Appendix A

Design Guidelines for Bicycle Facilities

A. Introduction

Purpose of the Guidelines

These design guidelines are intended to serve as an aid to engineers, designers, planners, and others in accommodating bicycle traffic in different riding environments and encouraging predictable bicycling behavior. They are based primarily on the national guidelines outlined in the 1999 *Guide for the Development of Bicycle Facilities* (AASHTO Guide), published by the American Association of State Highway and Transportation Officials (AASHTO), and the *Manual on Uniform Traffic Control Devices* (MUTCD), published by the U.S. Department of Transportation, and the Wisconsin Department of Transportation's *Facilities Development Manual*, Procedure 11-45-10. However, other sources and the experience of Madison area facility designers and users have also been considered. A list of sources consulted is provided at the end of this appendix.

The guidelines are intended as a primer on bicycle facilities design, not as a stand-alone document. They highlight important issues, cover issues not addressed or addressed in insufficient depth by the AASHTO Guide, and note a few instances where the recommended guidelines differ from the AASHTO Guide. The AASHTO Guide, MUTCD, and other sources should be used in conjunction with these guidelines. The AASHTO Guide provides a high level of detail on shared use path design, in particular.

Bicycle facility guidelines will not cover all of the design details encountered in developing bicycle facilities. Where details are not covered, appropriate engineering principles and judgment must be applied in providing for the safety and convenience of bicyclists, pedestrians, and motorists. It should be noted that knowledge of the human and environmental factors contributing to bicycle crashes is also very important for facility designers. Chapter 5 of this plan and the *Wisconsin Bicycle Transportation Plan 2020* summarize some of this information.

Plan Policy Regarding Provision of Bicycle Facilities

Chapter 2 of this plan provides an overview of the needs of bicyclists, which include safe, convenient, well-designed bicycle facilities. Since bicyclists may ride on all non-access restricted roadways, bicycle facilities should be included as part of all appropriate projects unless there is a compelling reason not to include them (e.g., would reduce safety or the cost is excessively disproportionate to projected use). An example is the case of a rural roadway with narrow, steep shoulders where bicycle travel demand is low and expected to remain low in the future. It is best to estimate high levels of use. Judging the need for facilities based on current bicycle counts and/or projected levels is often unreliable due to past and still-existing disincentives for bicycling. Paved shoulders, bike lanes, and wide curb lanes, which benefit bicyclists, also provide a number of other benefits related to maintenance, general safety, and joint uses, and can often be justified for these reasons.

Since facilities are constructed on a project-by-project basis, bicycle facilities should generally be provided even for short sections (e.g., as part of an intersection improvement). If desired, bike lane striping, markings, and signing can be left out until the segment is connected to a longer facility.

Bicycle lanes should be added as part of intersection projects.

If there is a question as to whether or not a special effort (e.g., purchasing additional right-of-way, eliminating parking on one side of the street, etc.) to accommodate bicyclists is justified, the following factors should be considered:

- Whether the roadway section is identified as in need of bicycle facility improvements in this plan (and the level of priority assigned to it), any applicable state plans, and the local community's plans;
- Whether the roadway section is identified as a recommended bicycle route in this plan and/or the local community plan;

- Whether the project is within or close to an urban area;
- The location of existing or planned schools, parks, bicycle paths/trails, employment centers, commercial areas, or other likely bicyclist destinations near the project location or corridor;
- The need for access to destinations along the project corridor and/or connectivity of the bicycle facility network;
- Existing and potential bicycle use; and
- Any available information on bicycle crash history.

Definitions

ADT – Average Daily Traffic. The measurement of the average number of vehicles passing a certain point each day on a roadway or path.

ARTERIAL ROAD – Divided or undivided, relatively continuous routes designed to serve primarily through traffic, high traffic volumes, and long average trip lengths.

BICYCLE FACILITY – A general term denoting improvements and provisions made by public agencies to safely accommodate or encourage bicycling, including shared-use paths, bicycle lanes, paved shoulders, signed bicycle routes, and shared roadways not specifically designated for bicycle use. Also includes bicycle parking and storage facilities and lockers and showers at employment sites.

BICYCLE LANE – A portion of roadway (typically 4 to 5 feet), which has been designated by signing and pavement markings for the preferential or exclusive use by bicyclists.

COLLECTOR STREET – A street designed to carry traffic between local streets and arterial roadways, or from local street to local street.

GRADE – A measure of the steepness of a roadway, shared-use path, or sidewalk, expressed as a ratio of vertical rise per horizontal distance, usually in a percentage. For example, a 5% grade equals five feet of rise over a 100-foot horizontal distance.

GRADE SEPARATION – The vertical separation of conflicting travelways with a structure. An overpass and tunnel or underpass are examples of common grade separations used to avoid conflicts.

LOCAL STREET – A street designed to primarily provide access to and from residences and businesses, generally with low traffic speeds and volumes.

MUTCD – The "Manual on Uniform Traffic Control Devices," approved by the Federal Highway Administration as a national standard for placement and selection of all traffic control devices on or adjacent to all highways open to public travel.

PAVEMENT MARKINGS – Painted or applied lines or legends placed on a roadway or shared-use path surface for regulating, warning, or guiding traffic.

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

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

SHARED ROADWAY – A roadway that does not have designated bicycle lanes and has not been designated as a preferred route for bicycle use, but which is open to both bicycle and motor vehicle travel. This may be a local roadway with narrow or standard travel lanes, a roadway with wide curb lanes, or a roadway with paved shoulders.

SHARED-USE PATH – A path or way, often paved, which is physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent alignment. In addition to bicyclists, pedestrians, in-line skaters, wheelchair users, and joggers will use such paths.

SHOULDER – That portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and for lateral support of subbase, base, and surface courses. Frequently, part of the shoulder is paved.

SIGNED SHARED ROADWAY (SIGNED BIKE ROUTE) – A shared roadway which has been designated by signing as a preferred route for bicycle use.

TRAVELED WAY – The portion of the roadway for the movement of vehicles, exclusive of shoulders.

WIDE CURB (OUTSIDE) LANE – A wider than normal curbside travel lane (14 to 16 feet) that is provided for ease of bicycle operation. The preferred treatment for bicyclists now is a bicycle lane, however the treatment is recommended where there is insufficient room for a bike lane or paved shoulder.

