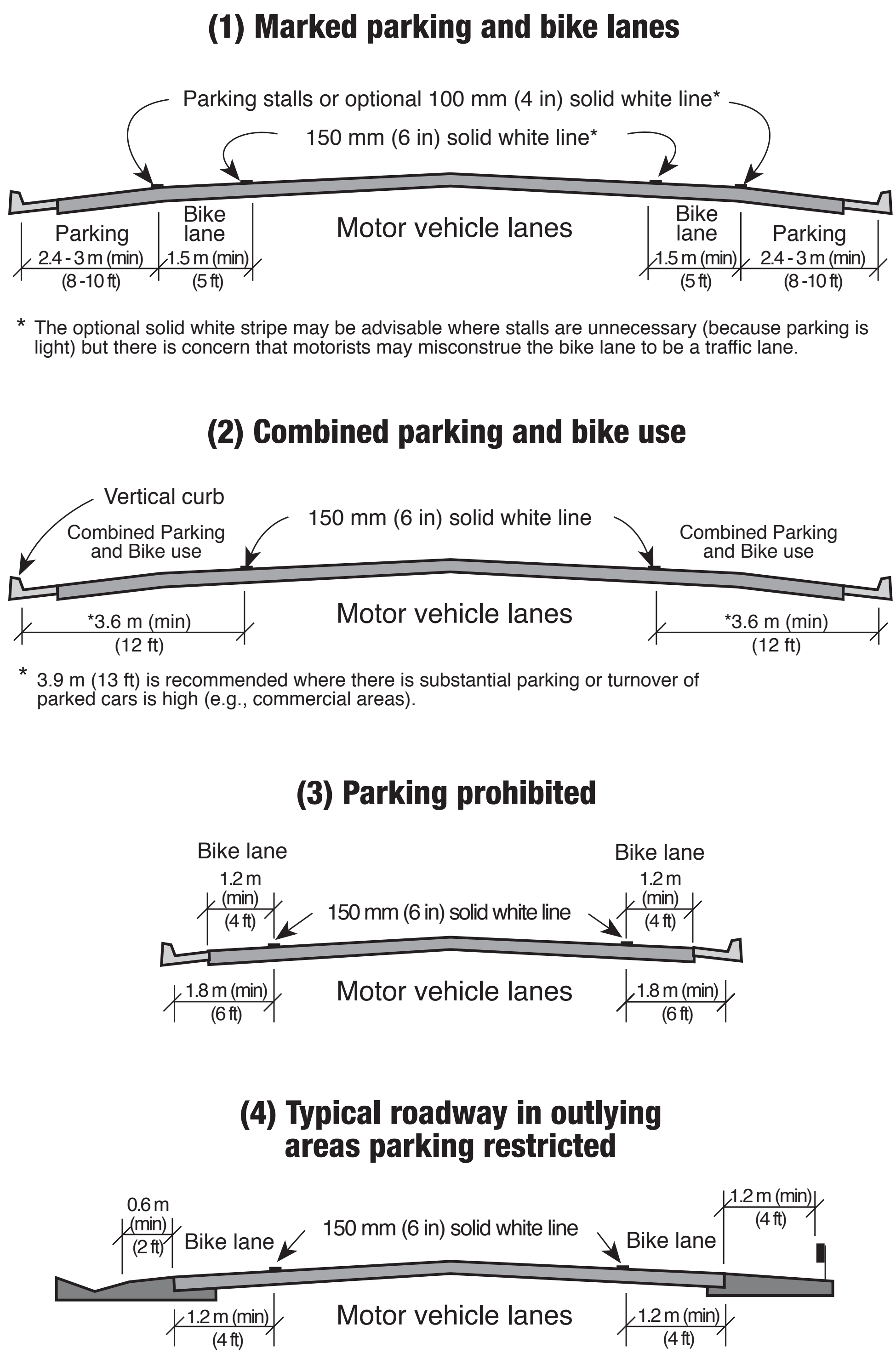


Figure 5-2: Typical bike lane cross sections on two-lane or multi-lane highways.

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

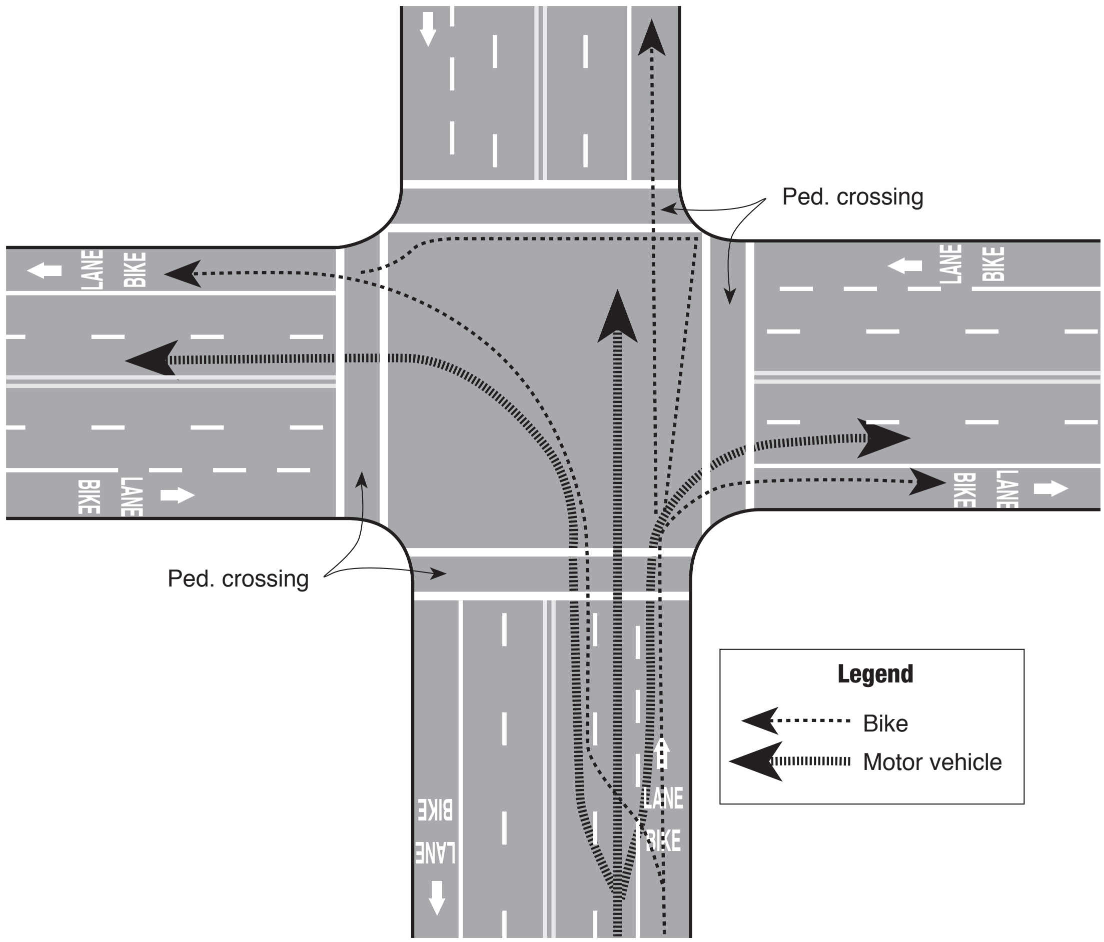
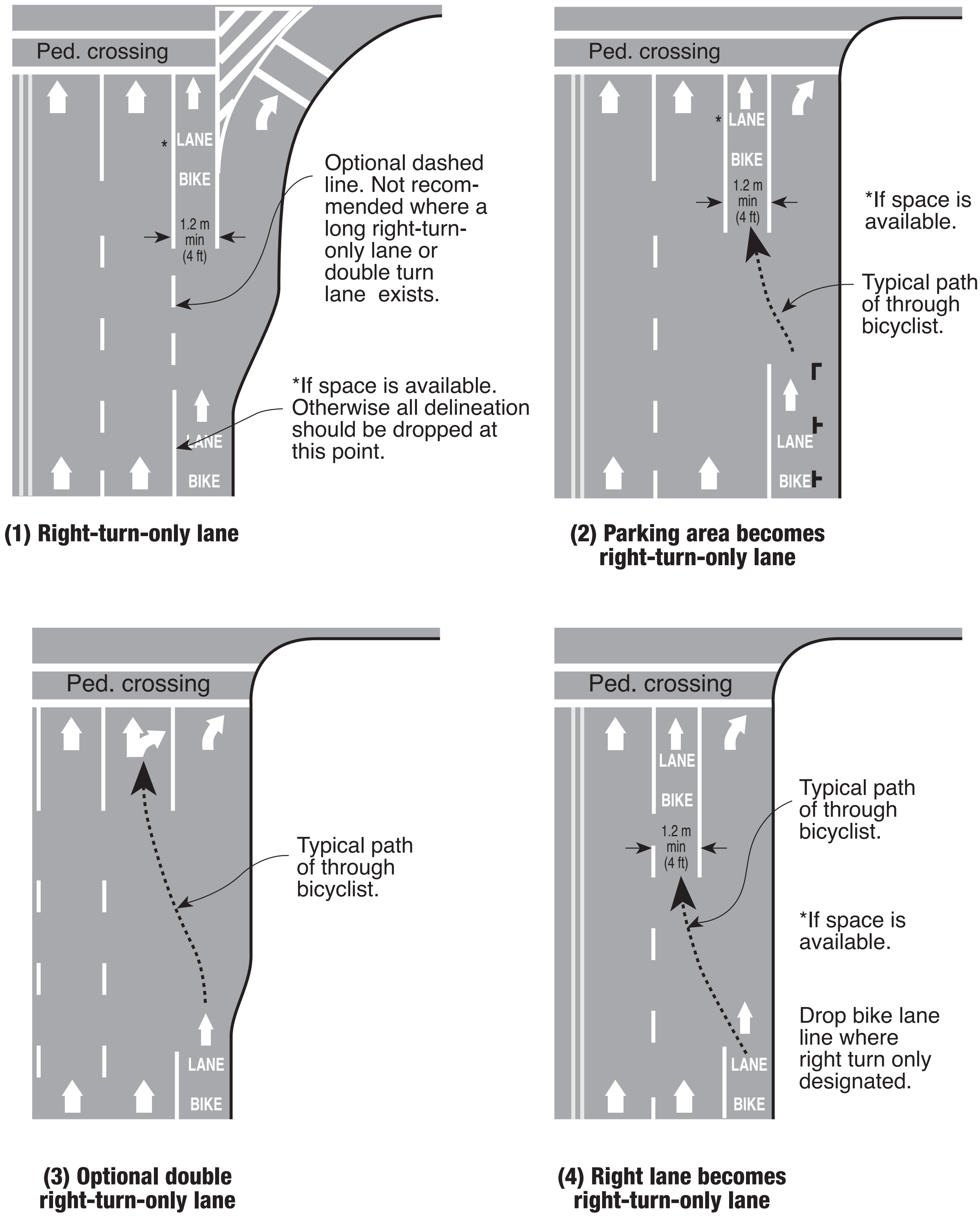


Figure 5-3: Typical bicyclist and motor vehicle movements in an intersection of two multi-lane streets with bicycle lanes.
Source: Arizona Bicycle Facilities Planning & Design Guidelines, 1988

(where the bicyclist proceeds straight through the intersection, dismounts and then walks across the intersection on the cross street).

Figure 5-4 illustrates recommended striping patterns for bike lanes crossing a motorist right-turn-only lane. When confronted with such intersections, bicyclists will have to merge with right-turning motorists. Since bicyclists are typically traveling at speeds less than motorists, they should signal and merge where there is a sufficient gap in right-turning traffic, rather than at a predetermined location. For this reason, it is recommended that either all delineation be dropped at the approach of the right-turn lane (or off ramp) or that a single, dashed bike lane line be used, extended at a flat angle across the right-turn lane. A pair of parallel lines (delineating a bike lane crossing) to channel the bike merge is not recommended, as bicyclists will be encouraged to cross at a predetermined location, rather than where there is a safe gap in right-turning traffic. Also, some bicyclists are apt to assume they have the right-of-way and may not check for right-turning motor vehicle traffic.

A dashed line across the right-turn-only lane (or off-ramp) is not recommended on extremely long lanes, or where there are double right-turn-only lanes. For these types of intersections, all markings should be dropped to allow the bicyclist's judgment to prevail. Bike lanes crossing on-ramps do not present the same problems, as bicyclists normally have a good view of traffic entering the roadway and will adjust their path as necessary to cross ramp traffic. A "Bike Xing" sign may be used to warn motorists of the potential for bicyclists crossing their path.



(1) Right-turn-only lane

(2) Parking area becomes right-turn-only lane

(3) Optional double right-turn-only lane

(4) Right lane becomes right-turn-only lane

Figure 5-4: Bicycle lane marking options at intersections with right-turn-only lanes.

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

Where there are numerous left-turning bicyclists, a separate turning lane, as indicated in Part IX of the MUTCD (see Appendix 4), should be considered. The design of bicycle lanes also should include appropriate signing at intersections to reduce the number of conflicts. General guidance for pavement marking of bicycle lanes also is contained in the MUTCD.

6 Bicycle Routes

Introduction

One of the most common questions that new bicyclists ask is where to ride. A person who has done very little bicycling as an adult may find the main roads too challenging but may not know how to find alternative routes. Similarly, someone who is new to town may wish to try out the local scenic backroads but may not be able to find them, given a standard road map. Solving these problems are functions of the bicycle route.

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.

A bicycle route may include stretches of road with marked bicycle lanes, but in general the bicycle route concept does not require that the road include any such special bicycle facilities.

In rural areas, signed touring routes may 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 planning

Planning a bicycle route, or a network of such routes, begins with development of the statement of purpose. Choosing the appropriate purpose requires consideration of an agency's goals and objectives. For example, within the scope of its overall transportation plan, a transportation agency's purpose may be to encourage utilitarian bicycle use along a network of quiet through streets.

On the other hand, a recreation agency may see part of its mission as encouraging recreational bicycling by identifying a series of loop rides. The following are typical uses of the bicycle route concept.

Bicycle route networks: In deciding to designate a local network of bicycle routes, the first step is to develop a list of common destinations. Such destinations might include, for example, local shopping areas, schools and universities, sports and recreation complexes, parks and discontinuous segments of bicycle paths.

Each destination will have a reasonable capture area from which it may attract bicyclists. In general, the average bicyclist will travel between 3 km to 6 km (2 mi to 4 mi) per trip. As a result, a capture radius of 6 km (4 mi) will be appropriate for most bicycling destinations.

Schools often have specific districts; maps of these may be obtained from the local school district offices. Universities and colleges are often adjacent to student housing neighborhoods which help identify logical bicycle transportation corridors.

Placing the common destinations and their likely capture areas on a map will begin to suggest potential bicycle route corridors. Since a bicycle route goes both directions, it is useful to identify two end points for each route. With the potential corridors chosen, the next step is to identify alternative routes. This step is discussed in "Selecting bike routes."

Looped routes: In developing a series of looped routes, the first step is to identify scenic areas of interest. Such areas might include large parks, scenic farm country, areas around lakes or other bodies of water or pristine woodlands. Place these general locations on a map of the area.

Within these areas, identify points of interest that a route should pass by. Historic sites, scenic overlooks, picnic areas and other such attractions should be located on the map. Once these sites have been identified, look for potential loop routes approximately 16 km to 64 km (10 mi to 40 mi) in circumference. Longer routes with challenging hills will be popular with more experienced riders while casual family riders will prefer the shorter, flatter and less challenging routes.

Touring routes: Long-distance bicycle touring routes are a specialized application of the bicycle route concept. The North Carolina Department of Transportation Office of Bicycle and Pedestrian Transportation has been active in the development of such routes over a period of more than ten years. For this reason, it is important to contact the office and work closely with its staff on the development of such routes. A detailed pamphlet on the subject has been published which should be consulted.

Selecting bike routes

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 fall into three main categories: (1) geometrics, (2) traffic conditions, and (3) appropriateness for the intended purpose.

Geometrics: The most important geometric considerations include roadway width, pavement quality, intersections, curves and hills. Chapter 4 of this guide explains how to make bicycle-related roadway improvements. To some extent, low motor vehicle traffic volumes can compensate for less desirable roadway conditions.

Roadway width: On lower speed roadways, widened curb lanes are beneficial for bicyclists. On high speed roads, smoothly paved shoulders are desirable. If a route is generally suitable but includes a short stretch of narrow road, consideration should be given to use of the “Share the Road” warning sign on that segment (see Appendices for details).

Pavement quality: Smooth roads are far preferable to roughly paved ones. Perhaps more than any other geometric consideration, pavement quality will determine how popular a bicycle route will be.

Intersections: Intersections should be relatively simple and should include few complex features, like multiple turn lanes. Points where bicyclists will be expected to turn left should be carefully evaluated for their safety. Traffic lights should be responsive to bicycle traffic. And the presence of high numbers of stop signs on the route will discourage bicycle users.

Curves: While curved stretches of roadway provide variety, a road with serious sight distance problems and many no-passing zones may not be an appropriate bicycle route.

Hills: Bicyclists' perception of the steepness of hills will vary with their fitness levels, cycling skills, trip purposes and expectations. While most utilitarian bicyclists will choose the flatest route, fit and skillful recreational riders may enjoy the challenge of a climb and the thrill of a descent.

Traffic conditions: Traffic conditions that affect the desirability of a potential bicycle route include traffic volume, traffic speed and percentage of truck and RV traffic.

Traffic volume: In general, the route with the least motor vehicle traffic will be the one many bicyclists will prefer. Experienced bicyclists, who have learned to cope with traffic, will be least concerned with this variable; for new bicyclists, however, it will be the overriding concern.

Traffic speed: For experienced riders, high speed traffic offers few concerns. However, most bicyclists fear high traffic speeds.

Percentage of truck and RV traffic: On high speed routes, the percentage of truck and RV traffic is a particular concern due to the buffeting that bicyclists experience when passed by heavy vehicles. When combined with narrow road conditions, a significant percentage of heavy vehicle traffic will make a route undesirable.

Appropriateness: Factors used to determine how appropriate a particular road is for a bicycle route include directness, scenery and available services.

Directness: For utilitarian riders, directness is important, and a route that wanders too much will see little use. For recreational riders, this factor is not as important.

Scenery: For utilitarian riders, scenery is relatively unimportant. For recreational bicyclists, on the other hand, varied and attractive scenery is one of the most important factors.

Services: Recreational riders, particularly those riding more than a few miles, will be particularly interested in services (food, water, restrooms). A route without such services will be less desirable than one with occasional stopping places.

Designating bike routes

When setting up a bicycle route, the placement and spacing of signs should be based on Part IX of the MUTCD, found in Appendix 4.

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 6-1 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 6-1) 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.

Numbered bike route: The numbered bike route sign (see Figure 6-2) is used to establish a unique identification for a state or local bicycle route. The sign may be combined with directional arrow subplates (M7-1 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.

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

Mapping

Bicycle users often want to know the extent of a network of bike routes, just what areas certain routes serve. Yet few bicyclists will follow a route just to see where it goes. Therefore, mapping bicycle routes can improve the utility of the system.

Depending on the budget available, a bike route map can consist of anything from a small one-color schematic to a large full-color production. While the former would require relatively few of an agency's resources, the latter could be time-consuming and demand significant support in terms of money and professional staffing. For more information on bicycle mapping, see Chapter 8, or contact the NCDOT Office of Bicycle and Pedestrian Transportation.

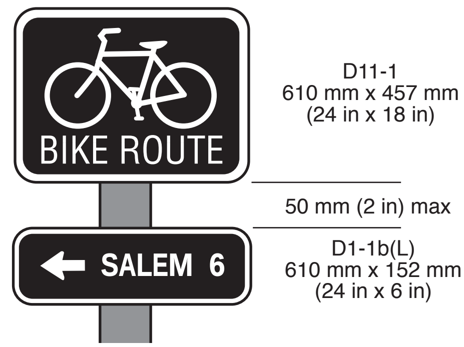


Figure 6-1: Typical signs used for designating bicycle routes. *Source: MUTCD, Part IX*

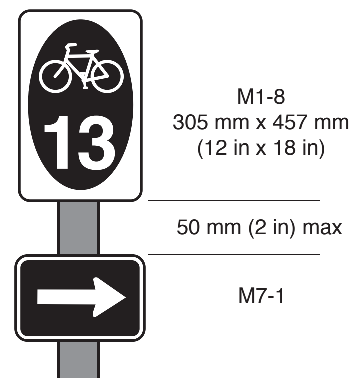


Figure 6-2: Signs used to designate numbered bicycle route. *Source: MUTCD, Part IX*

7 Bicycle Paths

Constructing bicycle paths is one way to create new recreational opportunities. It also can help bicyclists surmount major barriers or hazards.