B. The Design Bicyclist

Bicycles and bicyclists come in a variety of shapes and sizes. To effectively design bicycle facilities, the range of dimensions and characteristics of common commercially available bicycles and the physical details of the typical bicyclist (e.g., dimensions, speed) should be understood. Bicyclists generally require 3.3 feet of operating space based solely on their profile. Due to steering wobble, bicyclists typically track over a 4-foot width. The necessary width is increased to 5 feet or greater for steep hill climbs and descents.

The narrow width of bicycle tires and the lack of shock absorbers or suspensions on most bicycles make bicyclists much more sensitive to roadway surfaces than other road users. Most bicycles also require longer stopping distances at high speeds than autos. Emergency maneuvers on bicycles cannot be accomplished quickly because it takes time to set up for a quick turn.

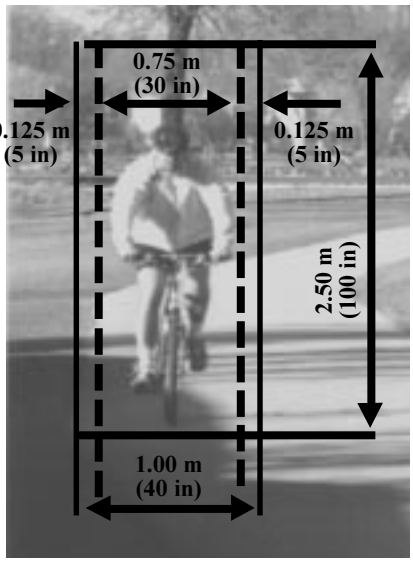

Figure A-1 Bicyclist Operating Space
Source: AASHTO Guidelines (1999)

C. Types of Bicycle Facilities

The appropriate bicycle facility for any given roadway depends on the roadway's classification, pavement and right-of-way width, motor vehicle speeds and volumes, adjacent land use and expected growth patterns, and other factors. On-street facilities generally consist of either bicycle lanes/paved shoulders or shared roadways (with or without wide outside travel lanes). Off-street facilities consist of shared-use paths and pedestrian/bicycle over- or underpasses. Shared-use paths are best used to supplement the on-street bikeway network by locating them in corridors not served by roadways and/or along utility, rail, or other linear corridors.

The travel volumes and choice of design of a roadway will affect the level of use by bicyclists and the level of mobility and accessibility the roadway affords bicyclists. For example, a high-speed, high-volume, four-lane divided highway will attract only more experienced bicyclists even with 4- to 6-foot wide paved shoulders. Bicycle facilities are still generally needed on major roadways in order to provide access to destinations in the corridor and to get across barriers, such as access-restricted freeways. No one type of bicycle facility will serve all bicyclists. Within any given travel corridor, it will often be desirable to provide more than one option to meet the through travel and access needs of all potential users.

Shared Roadways

Local streets with low traffic volumes and speeds safely accommodate bicyclists (except young children) without any special bicycle treatments. Shared roadways with narrow or standard 11- to 12-foot travel lanes are generally adequate for bicyclists on streets with speed limits of 25 mph and average daily traffic (ADT) volumes of 3,000 or less. In rural areas, the suitability of a shared roadway decreases as traffic volume reaches 750-1,000 ADT due to the higher traffic speeds and greater percentage of truck traffic on them. A large percentage of bicycling takes place on shared roadways with no dedicated space for bicyclists. Shared roadways that carry more traffic at higher speeds than they were designed for can be made more suitable for bicycling through "traffic calming" techniques. (See discussion of traffic calming on page A-22)

Residential streets with low traffic volumes do not need special facilities for bicyclists.

Paved shoulders are not necessary on rural town roads with low traffic volumes.

Wide Curb Lanes

On collector and arterial streets with higher traffic volumes and speeds that do not have bicycle lanes, outside travel lanes wider than the standard 11-12 feet are a desirable alternative. Wide curb lanes benefit bicyclists and motorists by providing additional operating space compared to a standard travel lane. In many cases, this will allow a motorist to pass a bicyclist without the need to change lanes. However, because they provide less operating space than bike lanes and are not designated for bicycle use, many bicyclists do not feel comfortable using them. They are therefore a least preferred option for use when adequate space isn't available for bike lanes.

To accommodate bicyclists, a wide outside (curb) travel lane should provide a usable width of 14-15 feet. Usable width would normally be from the edge of the pavement (gutter pan seam), absent surface irregularities or other hazards in the street. Where on-street parking is provided, an outside lane width of 16 feet (excluding the parking lane) is needed to accommodate bicyclists. In such cases, a bike/parking lane should be striped, if the adequate space is available. Provision of a 15- to 16-foot outside lane allows future striping of a bike lane, even if it is decided not to stripe the lane right away.

Wide outside travel lanes provide extra space for bicyclists on streets without bicycle lanes.

Re-striping to provide wide curb lanes (by making the remaining travel lanes and left turn lanes narrower) may be possible and should be considered on existing multi-lane facilities, where physical limitations prevent widening the road or reconstruction is not planned for a long time. This should be done only after careful review of the traffic characteristics of the roadway.

Right Turn Lanes

At intersections with right turn lanes, the extra width for bicycle use should be added to the rightmost through lane. If the right-turn-only lane is a high-speed merging lane (a practice generally not recommended in urban areas), providing extra width in that lane is desirable as well. A bicycle lane at the intersection, striped to the left of the right turn lane, is preferred. (See Bicycle Lane Treatments at Intersections)

Wide Streets with Low Parking Occupancy

Residential and local collector streets in newer neighborhoods have often been built to a width of 40 to 54 feet. A width of 44 feet is common, providing space for two extra wide 14-foot travel lanes as well as parking on both sides of the street, even though the parking space is rarely used due to off-street parking requirements. These wide streets encourage speeding. As traffic volumes increase, they also

Removing parking from one side and striping bicycle lanes should be considered for wide streets with low parking occupancy.

encourage the operation of two motor vehicles in one lane, resulting in the "squeezing" of bicyclists off the road.

Communities should carefully consider whether there is a need for parking on both sides of new streets. Where off-street parking requirements, proposed land uses, and other factors reduce the need for street parking, narrower streets should be allowed with parking on only one side and either wide curb lanes or bicycle lanes.. Elimination of parking from one side of the street and striping of bike lanes should be considered for existing streets that are wider then necessary, particularly where speeding is a problem.

Signed Shared Roadway

Signed shared roadways are designated by bike route signs. The AASHTO Guide cites the following reasons for designating bike routes:

- The route provides continuity to other bicycle facilities, generally bike lanes or shared-use paths;

Signed bike routes can be helpful for way finding and to indicate a preferred route through a corridor.

- The street is a preferred or recommended route through a major travel corridor;
- The route is preferred for bicycling in a rural area due to low traffic volumes and/or paved shoulder availability; and/or
- The route extends along local or collector streets that lead to neighborhood destinations, such as schools and parks.

It is desirable to include with bike route signs supplemental plaques that include direction, destination, and distance information, regardless of the type of roadway or facility they are used on.

Agencies must make sure that potential safety hazards have been removed prior to signing a bike route. Bike route signs should not end at a barrier. Information directing the bicyclist around the barrier should be provided. A commitment should also be made to maintain designated bike routes to a higher standard than that of other comparable streets (e.g., more frequent street sweeping).

Further guidance on signing bike routes is provided in the MUTCD.

Bicycle Boulevard

The bicycle boulevard involves modifying a local shared roadway to function as a through street for bicycles. Local access for motor vehicles is maintained, but not necessarily through motor vehicle traffic. Traffic calming devices are used to reduce traffic speeds and through auto trips. Traffic controls limit conflicts between automobiles and bicycles and give priority to through bicycle movement.

Bicycle boulevards work best on a street grid system with continuous connector streets parallel to major arterial roadways. The elements for creation of a bicycle boulevard are illustrated in Figure A-2.

Bicycle boulevards offer a number of advantages, including providing improved conditions for pedestrians and an attractive alternative for bicyclists that are not comfortable on higher volume arterial roadways. However, as with traffic calming devices in general, they require careful planning with residents to avoid traffic diversion onto other local streets and other undesirable impacts.

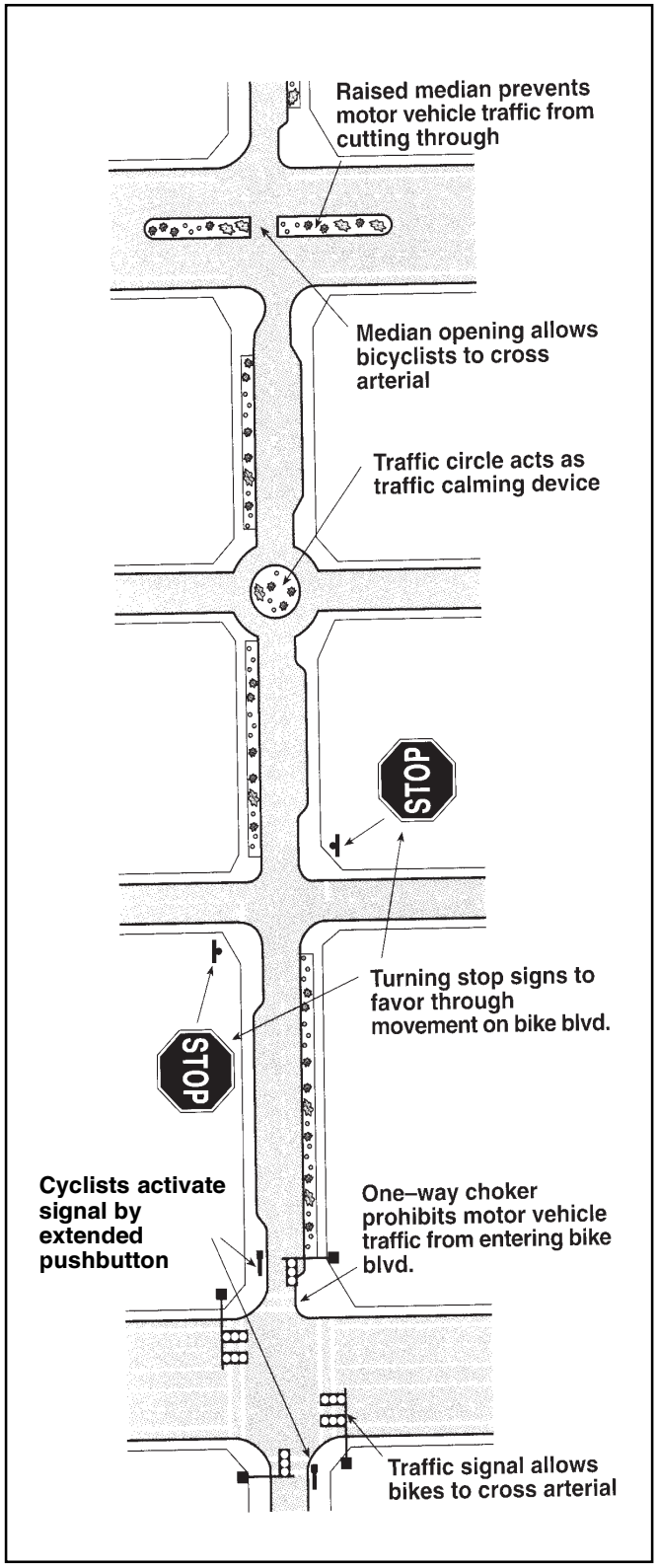

Figure A-2 ***Elements of a bike boulevard, with street crossings***
Source: ***Oregon Bicycle and Pedestrian Plan (1995)***

Bicycle Lanes

A bicycle lane is a portion of the roadway designated for the exclusive or preferential use by bicyclists, with pavement markings and signing. Bicycle lanes are the preferred bicycle facility on higher volume urban roadways where available right-of-way permits them.

Bike lanes define a space for bicyclists to ride, and create a buffer for pedestrians.

Among the benefits of bicycle lanes are:

- Defining a space for bicyclists to ride, helping less experienced bicyclists feel more confident and willing to ride on busier streets;
- Reducing motorist lane changing when passing bicyclists;
- Guiding bicyclists through intersections on the safest, most predictable course;
- Increasing the visibility of bicyclists in the transportation system.

Secondary benefits of bicycle lanes include:

- Reducing pedestrian/bicyclist conflicts due to fewer bicyclists using the sidewalk;
- Creating a buffer between the pedestrian and motorist (on streets without parking);
- Improving sight distances;
- Increasing effective turn radii at driveways and intersections; and
- Providing temporary space for disabled motor vehicles.

Location within Street Cross-Section and Width

Bicycle lanes should always be one-way facilities carrying traffic in the same direction as adjacent motor vehicle traffic. On one-way streets, a one-way bicycle lane should generally be located on the right side of the road, absent special circumstances (e.g., greater numbers of potential conflicts on the right side).