Introduction

Bicycle paths are trails generally located on exclusive rights-of-way and with minimal cross flow by motor vehicles. Bicycle paths can serve a variety of purposes. For example, a connecting trail between two cul-de-sac streets can provide commuter bicyclists with a shortcut through a residential neighborhood or around a barrier.

Located in a park, a bicycle path can provide a wide variety of users with an enjoyable recreational experience. Bicycle paths can be located along abandoned railroad rights-of-way, the banks of rivers and other similar linear corridors. Bicycle paths also can 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.

Bicycle paths should be thought of as non-motorized extensions of the highway system intended for the exclusive or preferential use of bicycles. It is important for designers to remember that the bicycle is a vehicle and that close attention to accepted design criteria is necessary for the provision of safe facilities. While there are many similarities between design criteria for bicycle paths and those for highways (e.g., in determining horizontal alignment, sight distance requirements and signing), some criteria (e.g., horizontal clearance requirements, grades and pavement structure) are dictated by operating characteristics of bicycles that are substantially different from those of motor vehicles. The designer should always be conscious of the similarities and differences and how these influence the design of bicycle paths. The following sections provide guidance for designing a safe and functional bicycle path.

Separating paths and highways

When two-way bicycle paths are located immediately adjacent to a roadway, operational problems may occur. The following are some problems with bike paths located immediately adjacent to roadways.

(1.) Unless paired, they require one direction of bicycle traffic to ride against traffic, contrary to normal rules of the road.

(2.) When the path ends, bicyclists going against traffic will tend to continue to travel on the wrong side of the street. Likewise, bicyclists approaching a bicycle path often travel on the wrong side of the street to get to the path. Wrong way riding is a major cause of bicycle/automobile crashes and should be discouraged at every opportunity.

(3.) At intersections, motorists entering or crossing the highway 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 highway instead of the bicycle path because they have found the highway to be safer, more convenient or better maintained. Bicyclists using the highway 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 highway 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 vehicle traffic 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 be a hazard to bicyclists and motorists, can complicate maintenance of the facility and can cause other problems as well.

For these reasons, wide curb lanes, bicycle lanes or bicycle routes may be the best way to accommodate bicycle traffic along highway corridors depending upon traffic conditions.

Multipurpose recreational trails

In some instances, it may be appropriate for recreational agencies to develop multipurpose recreational trails – for hikers, joggers, equestrians, bicyclists, etc. Many of these trails will not be paved and will not meet the standards for bicycle paths presented in this guide. As such, these facilities should not be signed as bikeways. Rather, they should be designated as recreational trails (or similar designation), along with regulatory signing to restrict motor vehicles, as appropriate. If recreational trails are to serve primarily bicycle travel, they should be developed in accordance with standards for bicycle paths.

Width and clearance

Paved width: The paved width and the operating width required for a bicycle path are primary design considerations. Under most conditions, the minimum paved width for a two-directional bicycle path is 3 m (10 ft) Paths narrower than 3 m (10 ft) are not recommended as they do not permit safe and frequent passing opportunities where there is high bicycle use, especially where pedestrian use is frequent. Also, a narrow path is subject to pavement edge damage from maintenance vehicle loading conditions. (A segment of path less than 3 m (10 ft) wide may be acceptable or necessary for short distances, such as when passing between buildings or utility poles that cannot be moved, or when crossing bridges that cannot be modified, or unusual items such as above-ground pipes to underground storage tanks. These should be treated on a case-by-case basis and signed in accordance with the MUTCD.)

In many cases, it may be desirable to increase the width of a bicycle path to 3.6 m (12 ft). For example, wider paths may be needed in cases involving substantial bicycle volume, probable shared use with joggers and other pedestrians, use by large maintenance vehicles, steep grades and locations where bicyclists are likely to ride two abreast.

One-way bicycle paths often will be used as two-way facilities unless effective measures are taken to assure one-way operation. For this reason, one-way paths are not recommended.

Horizontal clearances: A minimum 0.6 m (2 ft) wide graded area should be maintained adjacent to both sides of the pavement (see Figure 7-1). However, 0.9 m (3 ft) or more is desirable to provide clearance from trees, abutments, piers, polls, walls, fences, box culverts, guardrails or other lateral obstructions. A wider graded area on either side of the bicycle path can serve as a separate jogging path. If adequate clearance cannot be maintained between the path and vertical barriers or other features causing bikeway constriction, a warning sign, as described in Figure 7-1, should be used in advance of the hazard with a Type I, II or III object marker at the location of the hazard

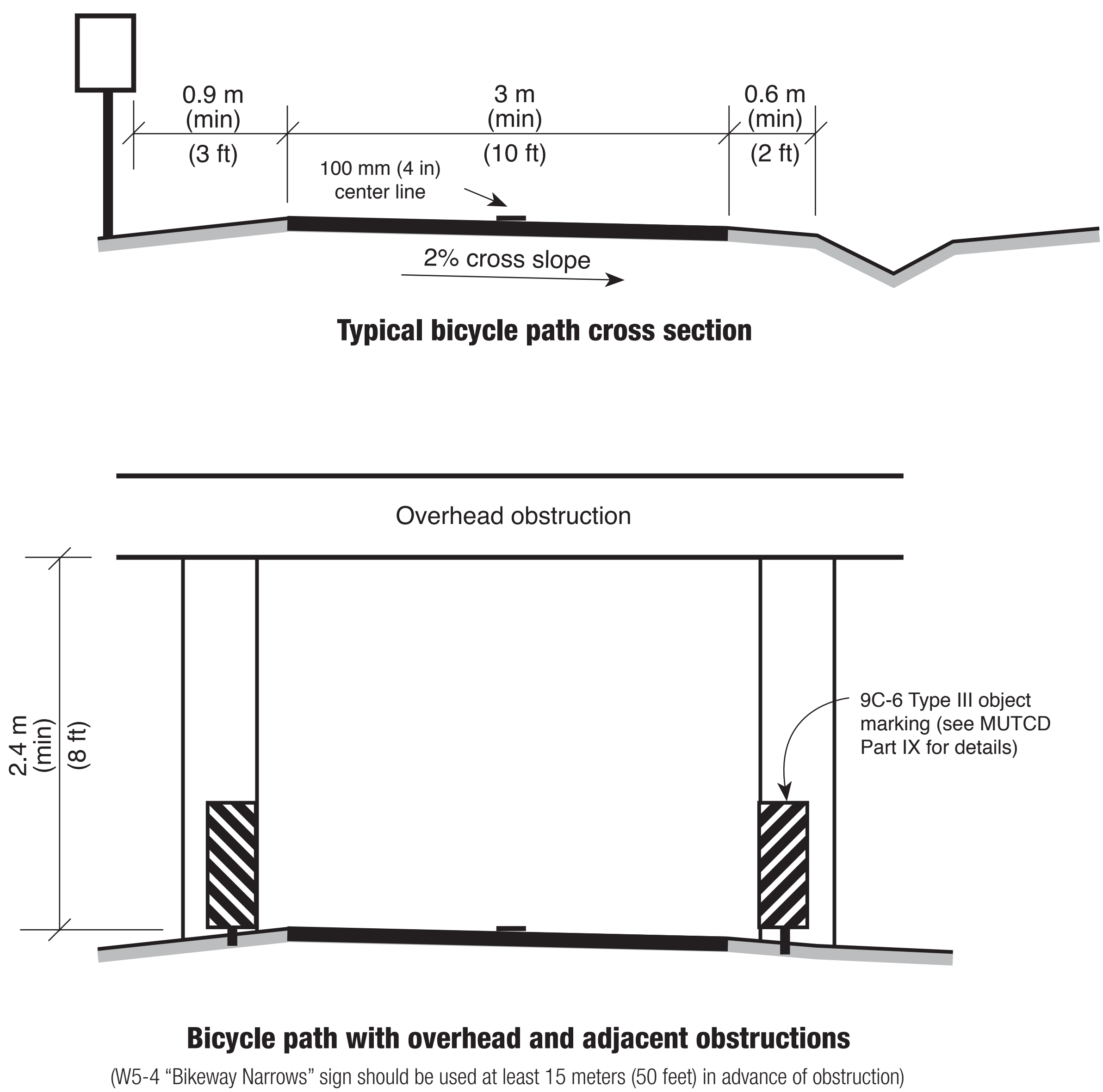


Figure 7-1: Bicycle path cross sections showing widths, clearances, cross slopes and center line marking

Source: Guide to the Development of New Bicycle Facilities, AASHTO, 1991 and MUTCD Part IX.

(see Part 9C-6 of the MUTCD for diagrams). This treatment should be used only where unavoidable and is by no means a substitute for good design.

A wide separation between a bicycle path and canals, ditches or other significant depressions is essential for safety. A minimum 1.5 m (5 ft) separation from the edge of the bike path pavement to the top of the slope is desirable. If this is not possible, a physical barrier such as dense shrubbery or a chain link fence should be provided (see Figure 7-2).

A wide separation between a bicycle path and any nearby highway is desirable to confirm

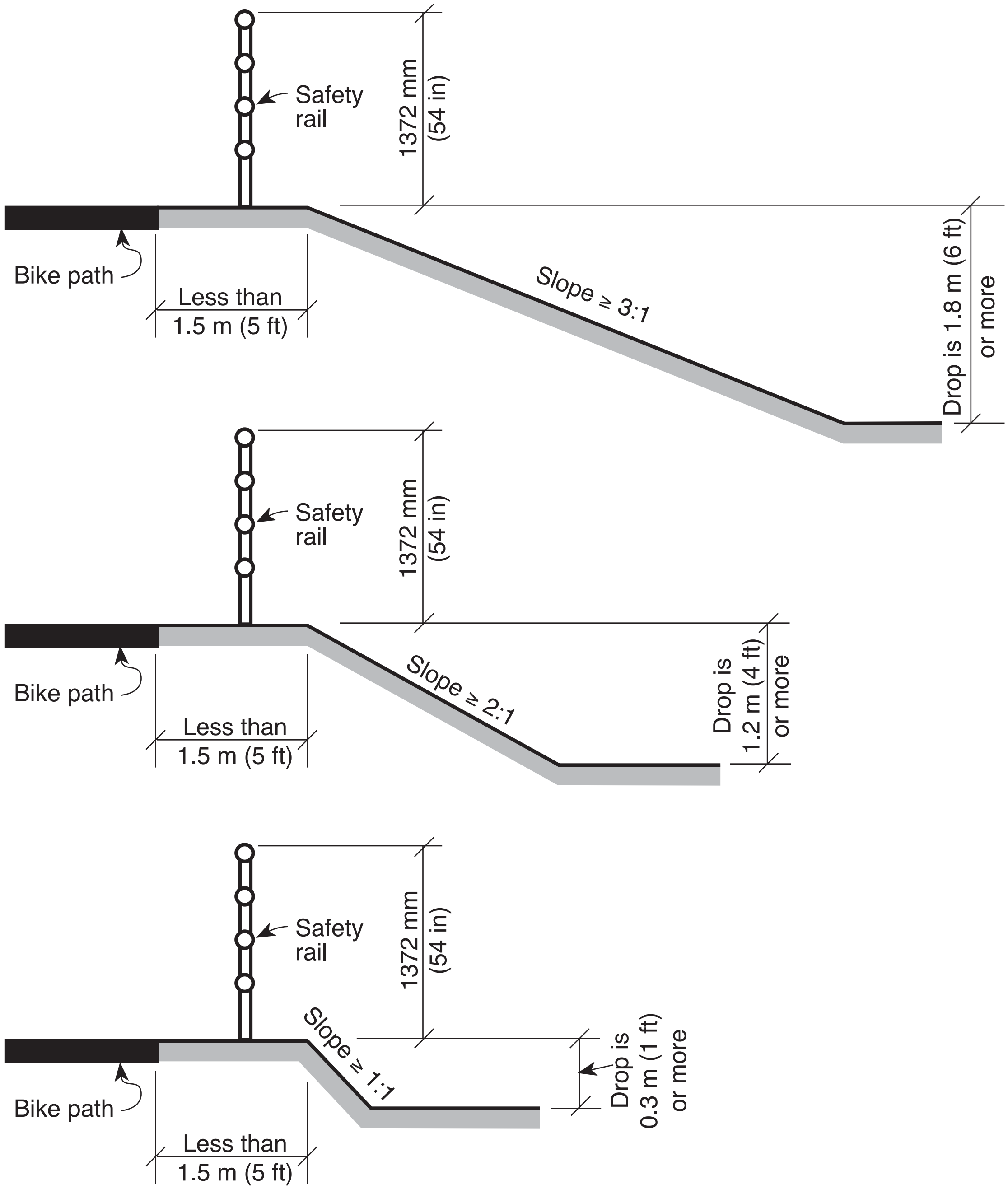


Figure 7-2: Safety rail between bicycle path and adjacent slope.

Source: Arizona Bicycle Facilities Planning & Design Guidelines, AZDOT, 1988.

to both the bicyclist and the motorist that the bicycle path functions as an independent facility for bicycles. When this is not possible and the distance between the edge of the roadway and the bicycle path is less than 1.5 m (5 ft) then a suitable positive barrier should be provided.

Such dividers serve to prevent bicyclists from making unwanted movements 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 1.35 m (54 in) high, to prevent bicyclists from toppling over it. Such a situation should be treated as a special case and appropriate roadside design and warning measures taken. Where the path approaches crossing roadways or driveways, the barrier should be modified as necessary to enhance visibility between bicyclists and motorists.

Vertical clearances: The vertical clearance to obstructions should be a minimum of 2.4 m (8 ft) (see Figure 7-1). However, vertical clearance may need to be greater to permit passage of maintenance vehicles and, in undercrossings and tunnels, a clearance of 3 m (10 ft) is desirable for adequate vertical shy distance.

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 presence of other traffic, 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 35 km/h (20 mph) should be used; however, when the grade exceeds four percent, or where strong prevailing tailwinds exist, a design speed of 50 km/h (30 mph) is advisable.

Speed bumps or similar surface obstructions, intended to slow down bicyclists in advance of intersections, should not be used. They may divert a rider's attention from traffic or catch a pedal causing the cyclist to fall.

On unpaved paths, where bicyclists tend to ride slower, a lower design speed of 25 km/h (15 mph) can be used. Similarly, where the grades or the prevailing winds dictate, a higher design speed of 40 km/h (25 mph) 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. With the growing popularity of mountain bicycles, provision of unpaved trails is likely to increase. However, little research has been done on the phenomenon. Quite possibly, speeds on some types of unpaved trails will equal or exceed those on paved trails, especially where there are significant grades. The engineer should exercise proper care when dealing with this new area of design.

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, the speed of the bicycle and the amount of lean the bicyclist can handle. Leaning is an important aspect of bicycle turns; the farther over a bicyclist can lean in a turn, the sharper a curve he/she can negotiate, given the limitations of friction. However, novice bicyclists are less able to lean over safely and, as a result, will be unable to negotiate a curve at the same speed as a more skilled rider. For this reason, a conservative approach to setting curve radius is important.

The minimum design radius of curvature can be derived from the following formula:

$$R_{min} = \frac{V2}{15\ (e + f)}$$

Where
R = Minimum radius of curvature (ft),
V = Design speed (mph),
e = Rate of superelevation (ft/ft),
f = coefficient of friction.

For most bicycle path applications, the superelevation rate will vary from a minimum of +2% (the minimum necessary to encourage adequate drainage) to a maximum of approximately +5% (beyond which maneuvering difficulties by slow bicyclists and adult tricyclists might be expected). The

minimum superelevation rate of +2% will be adequate for most considerations and will simplify construction. Negative superelevations are to be avoided, since they have the same effect on bicyclists' stability as leaning farther than intended in
a turn.

The coefficient of friction depends upon bicycle speed; surface type, roughness and condition; tire type and condition; and 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 friction factors for paved bicycle paths can be assumed to vary from 0.30 at 23 km/h (15 mph) to 0.22 at 50 km/h (30 mph). Although there are no 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%, minimum radii of curvature can be selected from Figure 7-3 below.

(e= +2%)

Design Speed - V km/h (mph)	Friction Factor - f	Design radius - R m (ft)
30 (20)	0.27	30 (95)
40 (25)	0.25	50 (155)
50 (30)	0.22	80 (250)
60 (35)	0.19	120 (390)
65 (40)	0.17	175 (565)

Figure 7-3: Design radii for paved bicycle paths.

Occasionally, designers are tempted to add curves for the purpose of controlling bicyclist speed or to provide some variation in the path alignment. While sometimes successful, this approach may lead bicyclists to cut corners when the resulting alignment appears either arbitrary or unsafe at typical approach speeds. Further, if the curve has a significantly lower design speed than the connecting trail, cyclists may misjudge the appropriate approach speed and leave the trail.

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 – such as a solid yellow center line – 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 (see Figure 7-4). The additional pavement may be added on either the inside or outside of the curve.

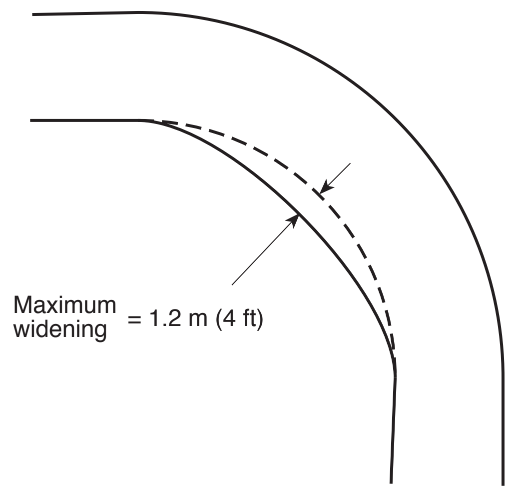


Figure 7-4: Curve widening may partially offset the effects of substandard curves.

Grades

Paved bicycle paths generally attract less-skilled and less-knowledgeable bicyclists, so it is important to avoid steep grades in their design. Bicyclists not physically conditioned will be unable to negotiate long, steep uphill grades and, as a result, may well dismount to walk up hill. For a bicycle path to be considered an acceptable alternative, it should have approximately the same amount of climbing as the roadways serving the same destinations. If it includes significantly more difficult climbs, few bicyclists will use it.

Since novice bicyclists often ride poorly-maintained bicycles and have difficulty in using their brakes for effective speed control, long downgrades can cause problems. For this reason, it is especially important to carefully consider design speed, curve radius, sight distance allowances and intersection location on lower sections of hills.

The maximum desirable grade rate recommended for bike paths is five percent. It is desirable that sustained grades be limited to two percent because of the wide range of riders to be accommodated.

Grades greater than five percent are undesirable. However, where terrain dictates, grades over five percent and less than 150 m (500 ft) long are acceptable when a higher design speed is used and additional width is provided. Grades steeper than three percent may not be practical for bicycle paths with crushed stone surfaces.