Bicycle lanes should be a minimum of 4 feet wide, measured from the inside edge of the bike lane stripe to the joint between the pavement and the gutter pan. Additional space should be provided if obstructions (e.g., storm sewer drains) reduce the usable bike lane width. The AASHTO Guide permits a 3-foot wide bike lane where there is a 2-foot gutter pan. However, this is *not* recommended since bicyclists are unable to use the gutter plan space and typically must ride away from the joint between the pavement and gutter pan. On streets with speed limits in excess of 35 miles per hour, high traffic volumes, and/or significant numbers of trucks and buses, a bike lane width of 5 to 6 feet is recommended. Motor vehicle travel lanes adjacent to bicycle lanes should be at least 11 feet wide.

A design that has been experimented with in the Madison area, but which is not preferred, is the use of 4- to 5-foot wide gutter pans for bicycle lanes. See photo. This design has a number of disadvantages. The joint between the street and gutter pan is often uneven and/or deteriorates over time. Using the gutter pan as the bike lane requires bicyclists to cross this joint in order to merge into traffic to get into proper position for a left-turn or straight through movement. The gutter pan also typically has a 4% versus 2% slope, creating a problem for bicyclists, especially in the winter. In the case of concrete streets, an integral curb design functions well if the longitudinal joint is placed on the inside edge of the right most travel lane and the 4% (vs. 2%) slope is reserved for a one-foot area closest to the curb. The bicycle lane should be striped 5 feet off the curb.

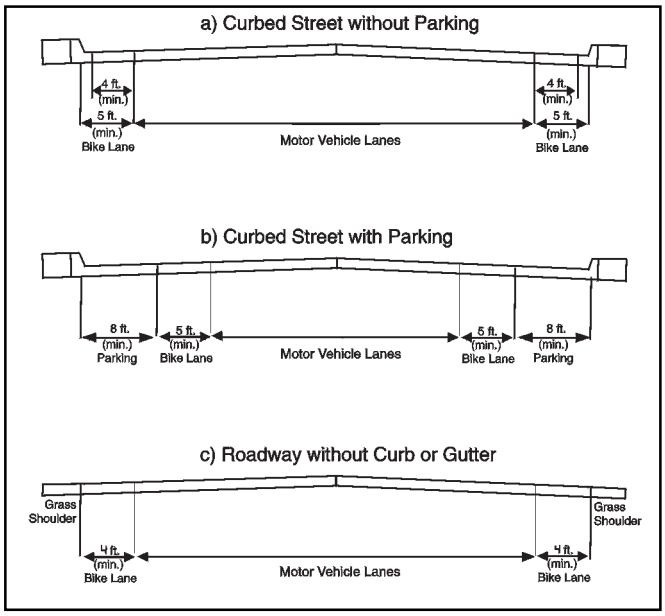

Figure A-3 Bicycle Lane Width Guidelines

Source: Florida Bicycle Facilities Planning & Design Handbook (2000)

Bicycle lanes should *not* be separated from motor-vehicle travel lanes by a parking lane, curbing, or other barriers. Such barriers prevent motorists and bicyclists from executing proper merging maneuvers in advance of intersections, and limit the ability of bicyclists to take evasive action at driveways. They also create significant operational problems relating to street maintenance, snow removal, and utility maintenance and construction.

Use of 5-foot gutter pans for bicycle lanes is generally not recommended.

Signing and Marking of Bike Lanes

Designated bike lanes should be marked and signed. The bike lane should be separated from the travel lane by a solid white line. The stripe should be placed so as not to encroach into the necessary 4- to 5-foot bike lane space. Striping material used should be durable, but skid-resistant. Temporarily substandard bike lanes (e.g., only 3 feet wide) may be left undesignated. In addition, a short or discontinuous bike lane may also be better left unmarked.

Pavement markings are used within the lane to designate the bike lane. Among the currently proposed changes to the MUTCD is a new standard pavement marking for bike lanes. The new standard marking is the bicycle symbol or

the words "Bike Lane" and a directional arrow. The diamond symbol, which is used to indicate a restricted use lane, will no longer be used for this purpose. Rather, the diamond symbol is reserved for preferential or restricted lanes, such as bus lanes, in the new MUTCD.

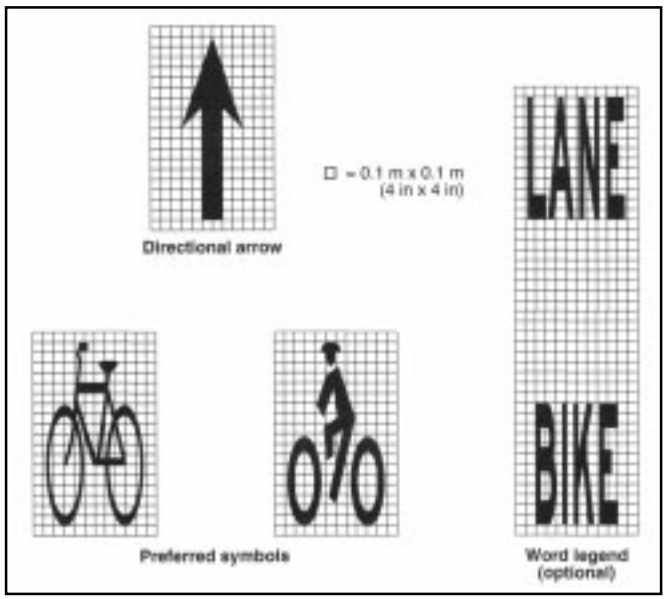

Figure A-4 Bicycle pavement markings
Source: AASHTO Guidelines (1999)

Lane markings should be appropriately spaced (e.g., around every 600 feet for urban sections and ¼ mile for rural sections) and placed after every major intersection. Lane markings should also be placed in the short sections of bike lanes used at intersections, most commonly to the left of the right-turn only lane. (See "Bike Lane Treatments at Intersections" on the following page). Care should be taken to avoid placing markings in an area where motor vehicles are expected to cross a bike lane (e.g., commercial driveways and immediately after an intersection).

Bike lane signs should be used in advance of the beginning of a designated bike lane to call attention to it and the possible presence of bicyclists. Where a bike lane is ending, the same sign may be used with the word "Ends" substituting for the word "Ahead." Chapter 9B and C of the MUTCD address bicycle facility signs and markings, respectively.

Bicycle/Parking and Bus/Bicycle Lanes

Bicycle lanes may be put on an urban street where a parking lane is provided. In such cases, a width of 5 feet is needed for the bicycle lane, especially where there is substantial parking and turnover. The minimum combined bike lane/parking lane width is 13 feet. The bike lane should always be placed between the parking and outside motor vehicle traffic lane. Appropriate tapers should be used when transitioning to and from parking.

Combined bus/bicycle lanes can be used and should generally be 16-feet wide. Right-turns are also generally allowed from such bus/bicycle lanes. This tends to create problems with motorists remaining in the lanes between intersections. Simply increasing the width of the bus lane for bicyclists doesn't address this problem. Therefore, delineating a separate 4-foot bicycle lane and 12-foot bus lane is preferable, particularly on busy, higher speed arterial roadways.

Bicycle/parking lane.

Contra-Flow Bike Lanes

Contra-flow bike lanes (those in an opposing direction from the normal traffic flow) are generally not recommended, and should never be placed on a two-way street. However, they may sometimes be appropriate in the following circumstances:

- A substantial saving in out-of-direction travel is provided.
- Direct access to high-use destinations is provided.
- There are few intersecting streets, alleys, or driveways on the side of the contra-flow lane.
- Bicyclists can safely and conveniently enter and leave the contra-flow lane.

In addition to arterial roadways, a contra-flow bike lane may also be appropriate on local access or residential streets where a street has been made one-way to calm traffic or otherwise restrict motor vehicle access.

Contra-flow bicycle lane on Babcock Dr. provides access to UW campus.

The following important design features should be incorporated:

- Placement of the contra-flow bike lane on the right side of the street (to motorists' left), separated by a barrier or double yellow line.
- Posting of signs at intersecting streets and major driveways indicating to motorists that they should expect two-way bicycle traffic.
- Installation of appropriate traffic signs and signals for the contra flow bicycle traffic.
- Proper marking of the bike lanes, including a directional arrow.

Because of the potential serious safety problems associated with contra-flow bike lanes, they should only be used in rare circumstances, and should be carefully evaluated following installation.

Bicycle Lane Treatments at Intersections

Bicycle lanes and their position are a very important consideration in intersection design. A high percentage of bicycle-motor vehicle crashes occur at intersections. By their very nature, intersections put one group of travelers in the path of others. As with other roadway design features, bicyclists should be treated as vehicle drivers, except in rare cases. The striping of bicycle lanes at intersections should encourage bicyclists to properly position themselves, which is generally to the right side of the rightmost lane for their direction of travel.[1]

Intersections with Driveways

At high volume commercial driveways, the solid bike lane stripe may be replaced with a 2- to 4-foot long dashed or skip line to warn bicyclists of frequent motor vehicle turning movements across the bike lane.

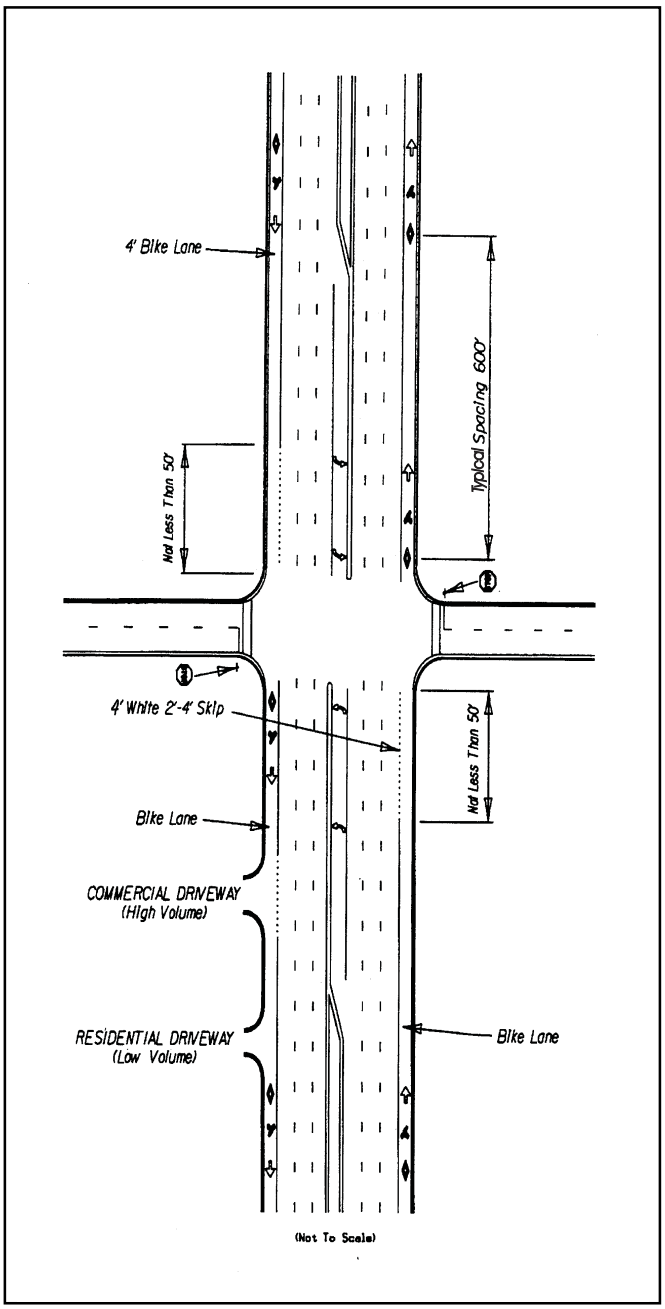

Figure A-5 ***Bicycle lane striping should be replaced with a dashed line at major intersections. Dashed lines may also be used at high volume driveways, as illustrated.***

Source: ***Florida Bicycle Facilities Planning and Design Handbook (2000)***

[1] Bicyclists should center themselves in the travel lane where there is insufficient space for the bicyclist and motorist to share the travel lane in order to discourage motorists from passing them unsafely.