Sight distance

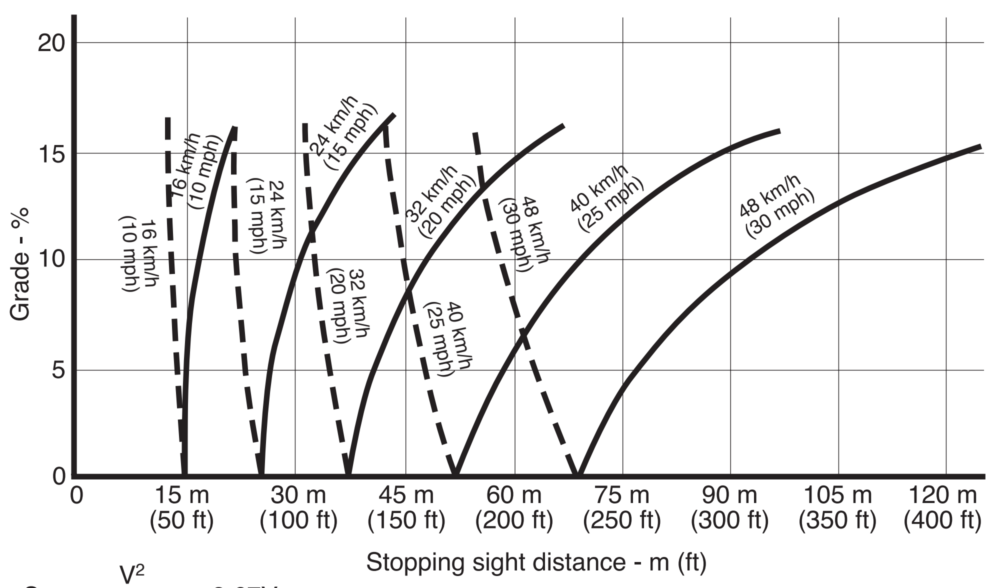
To provide bicyclists with an opportunity to see and react to the unexpected, a bicycle path should be designed with adequate stopping sight distances. The distance required to bring a bicycle to a full controlled stop is a function of the bicyclist's perception and brake reaction time, the initial speed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

Figure 7-5 indicates the minimum stopping sight distance for various design speeds and grades based on a total 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 the descending direction, that is, where "G" is negative, will control the design.

Figure 7-6 is used to select the minimum length of vertical curve necessary to provide minimum stopping sight distance at various speeds on crests. The eye height of the bicyclist is assumed to be 1.35 m (4.5 ft) and the object height is assumed to be zero to recognize that hazards to bicycle travel exist at pavement level.

Figure 7-7 indicates the minimum clearance that should be used to line-of-sight obstructions for horizontal curves. The desired lateral clearance is obtained by entering Figure 7-7 with the stopping sight distance from Figure 7-5 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



$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

Where: S = Stopping sight distance - ft
V = Velocity - mph
f = Coefficient of friction (use 0.25)
G = Grade - rise/run

Descend (-G) ———
Ascend (+G) – – –

Figure 7-5: Stopping sight distances on bicycle paths.

Source: Guide for the Development of Bicycle Facilities; AASHTO; 1991 head-on bicycle accident, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for bicyclists traveling in opposite directions around the curve. 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.

Intersections

Intersections are among the most important considerations in bicycle path design. If alternate locations for a bicycle path are available, the route that should be selected is one with the fewest intersections, the most favorable intersection conditions and the one that intersects the quietest cross streets.

For freeway crossings, a grade separation structure will be the only possible or practical treatment. When crossing other highways, providing for turning movements must be considered. In most cases, however, the cost of a grade separation will be prohibitive.

$$L = 2S - \frac{200(\sqrt{h_1} + \sqrt{h_2})^2}{A} \quad \text{When } S > L$$

$$L = \frac{AS^2}{100(\sqrt{2h_1} + \sqrt{2h_2})^2} \quad \text{When } S < L$$

$$L_{MIN} = 2V$$

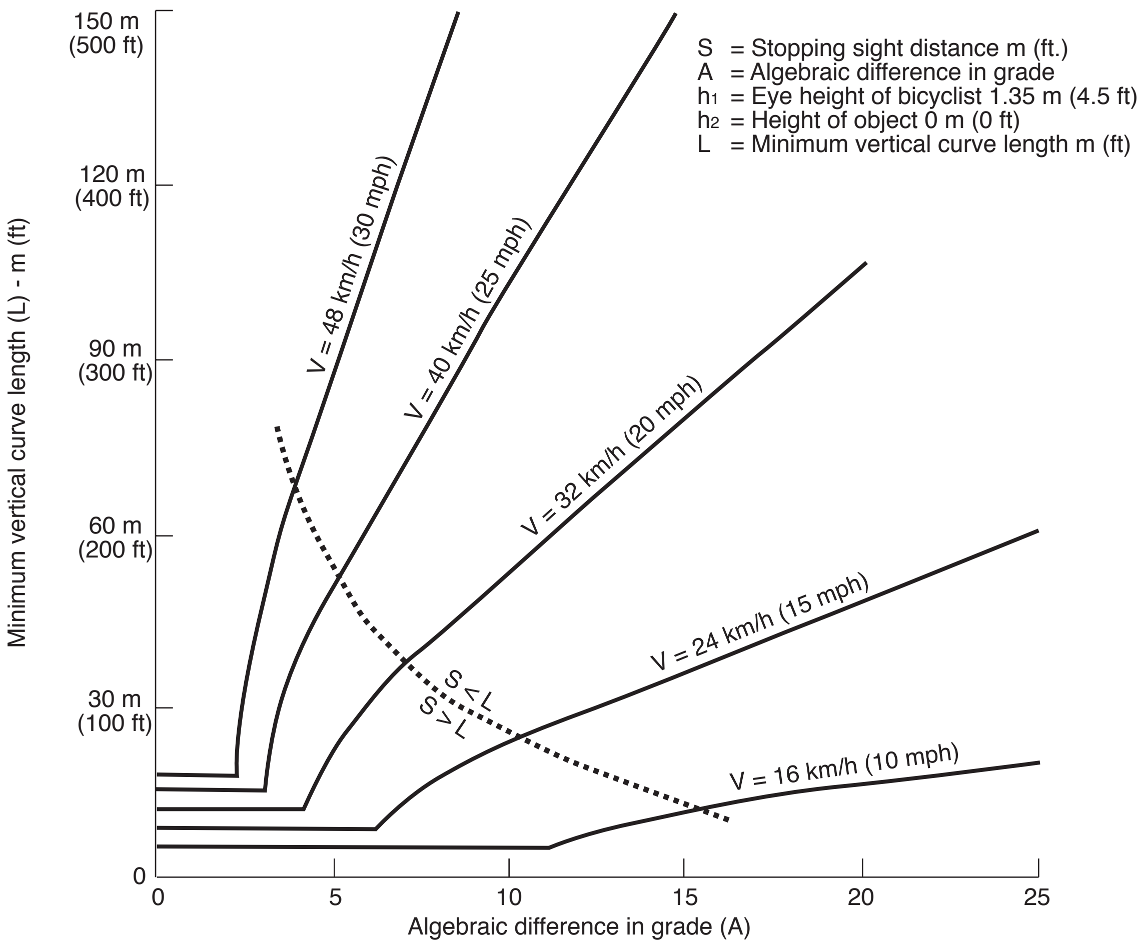


Figure 7-6: Sight distances for crest vertical curves on bicycle paths.

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

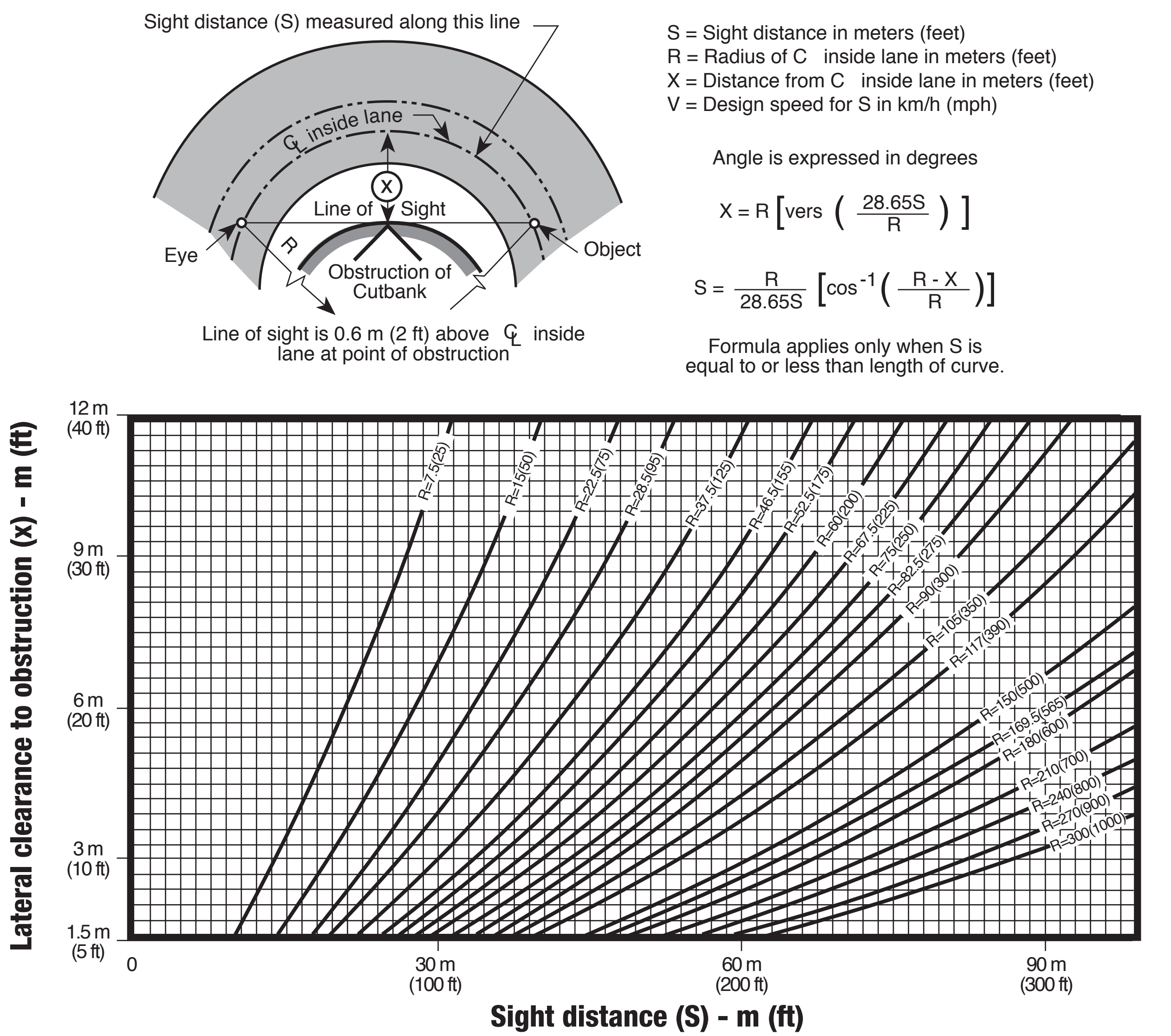


Figure 7-7: Lateral clearance on horizontal curves on bicycle paths.

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

Sign type, size and location should 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 highway signs are placed so that bicyclists are not confused by them.

If a bike path crosses a highway, such a crossing should occur well away from the influence of major intersections with other highways. Controlling vehicle movements at independent intersections is more easily and safely accomplished through the application of standard traffic control devices and normal rules of the road. Where signals are not warranted, consideration should be given to providing a median refuge area for crossing bicyclists. In this way, they can cross one direction of travel at a time.

Where physical constraints or high motor vehicle traffic volumes make crossing at such independent intersections difficult, the path may be brought to a nearby signalized intersection and the crossing made at or adjacent to the pedestrian crossing. Rights-of-way should be assigned and adequate sight distance should be provided so as to minimize the potential for conflict resulting from unconventional turning movements. It may be necessary to prohibit right-turn-on-red for the adjacent roadway and to provide a separate demand-actuated phase for the bicycle path.

Bicycle path intersections and approaches should be on relatively flat grades. Stopping sight distances at intersections should be checked and adequate warning should be given to permit bicyclists to stop before reaching the intersection, especially on downgrades.

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 along the roadway.

Restriction of motor vehicle traffic

Bicycle paths often need some form of physical barrier at highway intersections to prevent unauthorized motor vehicles from using the facilities. At the same time, the barrier should be designed to minimize the danger it poses for bicyclists and to allow the passage of emergency or maintenance vehicles. For this reason, proper materials, adequate design, good visibility and appropriate location are critical. While it is possible to restrict automobile and truck access, eliminating motorcycle access is very difficult. Barriers that can keep motorcycles out may make bicycle access difficult and potentially dangerous as well. At entrances to private driveways, motor vehicle barriers are less important than they are at highways. However, if a particular driveway is found to be a significant entry point for motorists, barriers should be considered there as well.

Lockable, removable posts at path entrances will allow entry of authorized vehicles. Posts should be at least 0.9 m (3 ft) high, permanently reflectorized for nighttime visibility and painted a bright color for improved daytime visibility. Their surface should be smooth and free of protrusions to prevent snagging a bicyclist's clothing or equipment.

To allow appropriate clearances, a 1.5 m (5 ft) spacing between posts should be used (see Figure 7-8). Wider spacing can allow entry to motor vehicles, while narrower spacing might prevent entry by adult tricycles and bicycles with trailers or present a hazard for less proficient bicyclists. On a 3 m (10 ft) path, the paving should be flared slightly and one post located near either edge and one post in the middle. A wider path will require more posts, again spaced at 1.5 m (5ft).

The barrier should be installed in a highly visible location with adequate sight distance from either direction. Lighting may be considered if the location has inadequate street lighting to illuminate the barrier. Marking an envelope around the barrier is recommended (see Figure 7-8). If sight distance is limited, special advance warning signs or painted pavement markings should be provided. It is best to locate the barrier 9 m (30 ft) from the

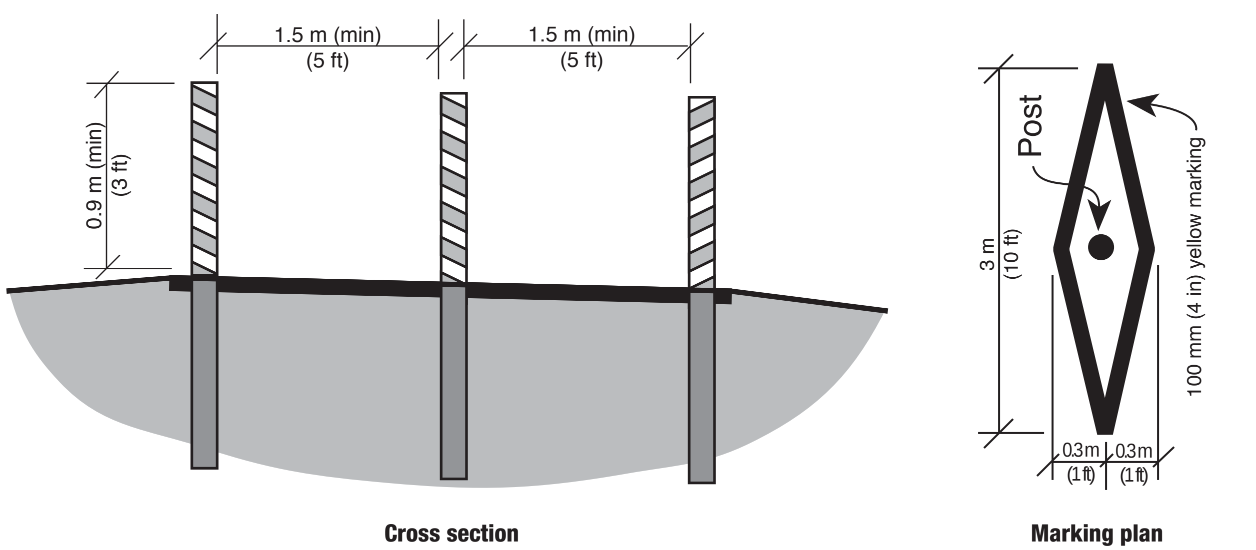


Figure 7-8: Reflectorized post barrier used to keep motor vehicles off bicycle paths and marking plan.

Source: California Highway Design Manual; CalTrans; 1987 intersection to allow bicyclists to pay full attention to traffic once they reach the crossing and to remove the barrier from the motorists clear recovery zone.

An alternative method of restricting entry of motor vehicles is to split the entry way for the last 3 m to 9 m (10 ft or 30 ft) before the intersection into two 1.5 m (5 ft) sections that enter the intersection approximately 1.5 m (5 ft) apart (see Figure 7-9). The sections may be separated and surrounded by low landscaping. Emergency vehicles can still enter if necessary by straddling the landscaping. The higher maintenance costs associated with landscaping should be acknowledged, however, before this alternative method is selected.

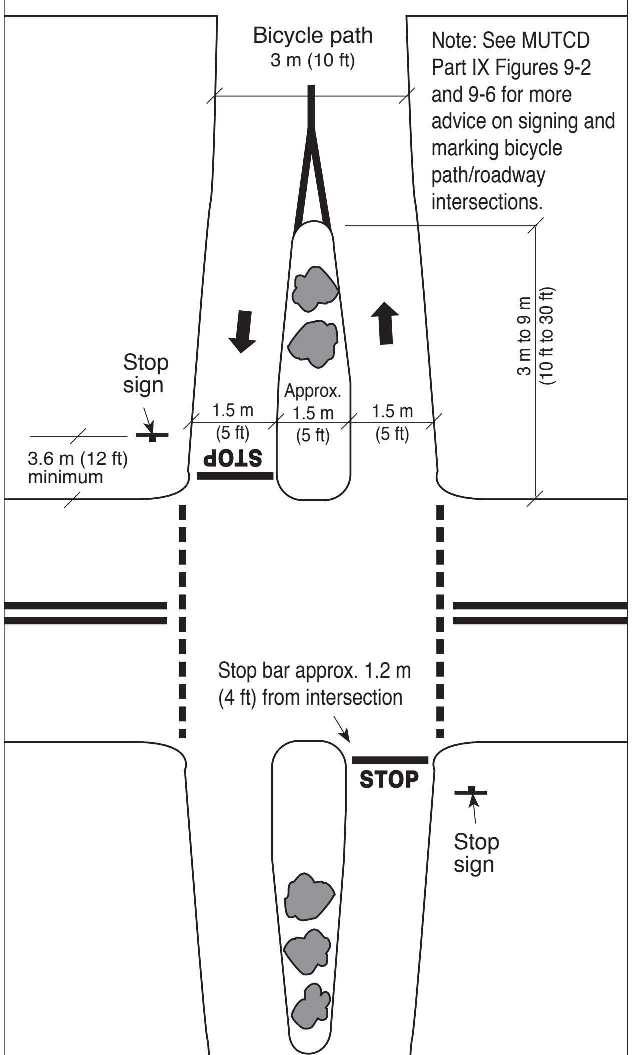


Figure 7-9: Alternative approach to bike path/roadway intersection. *Source: Bicycle Facility Design; OHDOT; 1988*

Whether the post or split entry method is used, pavement markings and signing may be used to warn bicyclists and direct them in the appropriate direction.

Bike path signing and marking

Adequate signing and marking are essential on bicycle paths, especially to alert bicyclists to potential hazards and to convey regulatory messages to both bicyclists and motorists at highway intersections. In addition, guide signing 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 will tend to encourage proper bicyclist behavior. When deciding whether to install a sign, the designer should ask whether he or she would install one on a roadway with a similar situation. Further, using standard rather than unique signs should reduce sign theft.

General guidance on signing and marking is provided in the MUTCD. Part IX of the MUTCD (reproduced in Appendix 4), refers specifically to traffic controls for bicycle facilities.

In order to keep signs from becoming hazards themselves, they should be offset horizontally from the edge of the bicycle path as shown in Figure 7-1.

A dashed 100 mm to 150 mm (4 in to 6 in) wide yellow center line should be used to separate opposite directions of travel. A solid double yellow center line should be used on curves, especially those with restricted sight distance. White edge lines, 100 mm to 150 mm (4" to 6"), also can be beneficial where significant night-time bicycle traffic is expected (e.g., near a university campus).

If a pedestrian area is to be designated, it should be separated from the bicycle path by at least a 100 mm to 150 mm (4 in to 6 in) solid white line (Figure 7-10). Regulatory signs (see sign R9-7 on page 80) also should be used. However, if space allows, a physical separation like a bicycle-safe barrier or a 0.9 m (3 ft) grassy berm is preferred (Figure 7-10).