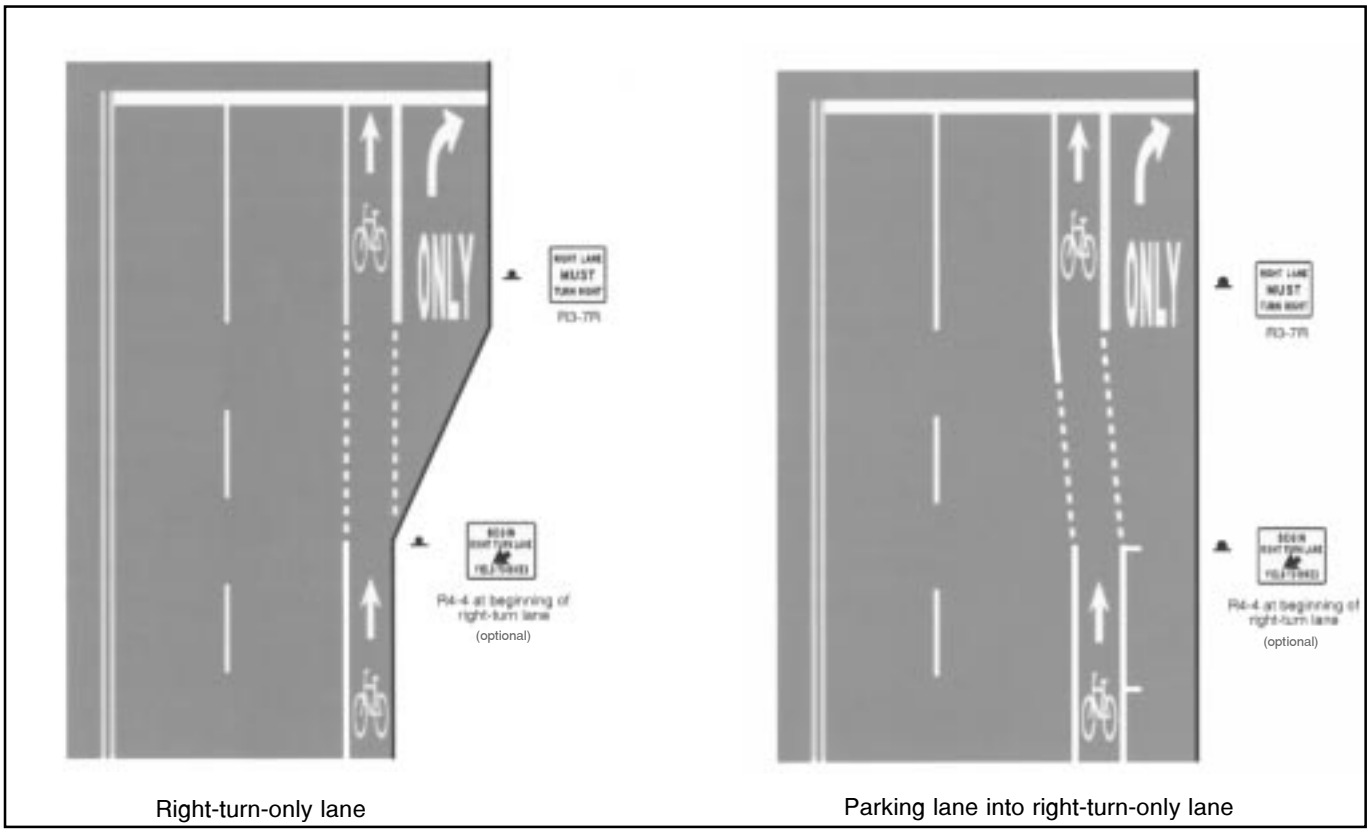

Figure A-6 Markings for Right turn bike lanes
Based on AASHTO Guidelines (1999)

Intersections without Right-Turn Lanes

At signalized or stop-controlled intersections on streets with bicycle lanes, but no exclusive right-turn lanes, the solid bike line stripe should generally be replaced with a dashed or skip line at least 50 feet prior to the intersection, as illustrated in Figure A-5. The dashed line delineates the bicycle lane for through bicyclists, and encourages right turning motorists to merge into the bicycle lane so that they can properly make their turn from the right side of the roadway.

At non-signalized minor intersections with no stop controls, the bike lane may be continued to the crosswalk on the near side of the intersection. However, if there is a bus stop or high volume of right turning vehicles, the solid bike lane stripe should be replaced with a dashed line at least 50 feet prior to the intersection (including the entire length of the bus stop).

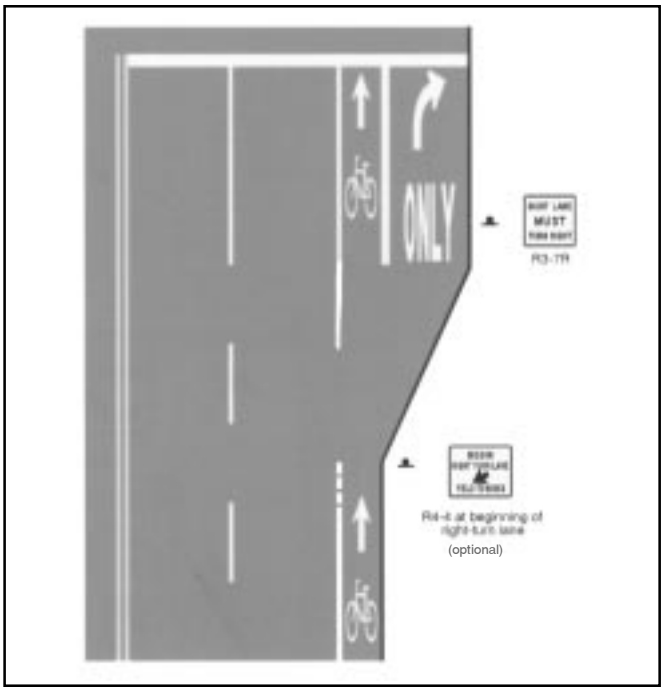

Figure A-7 Right-turn-only lane (without dashed lines)
Based on AASHTO Guidelines (1999)

Intersections with Right-Turn Lanes

Right-turn lanes present special problems for bicyclists because right-turning cars and through bicyclists must cross paths. Merging and lane changes should occur in advance of the intersection. The intersection design should channelize through bicycle traffic to the left of the right-turn lane.

It is recommended that the bicycle lane stripe be dashed at least 50 feet before the intersection to allow and encourage motor vehicle and bicycle traffic to cross paths prior to the intersection. (See Figure A-6) Another less desirable option is to simply drop the bicycle lane markings. (See Figure A-7) In either case, it is recommend that the striped bicycle lane be resumed at the intersection between the regular through lane and the right-turn lane.[2] The bike lane at the intersection should be marked. Although not required by the MUTCD, it is also recommended that a "Begin Right Turn Lane, Yield to Bikes" sign be placed at the beginning of the right-turn lane. (See Figures A-6 and A-7)

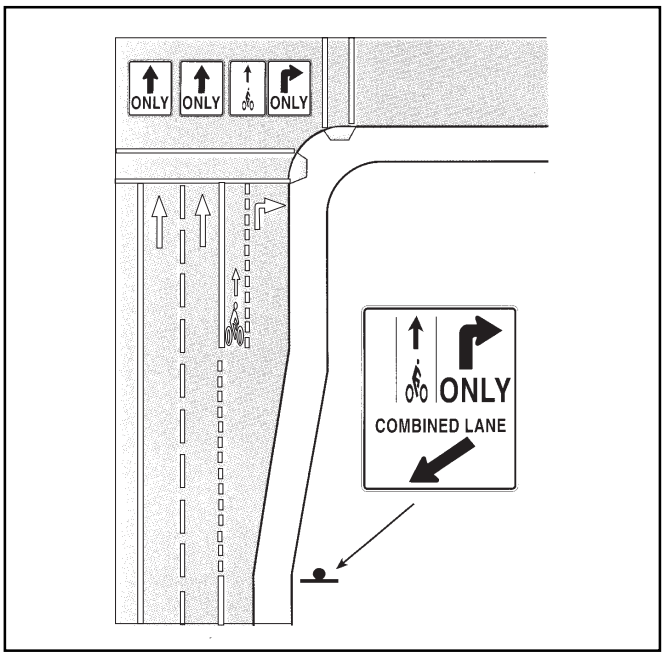

Figure A-9 ***Shared use of a right-turn lane for through bicyclists where there is insufficient room for separate bike lane***

Source: ***Oregon Bicycle and Pedestrian Plan (1995)***

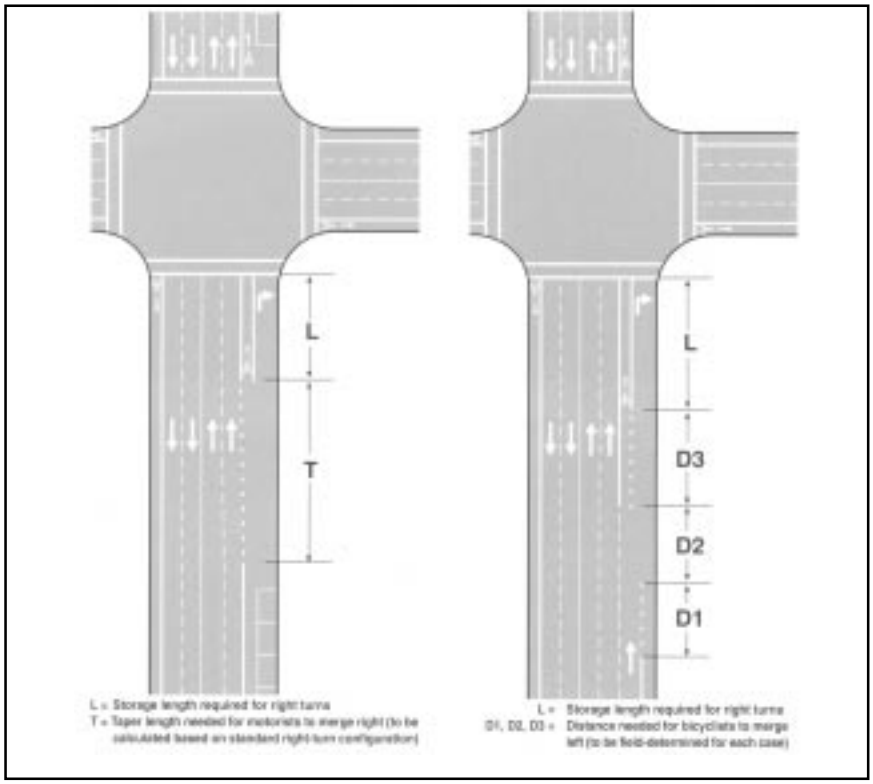

Figure A-8 ***Bike lane left of right-turn lane developed by dropping parking or a travel lane***

Source: ***Oregon Bicycle and Pedestrian Plan (1995)***

It is not always possible to widen intersections to provide a right-turn lane. In these situations, parking or a travel lane is typically dropped to create a right-turn lane. A bike lane to the left of right-turning cars should still be provided, if possible. (See Figure A-8)

On bike lane retrofit projects where there is insufficient space to mark a 4-foot bike lane to the left of the right-turn lane, a right-turn lane could be marked and signed as a shared-use lane. (See Figure A-9) This encourages through-bicyclists to occupy the left portion of the turn lane and alerts motorist to their possible presence and intentions. The design has been successfully used in Oregon, but is not included in the AASHTO Guidelines or MUTCD. It is best used on slow-speed streets.

[2] An exception to this is where the major traffic movement at the intersection is to the right (e.g., a highway is routed over local streets) and the straight through move leads to a minor street. In this case, the bike lane may be placed on the right and wrapped around the curve. This assumes the majority of bicyclists will want to turn right too.

Intersections with Dual Right-Turn Lanes

In some cases, intersections include a right-turn lane and a shared through/right-turn lane. This configuration is particularly difficult for bicyclists, because they must either merge into a lane where drivers could be either going straight or turning, or merge across two lanes. Some drivers make a last minute decision to turn right from the shared through/right-turn lane, catching bicyclists unaware. This configuration should only be used where found to be necessary based on a traffic study. Figure A-10 presents two alternative designs for such intersections. Use of the dashed line in example A is helpful in guiding the bicyclist along the proper path. Engineering judgment should be used to determine the most appropriate design for the situation. A curb cut with access to the sidewalk could be provided prior to the intersection for those bicyclists that prefer to proceed as a pedestrian.

Intersections with Predominant Left-Turn Movement

Providing a left-turn lane for exclusive use by bicyclists is useful where there are large numbers of left-turning bicyclists to ensure they properly position themselves. See the photograph above.