In areas where pavement markings are found to be cost effective, consideration should be given to using them in conjunction

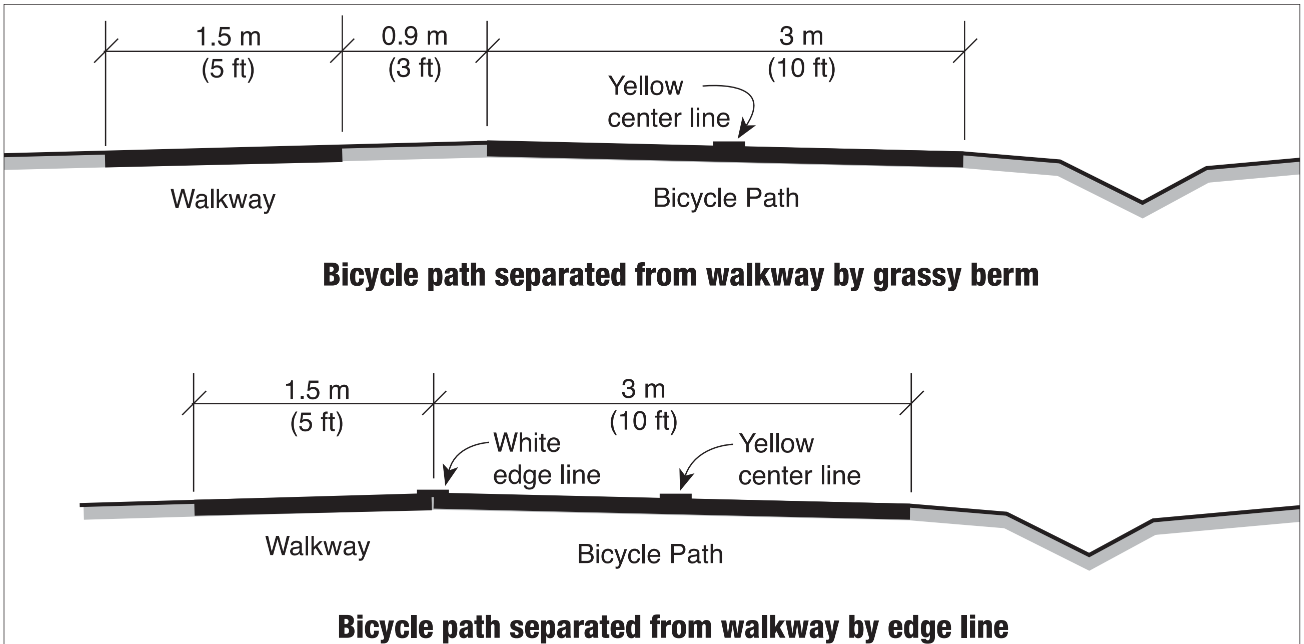


Figure 7-10: Two approaches to separating a bicycle path from a walkway.

with warning or regulatory signs, especially at critical locations. Otherwise, theft of warning or regulatory signs may result in bicyclists not being aware of serious hazards or their legal duties in a particular situation. Care should be exercised in the choice of pavement marking materials. Thermoplastic and preformed tape, for example, are slippery when wet and should be avoided in favor of more skid-resistant materials like traffic paint.

Whenever construction work is conducted on bicycle paths, it is important to sign, mark and, if necessary, barricade the construction zone with care as shown in the MUTCD, Part VI. If a detour is provided, it should be signed appropriately.

Pavement structure

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

In addition, several basic principles 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.

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 twelve feet, where right-of-way and other conditions permit, eliminates the edge raveling problem and offers two 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. Soil sterilants 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 saw cut to provide a smooth ride. Skid resistance qualities, however, should not be sacrificed for the sake of smoothness. Broom finish or burlap drag concrete surfaces are preferred over trowel finishes. In areas where climates are extreme, the effects of freeze-thaw cycles should be anticipated. Geotextiles and other similar materials should be considered where subsurface conditions warrant.

At unpaved highway or driveway crossings of bicycle paths, the highway or driveway should be paved as far as practible on either side of the crossing to reduce the amount of gravel scattered along the path by motor vehicles.

The pavement structure at the crossing should be adequate to sustain the expected loading at that location.

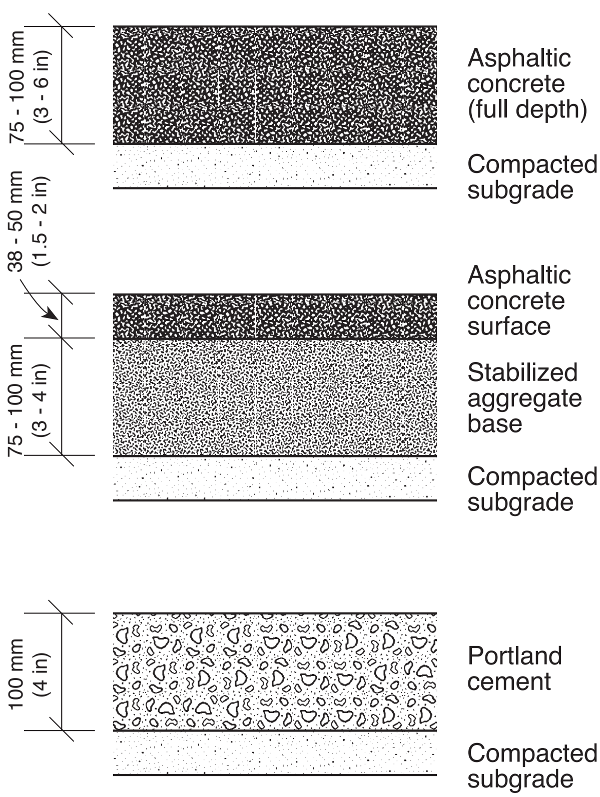


Figure 7-11: Typical pavement structural sections for bicycle paths.

Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

Good quality pavement structures can be constructed of asphaltic or portland cement concrete. Because of wide variations in soils, loads, materials and construction practices, it is not practical to present specific or recommended typical structural sections. Local standards for construction, preparation of sub-base and soil sterilization for a low-volume road should, in most cases, produce an adequate cross section for a bicycle path. However, Figure 7-11 shows some typical pavement structural sections.

Attention to the local governing conditions and to the principles outlined above is needed. Experience in highway pavement design, together with sound engineering judgment, can assist in the selection and design of a proper bicycle path pavement structure.

Hard, all-weather pavement surfaces are usually preferred over those of crushed aggregate, sand, clay or stabilized earth since these materials provide a much lower level of service. However, with the growth in popularity of mountain bikes, non-paved surfaces are being considered more frequently. With their wider lower-pressure tires, mountain bikes can easily handle surfaces that would prove unstable for thin-tired bikes. Further, an unpaved path will have a lower design speed, reducing the potential for conflicts between high-speed bicycles and low-speed pedestrians. The best surfaces for unpaved paths are crushed stone, stabilized earth or limestone screenings, depending upon local availability.

Utility covers and drainage grates should be flush with the pavement surface, and drainage grates should be designed to allow the crossing of bicycles from all angles. See Figure 4-1 on page 17 in the Roadway Improvements chapter for more details on grate design.

Railroad crossings should be smooth and should occur as close to 90 degrees to direction of travel as possible in order to minimize the danger of falls (Figure 7-12). Special rubberized crossings and flangeway fillers, as described in Figures 4-3 and 4-4 on pages 18 and 19, should be considered.

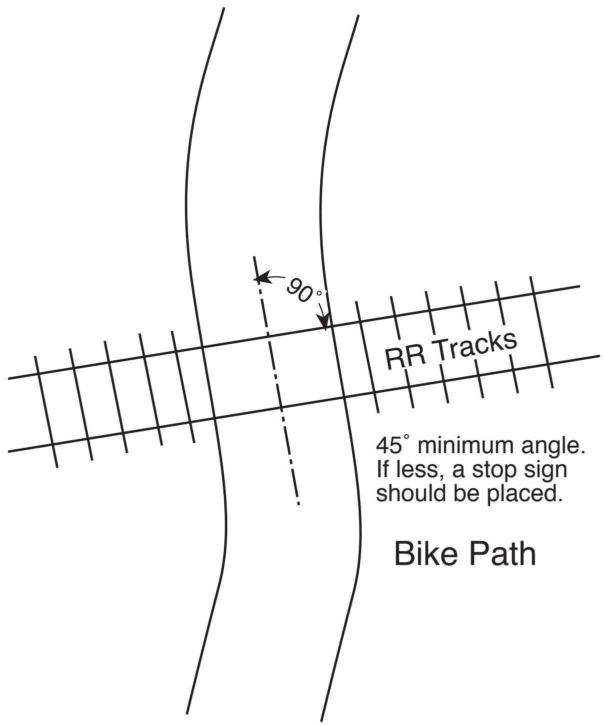


Figure 7-12: Bicycle path railroad crossing.
Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

Bike path structures

When a bicycle path meets a barrier – such as a railroad, a river or an interstate highway – some sort of grade-separated crossing may be necessary to provide continuity. This crossing may take the form of a bridge, an underpass or a facility on a highway bridge. On new bicycle structures, the minimum clear width should be the same as the approach paved bicycle path; and the desirable clear width should include the minimum 0.6 m (2 ft) wide clear areas on either side. 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 also may be dictated by occasional motor vehicles using the path. However, where practical, a vertical clearance of 3 m (10 ft) is desirable for adequate vertical shy distance.

Independent bicycle bridges: Railings, fences or barriers on both sides of a bicycle path bridge should be a minimum of 1372 mm (54 in) high (Figure 7-13). Smooth 250 mm (10 in) tall rub rails may be attached to the barriers at a handlebar height of 1.1 m (3.5 ft). Ends of railings should be offset away from the adjoining path to minimize the danger of cyclists running into them (Figure 7-14). If this is not possible, Type II or Type III object markers, as described in the MUTCD Part IX, should be used.

Bridges designed for bicycle and/or pedestrian traffic shall be designed for a live load of 4070 Pa (85 psf). On concrete decks, care should be taken to ensure that bicycle-safe expansion joints are used. Broom finish or burlap drag surfaces are preferred over trowel finishes.

If planking is used for decking, the joints between boards should be smooth and at least 45 degrees to the direction of travel to prevent their diverting bicycle wheels. In addition, boards should be placed in such a way as to curl down rather than up.

Bridges: If it is impossible to provide an independent bicycle bridge, one option is to retrofit a bicycle path onto one side of an existing highway bridge.

This should be done where:

- *The bridge facility will connect to a bicycle path at both ends;*
- *Sufficient width exists on one side of the bridge or can be obtained by either widening or restriping lanes;*
- *Provisions are made to physically separate bicycle traffic from motor vehicle traffic; and*
- *Any crossing difficulties with roadway turn ramps at either end can be overcome.*

Mounting a bicycle facility on an existing bridge requires that the bridge have sufficient strength to hold such a structure. An engineering study must be done to determine the safety of the proposed addition.

Merging a bicycle path onto the roadway at either end of the bridge, using either bicycle lanes or wide curb lanes, generally is not rec-

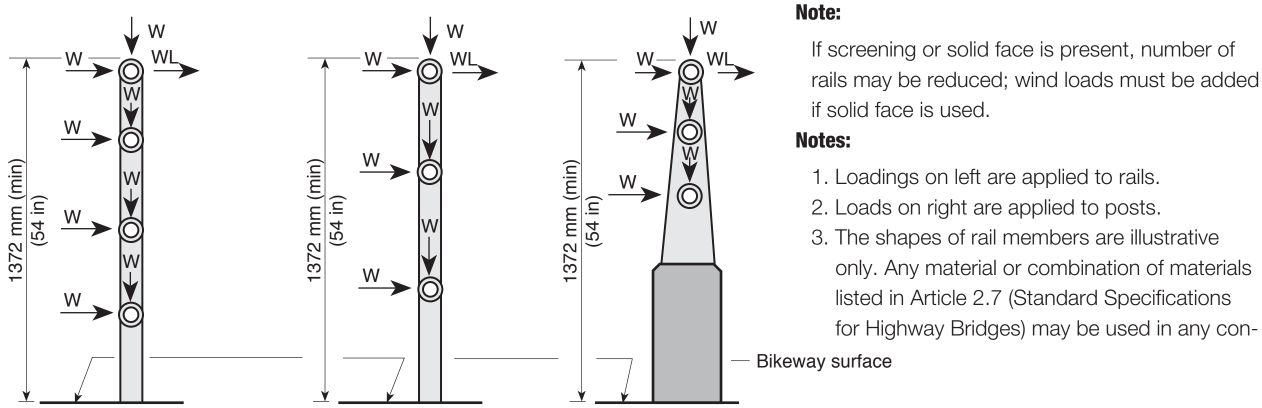


Figure 7-13: Alternative railing designs for independent bicycle bridges.

Source: Standard Specifications for Highway Bridges; AASHTO, 1989

ommended because of the likelihood that bicyclists will stay on that side of the bridge regardless of their direction of travel.

Sidewalks: Using existing sidewalks as two-way facilities is generally inadvisable. 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.

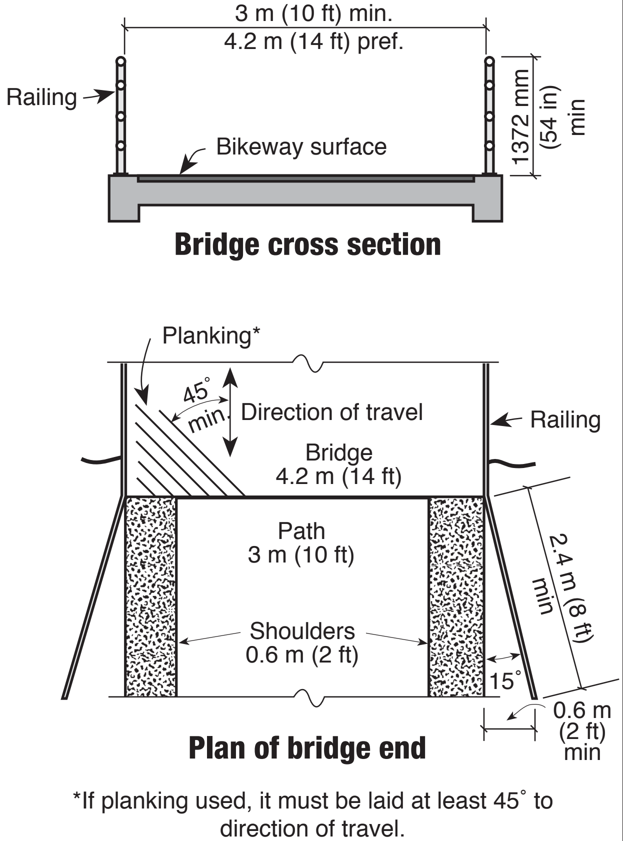


Figure 7-14: Bridge widths and clearances.

Underpasses and tunnels: In some cases, an underpass will be the best way to carry a bicycle path under a highway. Figure 7-15 shows a typical underpass cross section for bicycle paths. Lighting, grades, approaching curve design, visibility and maintenance should be carefully considered.

Drainage

The recommended minimum pavement cross slope of two percent adequately provides for drainage. Sloping in one direction instead of crowning is preferred and usually simplifies the drainage and surface construction. On curves, the cross slope should be towards the inside of the curve.

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. Ditches and drainage structures should be designed so that they do not create hazards for bicyclists and should be offset from the edge of the path as described in the topic, Width and Clearance, on page 42. If drainage structures cannot be offset sufficiently, object markers should be used to warn bicyclists of their presence.

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.

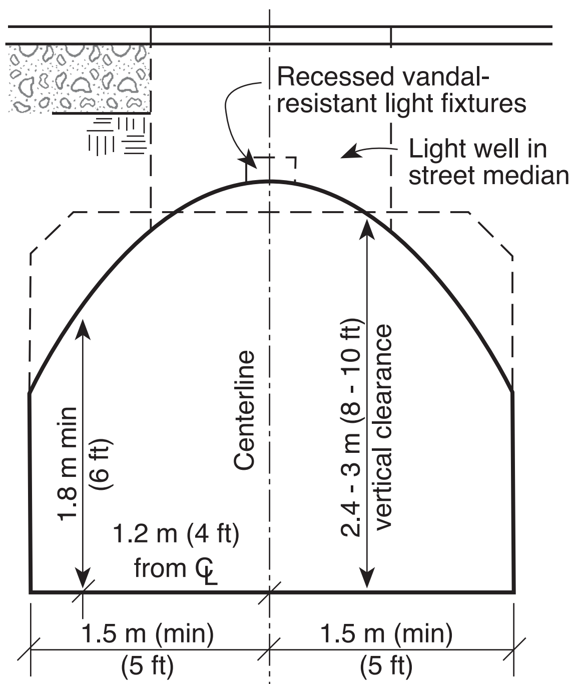


Figure 7-15: Bicycle path underpass.

Source: AZ Bicycle Facilities Planning & Design Guidelines; AZDOT, 1988

Lighting

Fixed-source lighting reduces conflicts along paths and at intersections. In addition, lighting allows the bicyclists to see the bicycle path direction, surface conditions and obstacles. Lighting for bicycle paths should be provided where considerable riding is expected at night, such as bicycle paths serving college students or commuters, where there is insufficient available light from the surrounding area, and at highway intersections, especially if there are post barriers that the cyclist must avoid. While the North Carolina motor vehicle laws require bicycles to have headlights after dark, the low level of lighting required by law won't necessarily light up a bicyclist's path sufficiently to see and avoid obstacles.

Each lighting situation is unique and must be dealt with on a case-by-case basis, however, average maintained horizontal illumination levels of 5 lux (0.5 foot candles) to 22 lux (2 foot candles) should be considered. Where special security problems exist, higher illumination levels may be considered. Light poles should be 3.6 m to 4.5 m (12 ft to 15 ft) high and must meet recommended horizontal clearances. Luminaires and poles should be at a scale appropriate for a pedestrian or bicycle path.

Underpasses and tunnels (except where there is a completely open view into the tunnel from the surrounding area) may need additional lighting, even in the day time, for both visibility and security. On bright, sunny days, bicyclists entering a dark underpass may be momentarily blinded and unable to see potential hazards; for this reason, they may need lighting to navigate safely.

Because lighting is important for cyclists' safety and security, vandal-resistant lighting fixtures are recommended in all locations.

Multi-use paths

Pedestrians: While multi-use paths may be undesirable due to the mixing of bicycles and pedestrians, in reality, most bicycle paths are multi-use to some extent. The degree of incompatibility between bicyclists and pedestrians is a function of density, speed, congestion and the presence of crossing and turning opportunities. The design of a multi-use trail should reflect consideration of each of these factors. Further, the more pedestrian traffic a trail receives, the less suitable it will be for bicycle traffic. In most situations, a multi-use trail with significant pedestrian traffic should not be designated as a bicycle trail.

Linear trails through greenbelts may have lower pedestrian densities—especially away from entry points and significant attractors (e.g., picnic areas and playgrounds)—and may suffice for multi-use if sufficient width is provided and adequate sight distances and clearances are maintained.

If higher pedestrian volumes are expected on a multi-use trail, as is the case in large urban areas, consideration should be given to providing a separate pedestrian trail adjacent to, but separated from, the bicycle trail. In some cases, a simple stripe between the pedestrian and bicycle areas may suffice. In others, providing a physical barrier and/or unpaved shoulder between may be necessary. (See Figure 7-10 for details.)

In areas with considerable congestion and diffuse patterns of pedestrian cross-traffic, a more appropriate design may be necessary. College campus "quads," for example, are very difficult situations in which to incorporate a bicycle facility. With pedestrians crossing in many places and at many angles, it is impossible to provide sufficient protection for the bicycle facility. In such situations, it may be more appropriate to direct bicycle traffic around the congested area and discourage fast bicycling within.

Mopeds: It also is undesirable to mix mopeds and bicycles on the same facility. Where it is necessary to do so, the facility should be designed to account for the higher operating speeds of mopeds, the additional maneuvering requirements of mopeds, and the increased frequency of passing maneuvers. Many of the design guidelines prescribed in this chapter (e.g., widths, design speeds, horizontal alignments, grades, etc.) would be inadequate for facilities intended for moped use.

Horses: Using a single path for bicycles and horses creates an unsatisfactory and potentially dangerous mix. Horses startle easily and may kick out suddenly if they perceive bicyclists as a danger. Two parallel paths within the same corridor, however, have been found to work well if there is a visual barrier and adequate separation between the two.

8 Supplemental Facilities

The need for bicycle parking varies with location. At popular destinations, like universities and schools, a successful bicycle parking program may require a substantial investment and a significant planning effort.

Bicycle Parking

Providing bicycle parking facilities is an essential element in an overall effort to promote bicycling. People are discouraged from bicycling unless adequate parking is available. Bicycle parking facilities should be provided at both the trip origin and the trip destination and should offer protection from theft and damage. If bicycle parking is not properly designed and located, bicyclists will use trees, railings and other appurtenances. This practice can cause damage and create a hazard for pedestrians.

Choosing bicycle parking devices: The following tips should be kept in mind when choosing bicycle parking devices. An overall parking program may include several different types of devices.

(1.) Decide on the level of security needed. Generally, short-term customer parking in front of retail stores need not be as secure as long-term employee parking at work places. Short-term parking needs can be satisfied by racks that simply allow use of high security, U-shaped locks. Long-term parking needs, on the other hand, may be satisfied by bicycle lockers, locked enclosures or locked rooms within the building.

(2.) Look at how the device works. Racks should not look complicated or have many moving parts. They also should work with all types of locks. If, in holding the bike, they come into excessive contact with the frame or delicate mechanisms, cyclists may not use the racks, fearing damage to their bicycles. Devices also should hold the bike in a way that makes it less likely to fall over; bent rims are common with racks that only support one wheel.

(3.) Decide on the number of spaces needed. As a rough estimate, determine current levels of bike usage. However, adequate bike parking can attract additional users, so, increasing that estimate somewhat may be justified. Consider doing an informal survey of potential users.

A bicycle rack in use on a downtown sidewalk. Tough galvanized coating, a vandal-resistent design, and ease of use with high security locks make this design popular.

(4.) Determine whether vandalism is a factor. Some sites are prone to vandalism. In these cases, the best bicycle parking is that which attracts the least amount of attention from vandals, can be mounted securely and is very sturdy.

(5.) Consider the budget. Bicycle parking can cost from $35 per bike space to over $300 per space. The need to save money must be weighed against the possibility that inadequate parking devices may not be used by bicyclists or may be destroyed by vandals.

(6.) Contact other users. Once the list of potential parking devices has been narrowed, ask for names of people who already have each type. Contact these people and ask about vandalism problems, user reactions, ease of installation, weather resistance, maintenance requirements and site constraints. Ask how long they have used the devices and how many have been installed.

Locating bicycle parking: Deciding just where to put bicycle parking can be difficult. The right location can mean the difference between a popular rack and an unpopular one. The following points should be kept in mind when locating bicycle parking facilities.

(1.) Distinguish between long-term and short-term parking needs. Long-term parking is needed at locations such as schools and universities, employment centers, transit stations and multi-family dwellings. In locating long-term parking, convenience is slightly less important than security.

(2.) Locate bike parking near popular destinations, at the entrance bicyclists use. Short-term parking is needed at locations such as shopping centers, libraries, recreation areas and post offices. Facilities should be conveniently located, near building entrances. The farther away from users' destinations the parking is located, the less likely it will be used. As is true with motorists, it is very difficult to force cyclists to park in an inconvenient place.

(3.) Bike parking located next to car parking or traffic lanes will need protection. If insufficient clearance is allowed, unprotected bike racks, as well as the bikes parked in them, can be damaged by car bumpers and fenders.

(4.) Bicycle parking should be kept out of major pedestrian paths. People often walk without watching where they are going. Some racks, when empty, can be easy to ignore but dangerous to shins. If parking must be placed where people walk, it should be very noticeable, large and high enough to see easily, and it should be free of dangerous projections.

(5.) Parking should be located within view of windows, security offices or high volumes of pedestrian traffic. Such locations tend to be self-policing, reducing the temptation for thieves and relieving the fears of bike users.

(6.) Protection from the weather is useful, particularly for long-term commuter or short-term utilitarian parking. Placing the parking under a roof overhang, but not under the drip line, can provide shelter from the weather at little cost. Bicyclists will appreciate the protection, both for their bikes and for themselves when locking up.

(7.) Potential expansion and project phasing are important. It may be best to try a few units at first and then, when demand warrants, expand. Parking location should allow for expansion in modular increments.

Other facilities and services

In addition to bicycle parking, several other improvements can complement roadway improvements and bicycle paths. For example, on long, uninterrupted bicycle paths, turnouts, picnic areas with tables and benches, or rest room facilities may be provided. Other improvements include the following:

Bicycle-transit interface: Provisions also should be considered for interfacing bicycle travel with public transit. In some communities, for example, buses on certain routes have bicycle racks mounted on either front or rear. In other communities, the transit company allows users to carry their bicycles on the bus during off-peak hours.

In several large metropolitan areas, bicyclists with special permits may take their bicycles on transit cars during certain hours. Developing and enhancing the connection between transit and bicycle use can increase the effectiveness of both modes in serving suburban areas.

Bicycle user maps: Printing and distributing bicycle maps is a popular high-benefit/relatively low-cost project. Several approaches are used, each with a different purpose. Those approaches and purposes are described briefly in the following sections.

Bicycle facility locations: In some communities, for example, agencies have published bicycle route maps to show designated bike lanes, routes and paths. These often show little else and are strictly guides to the facilities provided by the agency.

Bicycling suitability maps: In other communities, agencies have developed "suitability maps" which identify the relative difficulty of different segments of the road system. Such maps can help bicyclists avoid narrow, high-speed or high-volume roads, barriers and other problems. In addition, maps can provide information on traffic law, safety, mass transit and locations of parking facilities.

Hybrid maps: Because some agencies desire to show both their designated bicycle facilities and suitability features of the overall roadway network, they have developed hybrid maps. These combine the features of the previous two types.

Individual route maps: In some cases, agencies have developed one or more maps that show individual bicycle routes. For local loop routes, these can often be inexpensively printed

A bicyclist loading his bicycle onto a transit bus in Seattle, Washington. Such services are especially popular among utilitarian riders in many communities.

and quickly produced and updated. On the other hand, agencies like the North Carolina Department of Transportation Office of Bicycle and Pedestrian Transportation have produced more elaborate long distance route map sets.

9 Operation And Maintenance

General

A wide variety of local, state and national agencies have built bicycle facilities. These facilities may be trails located on independent rights-of-way or they may be on-road bicycle lanes, signed bicycle routes, wide shared traffic lanes or well-marked shoulder areas.

The agencies responsible for the control, maintenance and policing of bicycle facilities should be identified prior to construction. The costs involved with the operation and maintenance should be considered and budgeted for when planning a facility.

In general, the methods used for roadway repair and maintenance should be observed. Neglected maintenance will render bicycle facilities unridable, and the facilities will become a liability to the agency responsible. In addition, future repaving must be planned as the facilities age. Bicyclists should be encouraged to report bicycle paths and roadways needing maintenance. A central contact person with authority to authorize maintenance work should be designated to receive such reports.

Planning and budgeting: The growth of bicycle facility mileage should be carefully watched to assure that funding is commensurate with maintenance and operational responsibilities. While the special maintenance needs of on-road facilities are a relatively small part of the overall road maintenance budget, this is not the case with bicycle paths.

Budgets for path-side maintenance should include materials for planting, spraying, mulching, watering, fertilizing, pruning, selective clearing, etc.; equipment for mowing, irrigating, spraying, cultivating, hauling, etc; and skilled personnel. Costs can vary considerably from year to year depending upon increases in the number of miles of new bicycle paths and changes in maintenance practices and standards.

Improvements in maintenance effectiveness and lower costs which can be achieved by the application of new methods should merit study. Budgets should also include adequate supplies and services for rest areas.

Maintenance requirements and budgets for newly landscaped areas should be developed with the cooperation of the landscape designer, horticulturist or agronomist.

Standards of care: Standards of care for bicycle paths may ultimately be determined by the courts. As the views of the court may change with circumstances, maintenance managers should be aware of the latest court rulings. It can be expected that the standard of care may be high because of the vulnerability of bicyclists to accidents.

On-road facilities

Bikeways and roadways with bicycle traffic are often susceptible to having debris, such as glass or sand, accumulate in the area near the right edge where most bicyclists ride. Therefore, regular sweeping is necessary. A smooth surface, free of potholes and debris, should be provided. The pavement edges should be uniform. Highways with bicycle traffic may require a more frequent and a higher level of maintenance than other highways.

Special bicycle signs and markings should be routinely inspected and kept in good condition. Markings should be kept prominent.

The routine maintenance of roadways provides an excellent opportunity to improve the bicycle travel on those roads. Several bicycle facilities described in this guide can be implemented during routine maintenance activities. When lane markings for four- or six-lane streets are restriped, consideration can be given to adjusting the lane widths and providing a wide curb lane for bicycles (see the section entitled Wide Outside Lanes on page 26). The addition of edge lines can better delineate a shoulder, especially at night. When shoulders are resurfaced, a smooth surface suitable for bicycle riding should be considered.

Bicycle paths

For bicycle paths built in conformance with design standards, the agency responsible for maintenance should seek to maintain those standards. If standards are not prescribed,

A commitment to maintenance for bicyclists involves paying particular attention to debris and road surface conditions at the right edge of the roadway.

they should consider improvements that are within their capability and which will improve the facility's safety and operation. Trail widening, curve improvements, drainage improvements, addition of dividers, or curbs should be considered as appropriate maintenance functions on paths constructed without design standards.

Use of paths will be considerably influenced by weather. Good weather will cause high use rates. Bad weather will cause many recreational paths to be little used or even closed. Paths used by commuters may require special consideration. Puddles, ice and snow may become maintenance problems if commuter paths will operate year round.

Inspection: The condition of bicycle paths is more directly associated with public recreation and enjoyment than the condition of roadways. Maintenance requirements should be evaluated from the standpoint of the user.

Signs and traffic markings: Signs, especially warning or regulatory signs, and markings should be routinely inspected and kept in good condition. Center line marking on the path should be kept prominent.

Part IX of the MUTCD, reproduced in Appendix 4, prescribes the proper signs and markings for bicycle paths.

Visibility:

Illumination: Need for proper lighting of bicycle paths will usually vary according to the amount of vehicle traffic and the particular hazards an area presents. Roadway intersections are prime candidates for lighting improvements and, once installed, the lights should be maintained not only to ensure reliable operation, but also provide the desired luminance.

Sight distance and clearance: Sight distances on parallel roadways and paths should not be impaired leading up to crossings and curves.

Trees, shrubs and tall grass should be regularly inspected and either removed or trimmed if they can interfere. Sight distance requirements will vary with potential bicycle speeds. Adequate clearances on both sides and overhead should be checked regularly.

Tree branches should be trimmed to allow enough room for seasonal growth without encroaching onto the trail. Seeded and sodded areas in the vicinity of bicycle paths should have a regular schedule of mowing.

Surface repair: Patching and grading of paths should be much less demanding than similar roadway operations. Hand operated equipment should be adequate to make repairs in most cases. It is more important, however, that finished patches be flush with the surface of the path. Skid resistance of the surface should be the same as the adjoining path's surface.

Presence of ruts should indicate an improperly designed or constructed trail, or that use has not been limited to bicycles. Ruts should be removed by whatever measures are appropriate to give a satisfactory result and avoid recurrence. Attention should be given to maintaining the full paved width and not allowing the edges to ravel.

Drainage: Paths constructed across irregular or hilly land usually will encounter drainage problems. Seasonal washouts, silt or gravel washes across a path, or sinking should be watched for and appropriate measures taken. Installation of culverts or building small bridges could be considered a maintenance function to achieve an immediate result and avoid the expense of contracting.

Drainage grates should not have parallel openings that could catch narrow bicycle tires. Maintenance personnel should be especially instructed to assure that grates are positioned so that openings are at angles to the trail's direction.

Cleaning:

Sweeping and cleaning: The responsibility to maintain bicycle paths could present problems for cleanliness not ordinarily associated with motor vehicle travel. The tires of a bicycle can be easily damaged by broken glass and other sharp objects. Bicycle wheels slip easily on leaves or ice. Small solid objects such as loose gravel or sticks on an asphalt surface can cause a serious fall. There also should be concern when mechanically sweeping roadways that material is not thrown onto a bicycle path. Path-side materials such as bark or gravel may ravel and necessitate frequent sweeping.

Trash pick-up: Trash receptacles should be located with at least two functions in mind: where they will be needed in relation to use and where they can be easily available for pickup and emptying. Rest areas for bicyclists are the most logical locations for trash barrels.

Litter control: Paths are often subject to less littering than roadways, and the debris tends not to be of the same kind (e.g., few abandoned cars or dead animals). However, special attention is focused on the path-side appearance due to the more leisurely pace of traffic on trails. Paths should be kept free of litter and debris to maintain the path in a neat, clean and attractive manner.

Trash and rubbish deposited on or along the path should be picked up and disposed of periodically as necessary. Generally, path-sides should be given a thorough cleanup in the spring and periodically as needed thereafter. Debris, such as fallen branches, or rock or earth slides, should be removed from the path and ditches immediately after they are observed or reported. Citizen or civic group participation in clean-up efforts on trails should be encouraged.

Fencing: Fencing along paths should be maintained in the same manner as highway fencing.

Structural deterioration: Structures should be inspected annually to ensure they are in good condition. Special attention should be given to wood foundations and posts to determine whether rot or termites are present.

Special facilities: Steps and ramps on bicycle paths should be maintained at a level that will accommodate the type of use associated with the trail. Ramps for wheelchairs should be kept in good condition, and graded areas should receive adequate attention.

Enforcement: Special attention to law enforcement may be necessary. In some cases, unauthorized motor vehicles may routinely use a bicycle path, causing danger for users and potential damage for the path itself. In addition, the potential for crimes of violence on isolated paths should be carefully evaluated and monitored. It may be necessary to implement a routine path patrol.

Appendices

Appendix 1 Bicycle and Bikeway Act of 1974

G.S. 136-71.6. How Article cited.

This Article may be cited as the North Carolina Bicycle and Bikeway Act of 1974. (1973, c. 1447, s.1)

G.S. 136-71.7. Definitions.

As used in this Article, except where the context clearly requires otherwise, the works and expressions defined in this section shall be held to have the meanings here given to them:

(1)bicycle: a nonmotorized vehicle with two or three wheels tandem, a steering handle, one or two saddle seats and pedals by which the vehicle is propelled.

(2) bikeway: A thoroughfare suitable for bicycle, and which may either exist within the right-of-way of other modes of transportation, such as highways, or along a separate and independent corridor.

(3) Department: North Carolina Department of Transportation.

(4) Program: North Carolina Bicycle and Bikeway Program.

(5) Secretary: The Secretary of the North Carolina Department of Transportation. (1973, c.1447, s. 2; 1975, c. 716, 2.7; 1977, c. 1021, s.1.)

G.S. 136-71-8. Findings.

The General Assembly hereby finds that it is in the public interest, health, safety, and welfare for the State to encourage and provide for the efficient and safe use of the bicycle; and that to coordinate plans for bikeways most effectively with those of the State and local governments as the affect roads, streets, schools, parks and other publicly owned lands, abandoned roadbeds and conservation areas, while maximizing the benefits from the use of tax dollars, a single State agency, eligible to receive federal matching funds, should be designated to establish and maintain a statewide bikeways program. The General Assembly also finds that bikeways are a bona fide highway purpose, subject to the same rights and responsibilities, and eligible for the same considerations as other highway purposes and functions. (1973, c. 1447, s. 3; 1977, c 1021, 2.1.)

G.S. 136-71.9. Program development.

The Department is designated as such State agency, responsible for developing and coordinating the program (1973, c. 1447, s.4.)

G.S. 136-71.10 Duties.

The Department will:

(1) Assist and cooperate with local governments and other agencies in the development and construction of local and regional bikeway projects;

(2) Develop and publish policies, procedures, and standards for planning, designing, constructing, maintaining, marking, and operating bikeways in the State; for the registration and security of bicycles; and for the safety of bicyclists, motorists, and the public.

(3) Develop bikeway demonstration projects and safety training programs;

(4) Develop and construct a State bikeway system. (1973, c. 1447, s.5.)

G.S. 136-71-11. Designation of bikeways.

bikeways may be designated along and upon the public roads. (1973, c. 1447, s.5.)

G.S. 136-71.12. Funds.

The General Assembly hereby authorizes the Department to include needed funds for the program in its annual budgets for fiscal years after June 30, 1975, subject to the approval of the General Assembly.

The Department is authorized to spend any federal, State. local or private funds available to the Department and designated for the accomplishments of this Article. Cities and towns may use any funds available. (1973, c. 1447, s.6.)

G.S. 136-71.13. North Carolina Bicycle Committee; composition, meetings, and duties.

(a) There is hereby created a North Carolina Bicycle Committee within the Department of Transportation. The bicycle Committee shall consist of seven members appointed by the Secretary. Members of the Committee shall receive per diem and necessary travel and subsistence expense in accordance with the provisions of G.S. 138-5. Initially, three members shall be appointed for two years, and four members for four years; thereafter each appointment shall be for four years. Upon the resignation of a member in midterm, the replacement shall be appointed for the remainder of the unexpired term. The Secretary shall make appointments to the Committee with a view to providing representation to each of the State's geographical regions and to the various types of bicycle users and interest.

(b) The Bicycle Committee shall meet in various sections of the State, not less than once in any three months, and at such other times as may be necessary to fulfill its duties. A majority of the members of the Committee shall constitute a quorum for the transaction of business. The staff of the bicycle and bikeway program shall serve the Committee, maintain the minutes of Committee meetings, research questions of bicycle transportation importance, and undertake such other activities for the Committee as may be consistent with the program's role within the Department.

(c) The Bicycle Committee shall have the following duties:

(1) To represent the interests of bicyclists in advising the Secretary on all matters directly or indirectly pertaining to bicycles and bikeways, their use, extent, location, and other objectives and purposes of this Article;

(2) To adopt bylaws for guiding its operation, as well as an outline for pursuing a safer environment for bicycling in North Carolina;

(3) To assist the bicycle and bikeway program in the exercise of its duties within the Department; and

(4) To promote the best interest of the bicycling public, within the context of the total transportation system, to governing officials and the citizenry at large.

(d) The Secretary, with the advice of the bicycle Committee, shall coordinate bicycle activities among the divisions of the Department, as well as between the Department of Transportation and the other departments. Further, he shall study bicycle and bikeway needs and potentials and report the findings of said studies, with the Committee's recommendations, to the appropriate policy or legislative bodies. The Secretary shall transmit an annual report to the Governor and General Assembly on bicycle and bikeway activities within the Department, including a progress report on the implementation of the Article. (1977, c. 1021, 2.1.)

Appendix 2 NCDOT Bicycle Policy

North Carolina Department of Transportation

This bicycle policy revokes and replaces the former bicycle policy adopted by the Board of Transportation in November 1978. The revised bicycle policy was adopted on April 4, 1991.

General

Pursuant to the Bicycle and Bikeways act of 1974, the Board of Transportation finds that bicycling is a bonafide highway purpose subject to the same rights and responsibilities and eligible for the same considerations as other highway purposes, as elaborated below.

1. The Board of Transportation endorses the concept that bicycle transportation is an integral part of the comprehensive transportation system in North Carolina.
2. The Board of Transportation endorses the concept of providing bicycle transportation facilities within the rights-of-way of highways deemed appropriate by the Board.
3. The Board of Transportation will adopt "Design Guidelines for Bicycle Facilities." These guidelines will include criteria for selecting cost-effective and safety-effective bicycle facility types and a procedure for prioritizing bicycle facility improvements.
4. Bicycle compatibility shall be a goal for state highways, except on fully controlled access highways where bicycles are prohibited, in order to provide reasonably safe bicycle use.
5. All bicycle transportation facilities approved by the Board of Transportation shall conform with the adopted "Design Guidelines for Bicycle Facilities" on state-funded projects, and also with guidelines published by the American Association of State Highway and Transportation Officials (AASHTO) on federal aid projects.

Planning and Design

It is the policy of the Board of Transportation that bicycle facility planning be included in the state thoroughfare and project planning process.

1. The intent to include planning for bicycle facilities within new highway construction and improvement projects is to be noted in the Transportation Improvement Program.
2. During the thoroughfare planning process, bicycle usage shall be presumed to exist along certain corridors (e.g., between residential developments, schools, businesses and recreational areas). Within the project planning process, each project shall have a documented finding with regard to existing or future bicycling needs. In order to use available funds efficiently, each finding shall include measures of cost-effectiveness and safety-effectiveness of any proposed bicycle facility.
3. If bicycle usage is shown likely to be significant, and it is not prohibited, and there are positive cost-effective and safety-effective findings; then, plans for and designs of highway construction projects along new corridors, and for improvement projects along existing highways, shall include provisions for bicycle facilities (e.g., bike routes, bike lanes, bike paths, paved shoulder, wide outside lanes, bike trails) and secondary bicycle facilities (traffic control, parking, information devices, etc.).
4. Federally funded new bridges, grade separated interchanges, tunnels, viaducts and their improvements, shall be designed to provide safe access to bicycles, pursuant to the policies of the Federal Highway Administration.
5. Barriers to existing bicycling shall be avoided in the planning and design of highway projects.
6. Although separate bicycle facilities (e.g., bike paths, bike trails) are useful under some conditions and can have great value for exclusively recreational purposes, incorporation of on-road bicycle facilities (e.g., bicycle lanes, paved shoulders) in highway projects are preferred for safety reasons over separate bicycle facilities parallel to major roadways. Secondary complementary bicycle facilities (e.g., traffic control, parking, information devices, etc.) should be designed to be within highway rights-of-way.
7. Technical assistance shall be provided in the planning and design of alternative transportation uses, including bicycling, for abandoned railroad rights-of-way. This assistance would be pursuant to the National Trails Act Amendment of 1983, and the resultant national Rails to Trails program, as will the Railway Revitalization Act of 1975.
8. Wherever appropriate, bicycle facilities shall be integrated into the study, planning, design and implementation of state funded transportation projects involving air, rail and marine transportation, and public parking facilities.
9. The development of new and improved bicycle control and information signs is encouraged for the increased safety of all highway users.
10. The development of bicycle demonstration projects which foster innovations in planning, design, construction and maintenance is encouraged.
11. Paved shoulders shall be encouraged as appropriate along highways for the safety of all highway users, and should be designed to accommodate bicycle traffic.
12. Environmental documents/planning studies for transportation projects shall evaluate the potential use of the facility by bicyclists and determine whether special bicycle facility design is appropriate.
13. Local input and advice shall be sought, to the degree practicable, during the planning stage and in advance of the final design of roadway improvements to ensure appropriate consideration bicycling needs, if significant.
14. On highways where bicycle facilities exist, (bike paths, bike lanes, bike routes, paved shoulders, wide curb lanes, etc.), new highway improvements shall be planned and implemented to maintain the level of existing safety for bicyclists.
15. Any new or improved highway project designed and constructed within a public-use transportation corridor with private funding shall include the same bicycle facility consideration as if the project had been funded with public funds. In private transportation projects (including parking facilities), where state funding or department approval is not involved, the same guidelines

and standards for providing bicycle facilities should be encouraged.

Construction

It is the policy of the Board of Transportation that all state and federally funded highway projects incorporating bicycle facility improvements shall be constructed in accordance with approved state and federal guidelines and standards.

1. Bicycle facilities shall be constructed and bicycle compatibility shall be provide for, in accordance with adopted Design Guidelines for Bicycle Facilities and with guidelines of the American Association of State Highway and Transportation Officials.

2. Rumble strips (raised traffic bars), asphalt concrete dikes, reflectors and other such surface alterations, where installed, shall be placed in a manner as not to present hazards to bicyclists where bicycle use exists or is likely to exist. Rumble strips shall not be extended across shoulder or other areas intended for bicycle travel.

3. During restriping operations, motor vehicle traffic lanes may be narrowed to allow for wider curb lanes.

Maintenance

It is the policy of the Board of Transportation that the state highway system, including state-funded bicycle facilities, shall be maintained in a manner conducive to bicycle safety.

1. State and federally funded and built bicycle facilities within the state right-of-way are to be maintained to the same degree as the state highway system.

2. In the maintenance, repair and resurfacing of highways, bridges and other transportation facilities, and in the installation of utilities or other structures, nothing shall be done to diminish existing bicycle compatibility.

3. Rough road surfaces which are acceptable to motor vehicle traffic may be unsuitable for bicycle traffic. Special consideration may be given for highways with significant bicycle usage.

4. For any state-funded bicycle project not constructed on state right-of-way, a maintenance agreement stating that maintenance shall be the total responsibility of the local government sponsor shall be negotiated between the department and the local government sponsor.

5. Pot-holes, edge erosion, debris, etc., are special problems for bicyclists and their elimination should be a part of each division's maintenance program. On identified bicycle facilities, the bike lanes and paths should be routinely swept and cleared of grass intrusion, undertaken within the discretion and capabilities of Division forces.

Operations

It is the policy of the Board of Transportation that operations and activities on the state highway system and bicycle facilities shall be conducted in a manner conducive to bicycle safety.

1. A bicyclist has the right to travel at a speed less than that of the normal motor vehicle traffic. In exercising this right, the bicyclists also shall be responsible to drive his/her vehicle safely, with due consideration to the rights of other motor vehicle operators and bicyclists and in compliance with the motor vehicle laws of North Carolina.

2. On a case-by-case basis, the paved shoulders of those portions of the state's fully controlled access highways may be studied and considered as an exception for usage by bicycles where adjacent highways do not exist or are more dangerous for bicycling. Pursuant to federal highway policy, usage by bicyclists must receive prior approval by the Board of Transportation for each specific segment for which such usage is deemed appropriate, and those segments shall be appropriately signed for that usage.

3. State, county and local law enforcement agencies are encouraged to provide specific training for law enforcement personnel with regard to bicycling.

4. The use of approved safety helmets by all bicyclists is encouraged.

Education

It is the policy of the Board of Transportation that education of both motorists and bicyclists, regarding the rights and responsibilities of bicycle riders, shall be an integral part of the department's Bicycle Program.

School systems are encouraged to conduct bicycle safety education programs as a part of and in addition to driver's education program, to the maximum extent practicable, and in conjunction with safety efforts through the Governor's Highway Safety Program. The Division of Motor Vehicles is also urged to include bicycle safety and user information in its motor vehicle safety publications.

Parking

It is the policy of the Board of Transportation that secure and adequate bicycle parking facilities shall be provided wherever practicable and warranted in the design and construction of all state-funded buildings, parks and recreational facilities.

Appendix 3 THE Bicycle TIP Process

The Transportation Improvement Program (TIP) is the process through which local areas and citizens are asked to present their highway and transportation needs to state government. Bicycle safety needs are an important part of this process. Each year, a series of TIP meetings is scheduled around the state. Following the conclusion of the TIP meetings, all requests are evaluated. Bicycle improvement requests which meet project selection criteria are then scheduled into a four-year program as part of the state's long-term transportation program.

In fiscal year 1992, the North Carolina Board of Transportation allocated two million dollars annually for the provision of independent bicycle projects (i.e., those projects which are separate from any other scheduled highway improvements). Incidental projects, or those where the bicycle request is an incidental feature of a planned highway improvement, are built with a mixture of state and federal funds as part of overall highway improvement. Examples of bicycle projects already underway include signed bicycle routes, a greenway bicycle path, roadways with widened lanes, widened paved shoulders, bicycle parking, replacement of hazardous drainage grates and bicycle maps.

The Transportation Improvement Program Process: From Need to Bicycle or Pedestrian Improvement

I. *Recognizing a need for a bicycle improvement project.* Somewhere in a local area there may be unsafe or difficult riding conditions for bicyclists which highlight a need for bicycle transportation improvements – be it an on-road improvement project such as wide paved shoulders, bicycle parking, an off-road bike path, or printed materials such as maps and safety brochures. Pedestrian needs also may be recognized.

II. *The need is presented to the North Carolina Department of Transportation.* If it is a citizen or a private group, such as a local bicycle club, which has recognized a need for a bicycle improvement, there are several ways to present the need to transportation officials. First, a citizen or local club may write a letter presenting the need to the town or county manager's office. A follow-up telephone call should be made in order to learn the official's view of the proposed project. Town or county officials may, or may not, choose to include the improvement in their transportation improvement plan to be presented to the state at the yearly Transportation Improvement Program meeting.

If an official of an agency desires to make a bicycle request at a division TIP meeting but is not able to attend on the date of that meeting, there is a 30 day period following the meeting during which the request may be submitted in a letter addressed to the Secretary of the North Carolina Department of Transportation. All requests will receive the same degree of consideration.

III. *All bicycle project requests are documented.* Following the public TIP meetings, requests for bicycle transportation improvement projects will be organized and documented by the NCDOT Office of Bicycle and Pedestrian Transportation. A survey will be sent to each individual or agency which has made a request. Information obtained from this survey will be used to determine the feasibility of the requested project as well as to assign a level of priority to it.

IV. *Some bicycle and pedestrian improvement projects are selected for construction.* The Office of Bicycle and Pedestrian Transportation first evaluates and prioritizes all the requests; then a summary of the project requests is presented to the NCDOT Bicycle Committee for its review. Following their review, the committee forwards recommendations on the scheduling of some of the requested projects to the North Carolina Board of Transportation which makes the final decision on inclusion of the recommendations in the TIP. To be included in the TIP plan *does not guarantee that a requested project will be implemented. Rather, it means that the project will receive further study and will be implemented if feasible.*

V. *Projects which are included in the TIP fall into two categories.* Bicycle and pedestrian projects which can be incorporated into a planned and scheduled highway improvement are categorized as *incedental projects*. The bicycle or pedestrian element will be considered during the planning and design phases of the total project. Incedental projects are built with a combination of state and federal funds in the same manner as the larger highway project is constructed.

Bicycle projects which are not incorporated into a planned and scheduled highway improvement, but are planned, funded and built seperately, are categorized as *indepentent projects*. These projects are constructed using 80% federal/20% state funding.

VI. *Finally, some TIP projects are implemented.* In the case of a scheduled incidental bicycle or pedestrian improvement, inclusion in the TIP means that the bicycle facility will be considered in conjunction with the planning and environmental studies for the given highway project. If the bicycle or pedestrian component of the project is deemed feasible, it will be scheduled for construction.

Following inclusion in the Bicycle TIP, each independent project will receive further study. This detailed planning study will include an evaluation of the feasibility of the proposed improvement as well as an actual project cost. Upon completion and acceptance by the NCDOT, the planning study will then be submitted to the North Carolina Board of Transportation for final approval and funding. A project must successfully pass through each of these levels in order to be implemented. During any of the above phases of project development, it may be necessary to alter, or, in some cases, eliminate a proposed improvement due to regulatory and design constraints or because of unanticipated costs.

VII. *TIP bicycle projects may take many forms.* There are a number of bicycle improvement projects which involve construction of on-road and off-road facilities. Some of these projects include: wide paved shoulders (4 ft minimum width), specially striped lanes for bicycles, wide outside lanes (13-14 ft minimum width) which permit a safer bicycle/automobile mix, greenway-type bicycle paths, railroad crossing improvements for bicycle safety, and the addition of bicycle-safe bridge railings.

However, there are eligible bicycle improvements that do not require a construction project. Examples of these include: signing bicycle routes; producing maps and safety brochures for cyclists in local areas; replacing dangerous drainage grates with bicycle-safe drainage grates; making spot improvements such as paving potholes or hazard marking of dangerous roadway features; and providing bicycle safety education materials to local areas.

In many cases it may be difficult to determine which kind of facility improvements is most needed. Therfore, it is entirely appropriate to request that bicycle improvements be made along a particular corridor without specifying a particular type of treatment.

TIP Bicycle project selection criteria

The following factors which affect bicycle project selection for the TIP is intended to provide guidance to local area requestors. It is important to note that:

A. Many worthwhile projects will fulfill only a few of the following conditions. Nevertheless, we encourage submission of all needed projects, since cost constraints and regulations may change over the next few years, allowing us to schedule previously infeasible projects.

B. Detailed project justification based on the factors listed below is not required at the time of project submission. We will contact you during a follow-up period to obtain any additional needed information.

The criteria are as follows:

1. *Cost limitations:* Given current budget constraints, it is unlikely that any projects with a cost in exess of $300,000 will be scheduled.
2. *Right-of-way:* Complete information regarding the right-of-way situation should be provided. Due to the limited size of our annual budget, projects requiring that NCDOT acquire right-of-way are unlikely to be scheduled.
3. *Design standards:* Projects must be in conformance with federally adopted bicycle design guidelines, as described in the AASHTO Guide for the Development of Bicycle Facilities (1991) and the NCDOT Bike Guidlines (1994). The “sidewalk bikepath,” which is constructed adjacent to the roadway for two-way bicycle traffic, runs counter to the AASHTO guidelines and is discouraged within our program.
4. *Project purpose:* Each project must serve a primary bicycle transportation purpose, as opposed to a recreation or pedestrian purpose.
5. *Preliminary project approval:* All necessary permits and approval must be obtained for any project involving a public jurisdiction (including approval of Metropolitan Planning Organizations and inclusion in the local TIP, lease agreements, construction and encroaching permits, etc.).
6. *Local area involvement:* Project requests are viewed within the overall picture of bicycling in an area. Evidence of local concern and involvement via other bicycle projects or activities lends support to each specific bicycle request. Local participation (via a direct dollar share or design

services) is viewed as one measure of a local area's commitment to an improved bicycle environment.

7. *Inclusion in transportation or bicycle planning process.* Evidence that your specific bicycle request is an element of a comprehensive transportation or bicycle planning process provides critical support for your project.
8. *Project need:* Priority will be given to those projects where the greatest need can be demonstrated. Accident statistics, potential safety problems, and information regarding current or potential users of the facility can all provide project justification.
9. *Boardwalks:* Multi-use pathways that are intended to accommodate bicycles should not be designed with significant sections of boardwalk, or other such surfaces, which may be unsuitable for bicycle transportation purposes.

Appendix 4 MUTCD Part IX

A. GENERAL

9A-1 Requirements for Bicyclist Traffic Control Devices

Traffic control devices, whether they are intended for motorists or bicyclists, must adhere to five basic requirements to be able to perform their intended function. They must:

1. Fulfill a need.
2. Command attention.
3. Convey a clear simple meaning.
4. Command respect of road users.
5. Give adequate time for proper response.

The design, placement, operation, maintenance and uniformity of traffic control devices must be considered to meet the above requirements. Design is a critical feature to permit the device to fulfill a need and to command respect of road users. The placement – lateral, vertical and longitudinal – plays an important part in making the device effective and in giving adequate time for proper response. The operation of traffic in response to the device is, of course, the critical test of the device's effectiveness and a check on all five of the basic requirements.

Uniformity, achieved by following the recommendations and standards of this manual, greatly enhances the ability of a device to convey a clear, simple meaning to the user.

Whenever devices are installed, they should be warranted and based on a prior engineering study. Where the guidance provided by this part of the manual does not fully define where particular devices should be used, qualified traffic engineers should determine the application of devices on any bicycle facility before installation is made. It is intended that this m anual define the standards for traffic control devices, but shall not be a legal requirement for their installation.

9A-2 Scope

This part covers bicycle-use related signs, pavement markings, and signals which may be used on highways or bikeways.

The following terms are used throughout Part IX:

1. Bikeway: Any road, street, path or way which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive us of bicycles or are to be shared with other transportation modes.

2. Bicycle Trail: A separate trail or path from which motor vehicles are prohibited and which is for the exclusive use of bicycles or the shared use of bicycles and pedestrians. Where such trail or path forms a part of a highway, it is separated from the roadways for motor vehicle traffic by an open space or barrier.

3. Designated Bicycle Lane: A portion of a roadway or shoulder which has been designated for use by bicyclists. It is distinguished from the portion of the roadway for motor vehicle traffic by a paint stripe, curb, or other similar device.

4. Shared Roadway: A roadway which is officially designated and marked as a bicycle route, but which is open to motor vehicle travel and upon which no bicycle lane is designated.

5. Bicycle Route: A system of bikeways designated by appropriate route markers, and by the jurisdiction having authority.

9A-4 Standardization of Devices

Standards for basic design elements and devices using these standards are given in this Manual. These standard devices generally will serve most applications. Where particular conditions require the use of a device that is not included in this Manual, the general principles in this Manual as to color, size, and shape should be followed wherever practical. Such devices should also follow the design, installation and application concepts contained in the Manual.

9A-5 Maintenance

Bicycle signs and markings should be properly maintained to command respect from both the motorist and the bicyclist. When installing signs and marking on bicycle facilities, care should be taken to have an agency designated to maintain these devices.

9A-6 Legal Authority

Traffic control devices shall be placed only by authority of a public body or official having jurisdiction, for the purpose of regulating, warning or guiding traffic. No traffic control device or its support shall bear any advertising or commercial message, or any other message that is not essential to traffic control.

All regulatory devices, if they are to be enforced, need to be backed by applicable laws, ordinances, or regulations.

In this part as in other parts of the Manual, the words "shall," "should," and "may" are used to describe specific conditions concerning traffic control devices. To clarify the meanings intended by the use of these words, the following definitions are provided:

1. SHALL: A "mandatory" condition. Where certain requirements in the design or application of the device are described with the "shall" stipulation, it is mandatory that these requirements be met.

2. SHOULD: An "advisory" condition. Where the word "should" is used, it is considered to be advisable usage, recommended but not mandatory.

3. MAY: A "permissive" condition. No requirement for application is intended. If a particular device is used under a "may" condition, however, its design shall follow the prescribed format.

9A-8 Relation to Other Documents

The Uniform Vehicle Code and Model Traffic Ordinance published by the National Committee on Uniform Traffic Laws and Ordinances, have provisions for bicycles and are used as the legal basis for the control devices included herein. Under the Uniform Vehicle Code, bicycles are generally considered to be vehicles, so the bicyclists have the same privileges and obligations as other drivers.

Informational documents used during the development of the signing and markings recommendations in this part of the Manual include the following:

1. Guide for Bicycles, American Association of State Highway and Transportation Officials, 1974.
2. Bikeways, State of the Art, Federal Highway administration, 1974.
3. Bicycle Facility Location Criteria, Federal Highway Administration, 1976.
4. Bicycle Facility Design Criteria, Federal Highway Administration, 1976.
5. State and municipal design guides.

9A-9 Colors

The use of colors for bicycle facility traffic control devices should conform to the color code specified for signs and markings. This in part is as follows:

YELLOW-General warning
RED-Stop or prohibition
BLUE-Service guidance
BROWN-Public recreation and scenic guidance
ORANGE-Construction and maintenance warning
BLACK-Regulation
WHITE-Regulation

B. SIGNS

9B-1 Application of Signs

Bicycle-use related signs on highways and bikeways serve three basic purposes: regulating bicycle usage, directing bicyclists along pre-established routes, and warning of unexpected conditions. 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. The frequent display of guide signs, however, aids in keeping the bicyclist on the designated route and does not lessen their value. Some signs for the bicyclist can also serve the motorist and the pedestrian.

9B-2 Location and Position

Where signs are to serve both bicyclists and motorists, mounting heights and lateral placement shall be as specified in Part II, Signs. Figure 9-1 illustrates typical signing placement for bicycle trails. Overhead sign clearance on bicycle trails shall be a minimum of 8 feet. The clearance provided

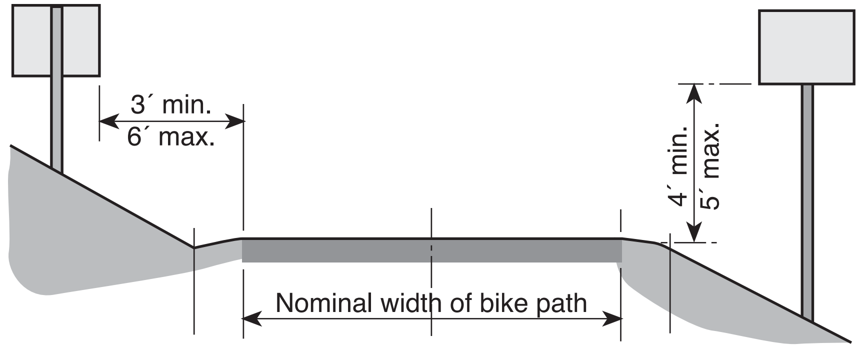


Figure 9-1: Bicycle sign placement on a trail.

should also be adequate for the typical maintenance vehicles used on the bikeway . Where signs are for the exclusive use of bicyclists, care should be taken that they are located so that motorists are not confused by them.

9B-3 Design

The design of signs for bicycle facilities should, whenever possible, be identical to that specified in this manual for motor vehicle travel. Uniformity in design includes shape, color, symbols, wording, lettering, and illumination or reflectorization. Detailed drawings of the standard signs illustrated in this Manual are available to State and local highway and traffic authorities, sign manufacturers, and similar interested agencies. Standardization of these signs does not preclude further improvement by minor changes in the proportion of symbols, stroke width, and height of letters, or width of borders. However, all shapes and colors shall be as indicated; all symbols shall be unmistakably similar to those shown and (where a word message is applicable) the wording shall be as provided herein.

The sign dimensions shown in this part of the Manual shall be considered standard for application on all types of bicycle facilities. Where signs shown in other parts of this Manual are intended for exclusive bicycle use, smaller sign sizes from that specified may be used. Incremental increases in special bicycle facility signs are also desirable to make the sizes compatible with signs for motor vehicles, where both motorists and bicycles benefit by a particular sign.

The sign lettering shall be in upper-case letters of the type shown in the Standard Alphabets for Highway Signs and Pavement Markings.

All signs should be reflectorized for bicycle trails as well as for shared roadway and designated bicycle lane facilities.

9B-4 Regulatory Signs

Regulatory signs are to inform bicyclists, pedestrians, and motorists of traffic laws or regulations and indicate the applicability of legal requirements that would not otherwise be apparent.

Regulatory signs normally shall be erected at the point where the regulations apply. The sign message shall clearly indicate the requirements imposed by the regulations and shall be easily visible and legible to bicyclists and where appropriate, motorists and pedestrians.

9B-5 Bicycle Prohibition Sign (R5-6)

This sign is intended for use at the entrance to facilities, such as freeways, where bicycling is prohibited. Where pedestrians and motor-driven cycles are also prohibited from using these facilities, it may be more desirable to use the R5-10a word message sign (sec. 2B-28).

In reduced size (18 x 18 inches), this sign may be used on sidewalks where bicycle riding is prohibited.

9B-6 Motor Vehicle Prohibition Sign (R5-3)

This sign is intended for use at the entrance to a bicycle trail.

9B-7 Bicycle Restriction Signs (R9-5 & 6)

This series of signs is intended for use where pedestrian facilities are being use for bicycle travel. They should be erected off the edge of the sidewalk, near the crossing location, where bicyclists are expected to dismount and walk with pedestrians while crossing the street.

The R9-5 sign may be used where bicycles can cross the street only on the pedestrian walk signal indication.

The R9-6 sign may be used where bicycles are required to cross or share a facility used by pedestrians and are required to yield to the pedestrians.

9B-8 Designated Lane Signs (R3-16 & R3-17)

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 (sec. 9C-4).

Where appropriate, the message ENDS may be substituted for AHEAD on the R3-16 sign and LEFT of CURB can be substituted for RIGHT on the R3-17 sign.

9B-9 Travelpath Restriction Signs (R9-7)

The R9-7 sign is intended for use on facilities which are to be shared by pedestrians and bicycles and on which a designated area is provided for each (sec. 9C-3). Two of these signs may be erected back-to-back with the symbols reversed for the opposite direction.

9B-10 Stop and Yield Signs (R1-1,2)

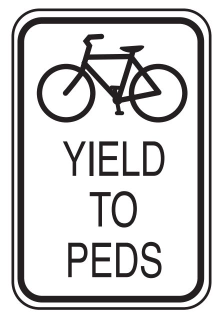
STOP signs are intended for use on bicycle facilities where bicyclists are required to stop. Where conditions require bicyclists and not motorists to stop, care should be taken to place the sign so it is not readily visible to the motorist.

YIELD signs are intended for use where the bicyclist can see approaching traffic and where bicyclist must yield the right of way to that traffic.

R5-6
24" X 24"

R5-3
24" X 24"

R9-5
12" X 18"



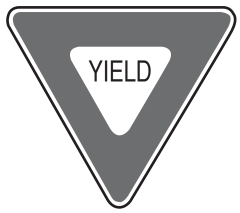
R9-6
12" X 18"

R9-7
12" X 18"

R3-16
24" X 30"

R3-17
24" X 30"

R1-1
18" X 18"



R1-2
24" X 24" X 24"

R7-9
12" X 18"

R7-9a
12" X 18"

R3-7
30" X 30"

R4-4
36" X 30"

The visibility of approaching traffic must be adequate to permit the bicyclist to stop or to take other measures to avoid that traffic.

For added emphasis STOP and YIELD signs in regular 30 x 30 inch and 36 x 36 x 36 inch sizes may be used.

The smaller signs shown below are intended for use on bicycle trails where bicyclists are required to stop or yield the right of way. If the sign applies to motorists and bicyclists, then the size should be as shown in Part II-B.

9B-11 No Parking Signs (R7-9, & 9a)

Where it is necessary to restrict parking, standing, or stopping in a designated bicycle lane, appropriate signs as described in sections 2B-31 through 2B-33 may be used, or signs R7-9 or R7-9a shall be used.

9B-12 Lane Use Control Signs (R3-7, R4-4)

Where right-turning motor vehicles must merge with bicycle traffic on designated bike lanes, the R3-7 and R4-4 signs may be used. The R4-4 sign is intended to inform both the motorist and the bicyclist of this merging maneuver. Where a designated bicycle lane is provided near the stop line, an R3-7 sign may be used to prevent motorists from crossing back over the bike lane.

9B-13 Warning Signs

Warning signs are used when it is deemed necessary to warn bicyclists or motorist of existing or potentially hazardous condition on or adjacent to a highway or trail. The use of warning signs should be kept to a minimum because the unnecessary use of them to warn of conditions which are apparent tends to breed disrespect for all signs.

Warning signs specified herein cover most conditions that are likely to be met. If other warnings are needed, the signs shall be of standard shape and color for warning signs, and the legends shall be brief and easily understood.

9B-14 Bicycle Crossing Sign (W11-1)

The Bicycle Crossing sign is intended for use on highways in advance of a point where a bikeway crosses the roadway. It should be erected about 750 feet in advance of the crossing location in rural areas where speeds are high, and at a distance of about 250 feet in urban residential or business areas, where speeds are low.

If the approach to an intersection is controlled by a traffic control signal, stop sign or yield sign, the W11-1 sign may not be needed.

9B-15 Hazardous Condition Sign (W8-10)

The Hazardous Condition sign is intended for use where roadway or bicycle trail conditions are likely to cause a bicyclist to lose control of his bicycle. These conditions could include slippery pavement, slick bridge, decking, rough or grooved pavement, or water or ice on the roadway. The W8-10 sign may be used with a supplemental plaque describing the particular roadway or bicycle trail feature which might be of danger to the bicyclist such as SLIPPERY WHEN WET, STEEL DECK, ROUGH PAVEMENT, BRIDGE JOINT, or FORD.

9B-16 Turn and Curve Signs (W1-1, 2, 4, 5, 6, 7)

On bicycle trails where it is necessary to warn bicyclists of unexpected changes in path direction, appropriate turn or curve signs should be used. They should normally be installed no less than 50 feet in advance of the beginning of the change of alignment.

9B-17 Intersection signs (W2-1,2,3,4,5)

Intersection signs are intended for use as appropriate to fit the prevailing geometric pattern on bike trails where connecting routes join and where no STOP or YIELD signs are required. They should be used wherever sight distance at the intersection is severely limited, and may be used for supplemental warning at intersections where STOP and YIELD signs are erected.

9B-18 Other Warning Signs

Other warning signs may be required on bicycle facilities to warn riders of unexpected conditions. The intended use of these signs generally is self-explanatory. They should normally be installed no less than 50 feet in advance of the beginning of hazards.

Where construction or maintenance activity is present on bicycle trails, appropriate signs from Part VI of the Manual should be used.

W11-1
30" x 30"

W8-10

Roadway Signs
30" x 30"
24" x 24"

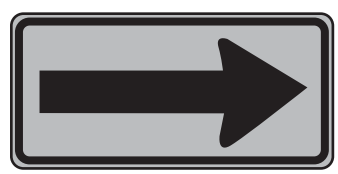
Bicycle Trail Signs
18" x 18"
12" x 9"

W1-1
18" x 18"

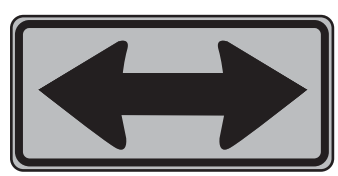
W1-2
18" x 18"

W1-4
18" x 18"

W1-5
18" x 18"



W1-6
24" x 12"



W1-7
24" x 12"


W2-1
18" x 18"

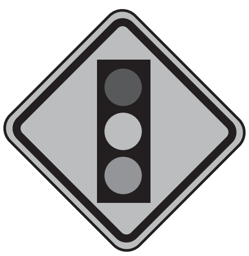

W2-2
18" x 18"


W2-3
18" x 18"


W2-4
18" x 18"


W2-5
18" x 18"

W3-1
18" x 18"


W3-3
18" x 18"

W5-4
18" x 18"


W7-5
18" x 18"


W11A-2
18" x 18"

W12-2
18" x 18"

W10-1
18" Diameter

9B-19 Guide Signs

On highways where a bicyclist is sharing a lane with motor vehicles or is using an adjacent bikeway, the regular guide signing as described in Part II of the Manual will serve both modes of travel. Where a designated bikeway exists, special bicycle route signing should be provided at decision points, including signs to inform cyclists of bicycle route direction changes and confirmatory signs to ensure that route direction has been accurately comprehended.

Figure 9-2 shows an example of the signing for the junction of a bicycle trail with a highway. Figure 9-3 shows the signing and marking for the beginning and ending of designated bikeways. Guide signing should be repeated at regular intervals to ensure that bicyclists approaching from side streets know they are traveling on an officially designated bikeway. Similar guide signing should be used for shared lane bikeways with intermediate signs placed frequently enough to ensure that cyclists already on the bikeway do not stray from it and lose their way.

D11-1
24" x 18"

M1-8
12" x 18"

9B-20 Bicycle Route Sign (D11-1)

This sign is intended for use where no unique designation of routes is desired. It should be placed at intervals frequent enough to keep bicyclists informed of changes in route direction and to remind motorists of the presence of bicyclists.

M1-9
18" x 24"

9B-21 Bicycle Route Markers (M1-8, M1-9)

Where it is desired to establish a unique identification (route designation) for a State or local bicycle route, the standard Bike Route Marker (M1-8) should be used. The route marker (M1-8) shall contain a numerical designation and shall have a green background with a reflectorized white legend and border.

Where a bicycle route extends for long distances in two or more States, it is desirable to establish a unique numerical destination for that route. A coordinated submittal by the affected States for assignment of route number designations should be sent to the American Association of State Highway and Transportation Officials, 444 North Capitol Street NW., Suite 225, Washington, D.C. 2001. The route marker

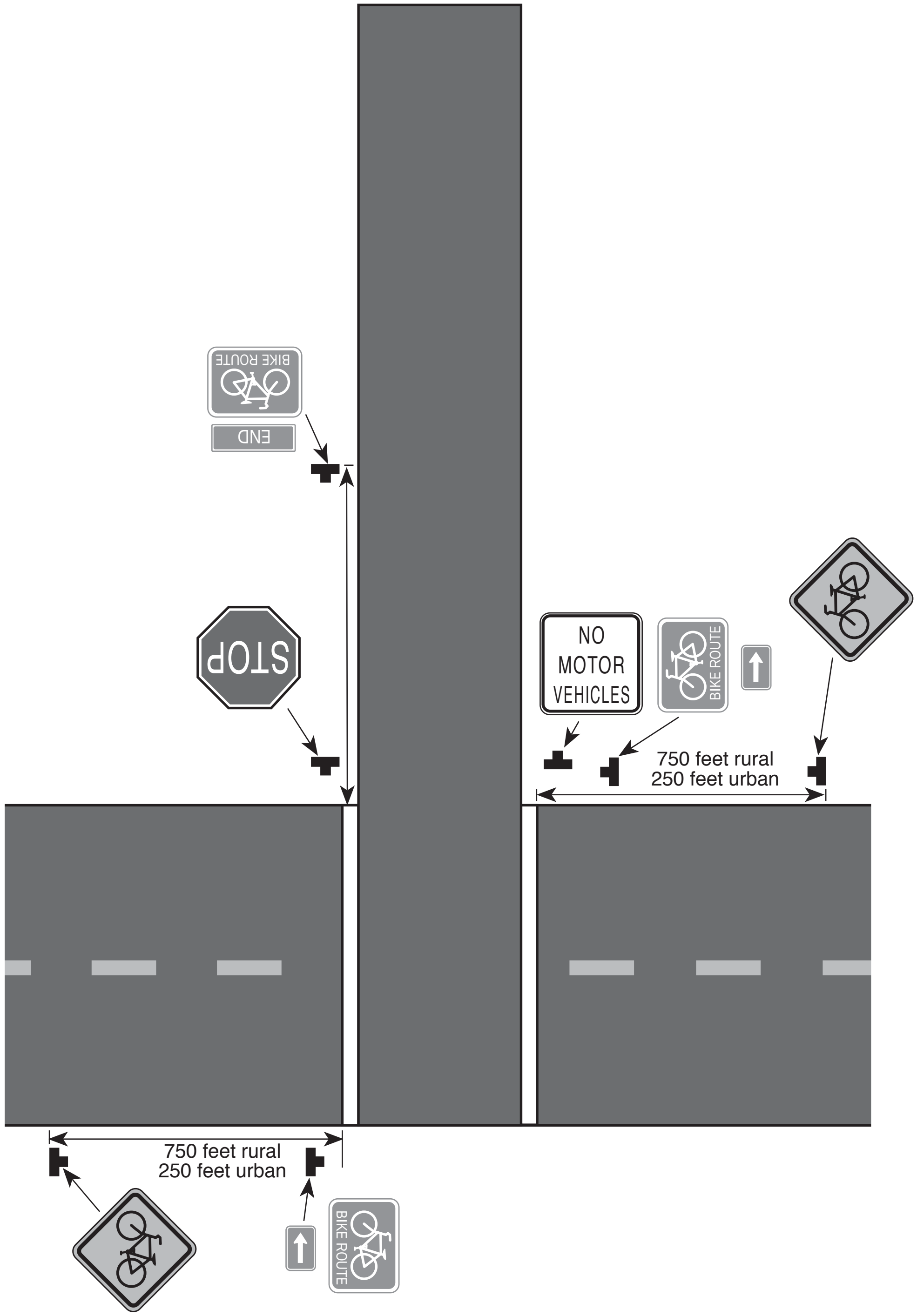


Figure 9-2: Typical signing for beginning and ending of bicycle trail.

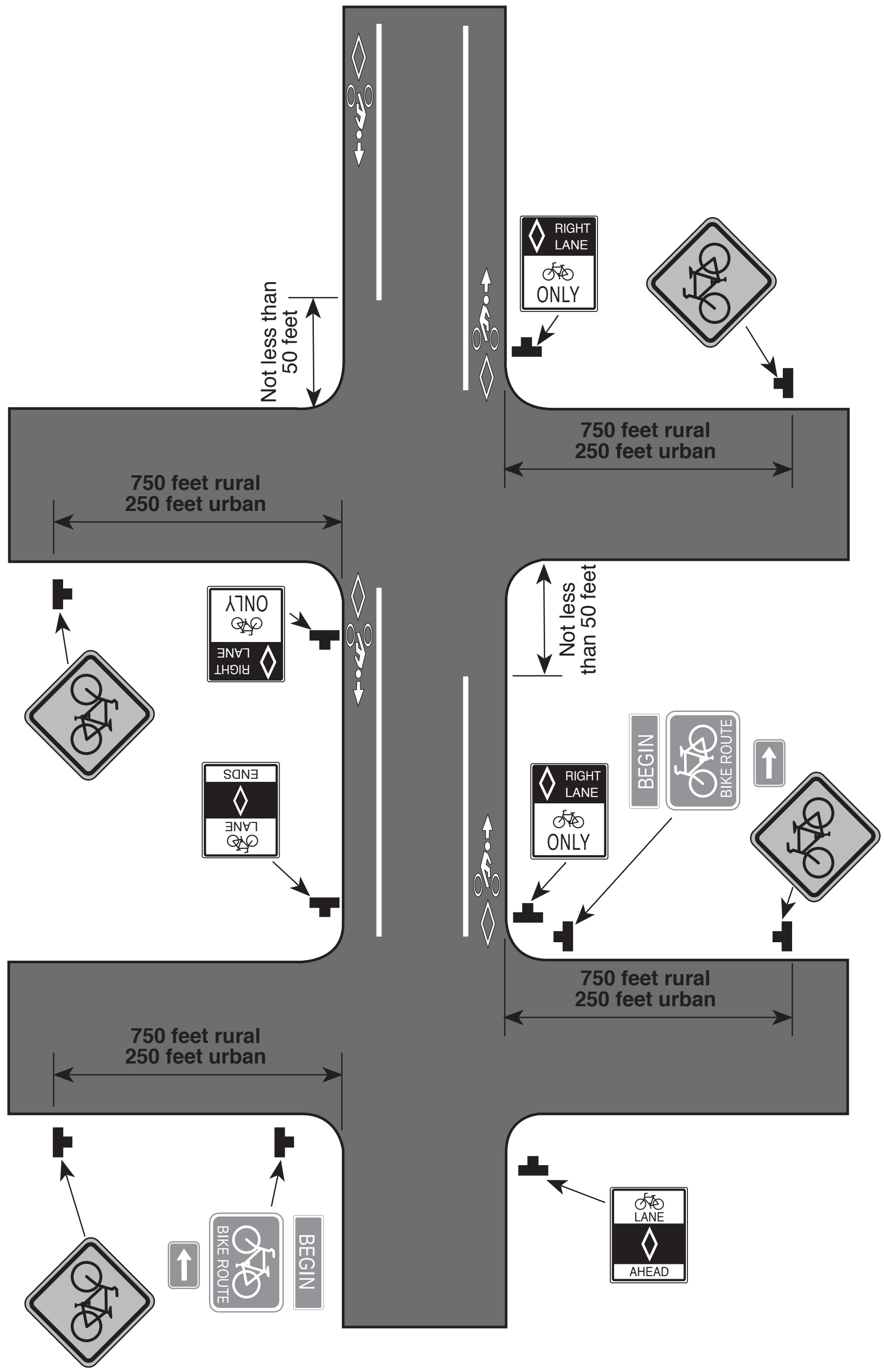


Figure 9-3: Typical signing for beginning and ending of designated bicycle lane.

(M1-9) shall contain the assigned numerical designation and have a black legend and border with a reflectorized white background.

Bike Route Markers are intended for use on both shared facilities and on designated bike ways, as required, to provide guidance for bicyclists.

9B-22 Supplemental Plaques for Route Signs and Markers

Where desired, supplemental plaques can be used with the D11-1 and M1-8 signs to furnish additional information, such as directional changes in the route, and intermediate range distance and destination information.

The M4-11 through M4-13 signs may be mounted above the appropriate Route Signs or Route Marker. Supplemental plaques D1-1b and c are intended for use with the D11-1 Bicycle route Sign. The appropriate arrow sign (M7-1 through M7-7), if used, should be placed below the Route Sign or Route Marker. These signs shall have a white arrow on a green background.

9B-23 Bicycle Parking Area Sign (D4-3)

The Bicycle Parking Area sign may be used where it is desired to show the direction to a designated bicycle parking area within a parking facility or at other locations. The sign shall be a vertical rectangle of a standard size of 12 by 8 inches. It shall carry a standard bicycle symbol, the word PARKING, and an arrow. The legend and border shall be green on a reflectorized white background.

M4-11
24" x 6" or 12" x 4"

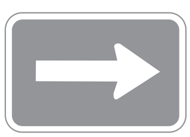
D1-1b(L)
24" x 6"

M4-12
24" x 6" or 12" x 4"

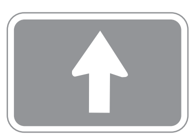
D1-1b(R)
24" x 6"

M4-13
24" x 6" or 12" x 4"

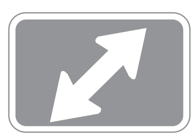
D1-1(c)
24" x 6"



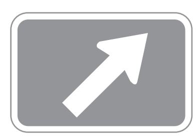
M7-1



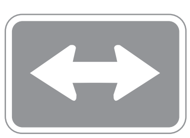
M7-2



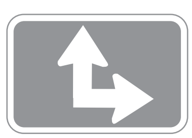
M7-3



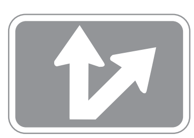
M7-4



M7-5



M7-6



M7-7

M7-1 through M7-7
12" x 9"

D4-3
12" x 18"

C. MARKINGS

9C-1 Functions and Limitations of Markings

Markings are important on roadways that have a designated bicycle lane. Markings indicate the separation of the lanes for motor vehicles and bicycles, assist the bicyclist by indicating assigned travel paths, and can provide advance information for turning and crossing maneuvers.

9C-2 General Principles

Although bicycles are generally not equipped with strong lighting equipment, the added visibility of reflectorized pavement markings is desirable even where there is exclusive use by bicyclists.

Markings shall be reflectorized on bicycle trails and on facilities use by both motor vehicles and bicycles.

Recognized bikeway design guides should be used when laying out markings for a bicycle lane on a highway facility (sec. 9A-8).

The frequent use of symbols and word messages stenciled in the bike lanes, is a desirable method of supplementing sign messages. Figures 9-4 through 9-6 show acceptable examples of the application of lines, word messages and symbols on designated bikeways with and without parking for motor vehicles.

If a specific path for a bicyclist crossing an intersection is to be designated, a dotted line may be used to define such a path.

9C-3 Marking Patterns and Colors

The color and type of lines used for marking bicycle facilities shall be as defined in section 3A-7. Normally, center lines would not be required on bicycle paths. Where conditions make it desirable to separate two directions of travel at particular locations, a double solid yellow line should be used to indicate no passing or no traveling to the left of the line.

Where bicycle paths are of sufficient width to designate two minimum width lanes, a broken yellow line may be used to separate the two directions of travel.

Broken lines used on bicycle paths should have the normal 1 to 3 segment-to-gap ratio. To avoid having gaps excessively long, a nominal 3-foot segment with a 9-foot gap is recommended.

Where bicycles and pedestrians use a common facility, it may be desired to separate the two traffic flows. A solid white line should be used to mark this separation of path use. The R9-7 sign may be used to supplement the pavement marking (sec. 9B-9).

9C-4 Marking of Designated Bikeways

The diamond-shaped Preferential Lane Symbol is intended for use on highway facilities where lanes are reserved for exclusive use by a particular class of vehicle. Designated bikeways are considered as this type of lane and shall include use of the Preferential Lane Symbol as a pavement marking and on appropriate signing (sec. 9B-8). The symbols as a pavement marking shall be white and shall be used immediately after an intersection to inform turning motorists of the restricted nature of the lane. If the Preferential Lane Symbol is used in conjunction with other word or symbol messages, it shall precede them. A supplemental lane symbol or word may be used following as shown in figures 9-4 through 9-6.

9C-5 Word Messages and Symbols Applied to the Pavement

Where messages are to be applied on the pavement, smaller size letters can be used on exclusive bike lanes than are used on regular highways. Where arrows are needed, half-size layouts of the arrows can be used (sec. 3B-17). Optional word and symbol markings considered appropriate for use with the Preferential Lane Symbol marking are shown in figure 9-6. Standard pavement marking alphabets and symbols have been prepared.*

*Available from the Federal Highway Administration (HTO20) Washington, D.C. 20590

9C-6 Object Markings on Bicycle Trails

There may be hazardous objects located adjacent to bicycle trails which, if visible to the rider, can be avoided with little difficulty. Such objects can be marked with highly visible markings to make their identification by approaching riders more certain. Care should

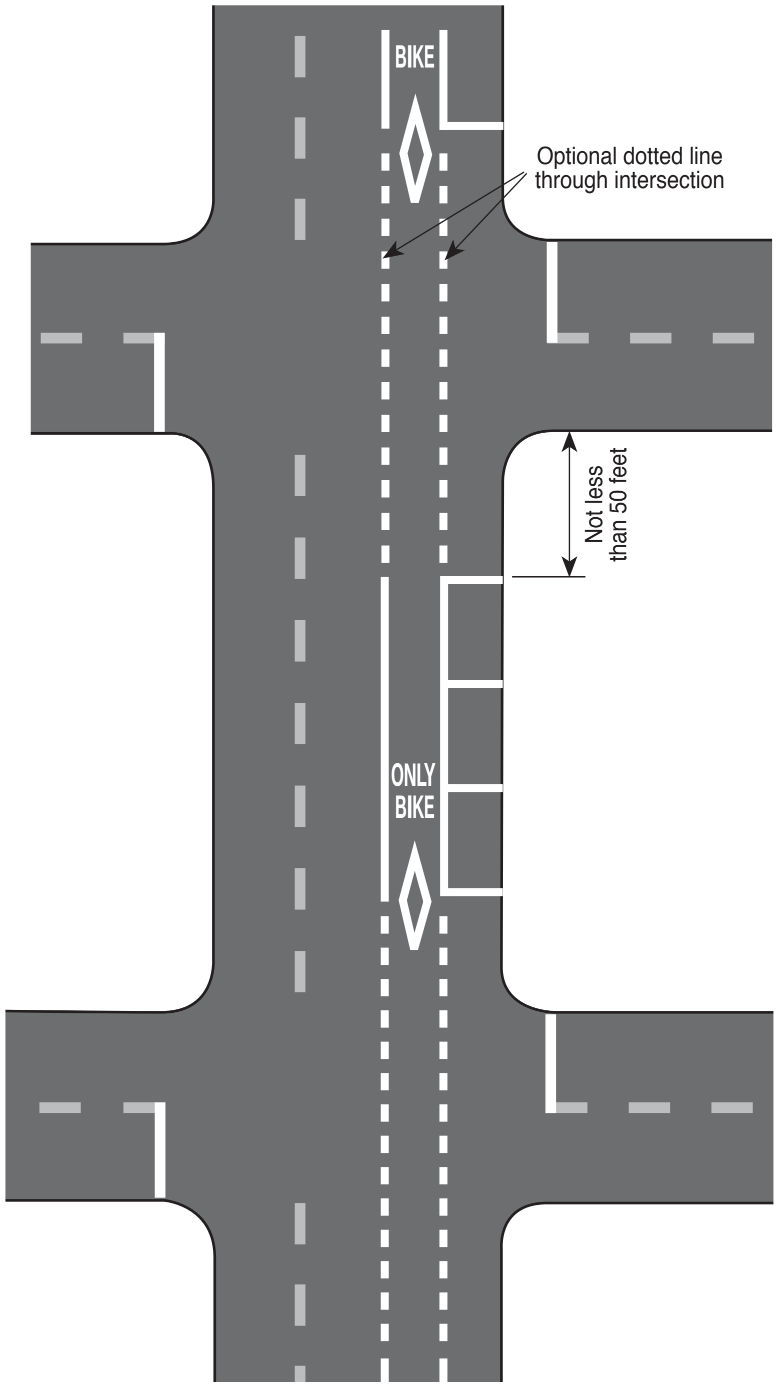


Figure 9-4: Typical pavement markings — designating bicycle lane, two-way traffic with parking and low right turn volume.

be taken to avoid having object markers become hazardous objects. Corners of object markers as well as signs should be rounded to prevent their becoming a hazard.

All object markers should be designed using reflective materials or coatings. where practical, markers such as those described in section 3C-1 of this Manual should be used.

Where a storm drain hazard cannot be eliminated, it may be made more visible to bicyclists by defining with a white marking, applied as shown in figure 9-7.

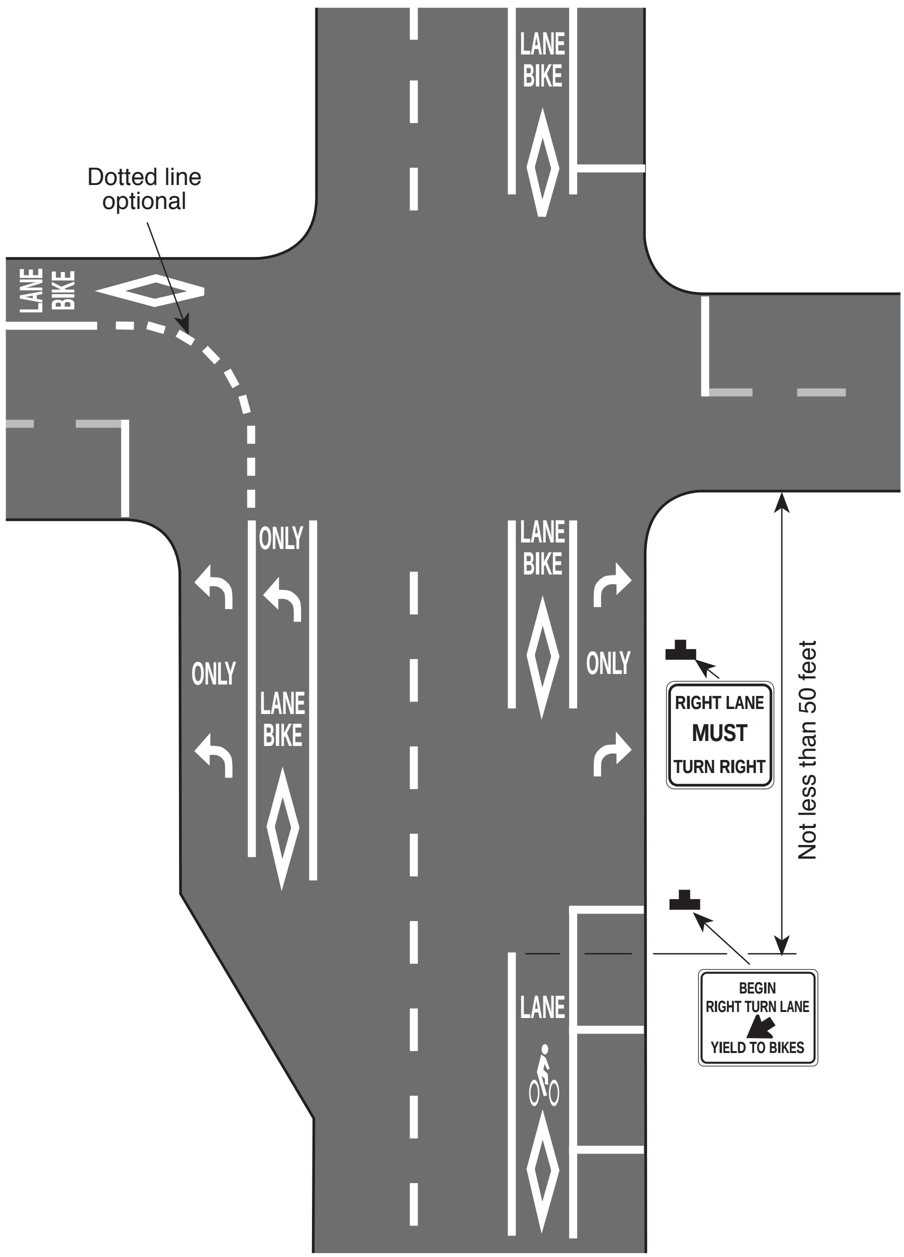


Figure 9-5: Intersection pavement markings — designated bicycle lane with left turn area, heavy turn volumes, parking, one-way traffic or divided roadway.

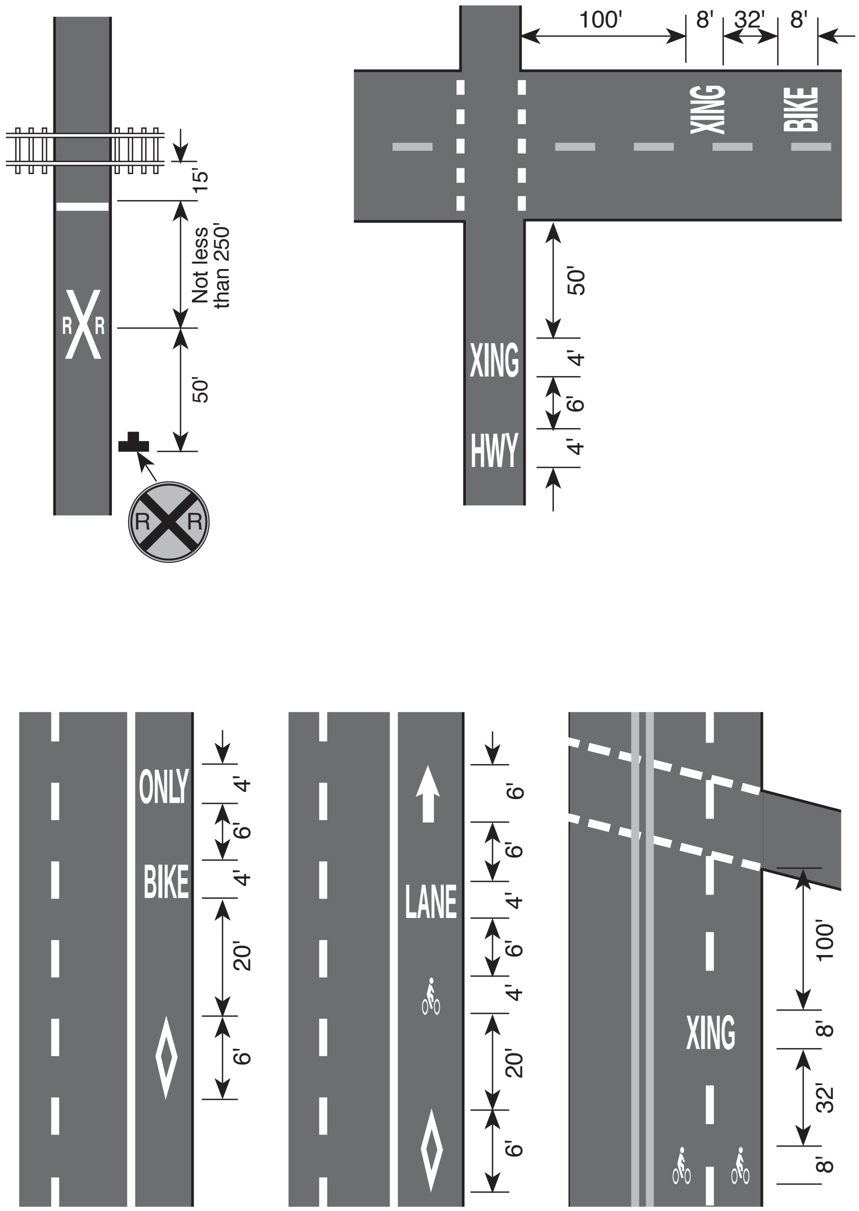


Figure 9-6: Word and symbol pavement markings for bicycle facilities.

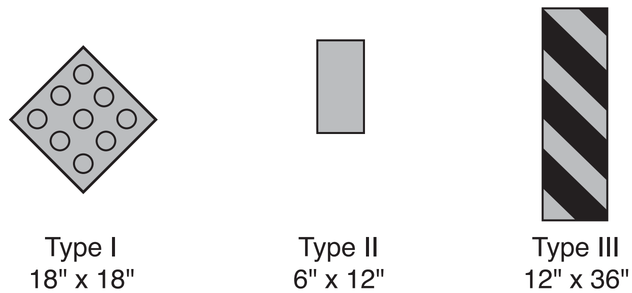
D. SIGNALS

9D-1 Application

It is rare when a traffic signal is installed solely for bicyclists; however, at some locations there may be a need to install signal devices to facilitate bicycle travel through the intersection. For warrants and other requirements relating to signal installations, see Part IV of this Manual. Warrants used for motor vehicles are considered appropriate for use in determining the need for signals to serve bicyclists. Warrant Four for school crossings is considered to be appropriate for bicyclists also.

9D-2 Visibility Requirements

At installations where programmed signals are



used, special attention should be given to adjusting the signals so bicyclists on the regular bicycle lanes or travel paths can see the signals. If programmed signals cannot be aimed to serve the bicyclist, then separate signals shall be provided.

9D-3 Signal Operation for Bicycles

Bicycles generally can cross intersections under the same signal timing arrangement as motor vehicles. Where bicycle use is expected, extremely short change intervals should not be used and an all red clearance interval may be necessary.

Chapter X included general comments on placing traffic control devices on bicycle routes, lanes, and paths. The reader should refer to the appropriate sections for suggested applications of traffic control devices. However, specific applications of traffic control devices on bikeways must be in accordance with the MUTCD.

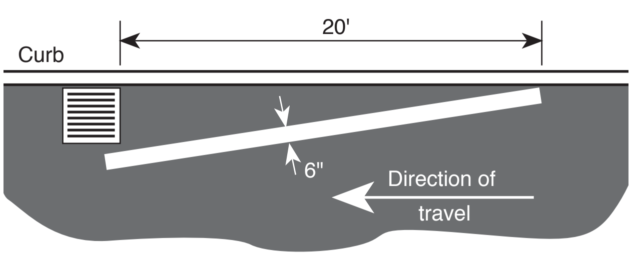


Figure 9-7: Typical marking in advance of drainage hazard.

For convenience, "Part IX Traffic Controls for Bicycle Facilities" of the MUTCD has been included in this Appendix. Readers are encouraged to purchase the entire document.

Appendix 5 North Carolina Signs

The following signs were created by the North Carolina Department of Transportation Office of Bicycle and Pedestrian Transportation and are specific to North Carolina.

Warning signs

Share the road (W28-1): This subplate, when combined with the W11-1 warning sign is intended to increase bicyclists' visibility without designating the signed roadway as a preferred route. It is intended for use on roadways with high levels of bicycle traffic, but relatively hazardous conditions for bicyclists. Its intention is not to encourage inexperienced bicyclists to ride on the roadway as a preferred route.

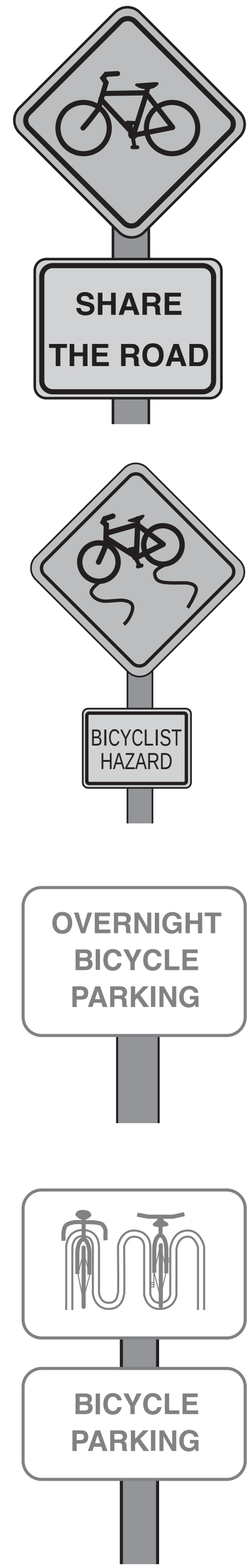
This sign is especially useful in cities and towns where there are large numbers of bicyclists riding on streets which are unsuitable for designation as preferred bicycle routes due to factors such as narrow lanes, high speed traffic and/or high traffic volumes.

Bicyclist Hazard (SP-537): This subplate, when combined with the W8-10 warning sign is intended to warn bicyclists of the presence of a surface condition that could cause them to lose control.

Information signs

Overnight Bicycle Parking (D4-4B): This sign is a special purpose sign intended to identify bicycle parking that may be used overnight.

Bicycle Parking (D4-4 and D4-4A): These signs are special purpose signs intended to show bicyclists how to use a Ribbon Rack-type parking device. They should be used at such installations where the probability of confusion is high, particularly those where new users, who may never have seen such a device, are common.



W11-1
30" x 30"

W28-1
24" x 18"

W8-10
30" x 30"

SP-537
18" x 9"

D4-4B
18" x 12"

D4-4
18" x 12"

D4-4A
18" x 9"

Figure 1: Various signs developed for specific purposes by the North Carolina Department of Transportation Office of Bicycle and Pedestrian Transportation.

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