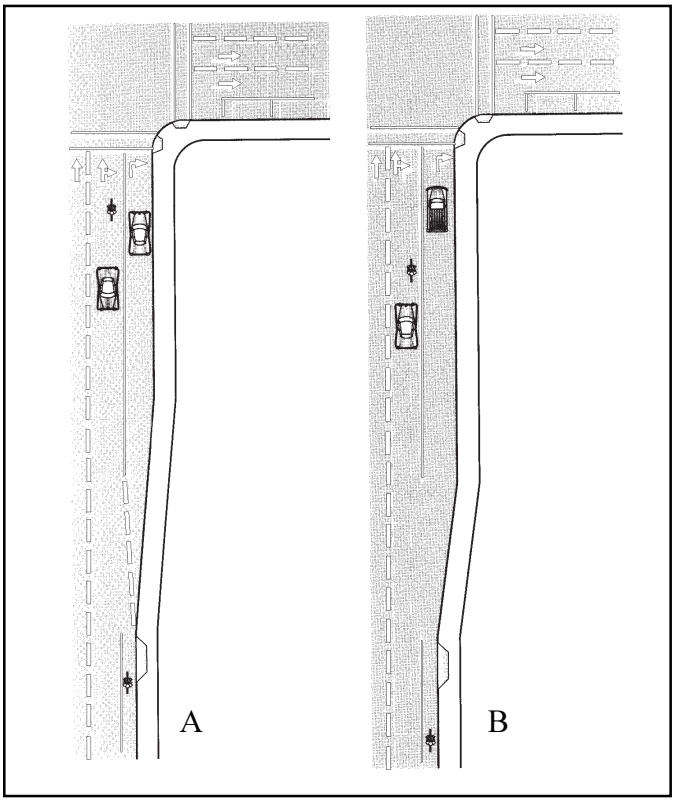

Figure A-10 ***Alternative bike lane treatments at intersections with dual right turn lanes***

Source: ***Oregon Bicycle and Pedestrian Plan (1995)***

Left turn for bicyclists is provided at Park St. and University Avenue.

Offset Intersections

At intersections with offset travel lanes, dashed offset motor vehicle and bike lane markings may be continued through the intersection to direct traffic flow (see MUTCD Section 3B-7). This helps ensure that motorists do not inadvertently drive in the bike lane because of the offset travel lanes.

Tee Intersections

At Tee intersections where the traffic is fairly evenly split between left- and right-turning vehicles, the bike lane should be dropped (again maintaining a wide curb lane) prior to the intersection to allow bicyclists to properly position themselves to the right or left. Where traffic volumes are high and sufficient space is available, both a left- and a right-turn bike lane should be considered. (See Figure A-11)

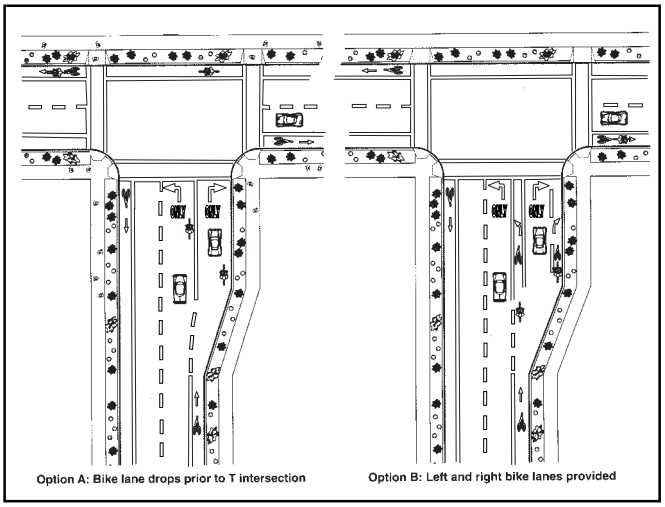

Figure A-11 ***Bike lanes at Tee intersections***

Source: ***Oregon Bicycle and Pedestrian Plan (1995)***

Freeway/Expressway Interchange Areas

Interchanges with free-flowing motor vehicle traffic movements are the most difficult for bicyclists to negotiate, and present barriers to bicycle circulation. Bicyclists must perform merging, weaving, or crossing maneuvers with motor vehicles, which are traveling at higher speeds.

Urban style interchanges with access ramps connected to local streets at a right angle are the easiest for bicyclists to negotiate. The distance needed to cross at the ramps is minimized, traffic is stopped at signalized or controlled intersections, and visibility is enhanced. See photo below.

Hwy 51 Interchange design on Milwaukee Street allows bicyclists to proceed straight through in bike lane.

Interchanges with free-flowing entrance and exit ramps on the cross street should generally be avoided in urban areas. The City of Portland, Oregon has been experimenting with the use of blue-colored pavement markings in addition to dashed lines to delineate the conflict area at exit and entrance ramps as well as intersections with right-turn lanes. For illustrations of designs and other information on this experimental program, see "Portland's Blue Bike Lanes," City of Portland Office of Transportation (July 1, 1999), available on the department's Web site at www.trans.ci.portland.or.us.

Retrofitting Streets with Bike Lanes

Many major roadways in urban areas were built without bike lanes. These roadways often serve as deterrents to bicycle travel. Physically widening the roadway to add bike lanes is not always possible or desirable (e.g., if it reduces sidewalk space) within existing developed areas. Retrofitting bike lanes onto existing urban streets with little or no

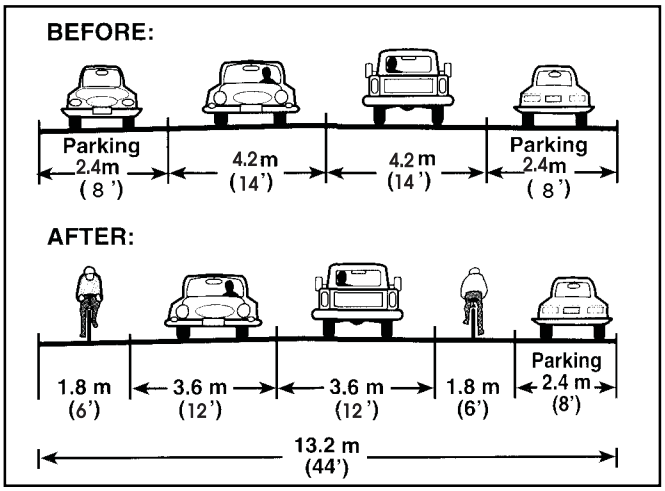

Figure A-12 Bicycle lanes can be striped on existing streets if parking is removed on one side.

widening of the street is sometimes possible using one or more of the following methods:

1. Restriping to reduce the widths of the other travel, turn, and/or parking lanes.
2. Removing parking on one side of the roadway, as illustrated in Figure A-12.
3. Reducing the number of travel lanes from 4 to 2 with a center turn lane, as illustrated in Figure A-14.
4. Reducing the width of the gutter pans, typically from 2 to 1 feet, as part of street re-construction.

On streets with posted speeds of 40 mph or less, travel lane widths can be reduced to 10-11 feet.[3] Parking lanes may be reduced to 7 feet. Parking may only be needed on one side of the street and doesn't necessarily need to be on the same side of the street through an entire corridor. It may be possible to work out alternative parking arrangements (e.g., use of adjacent lots during special events) or replace some of the lost parking, as shown in Figure A-13.

Reducing the number of motor vehicle travel lanes is another potential solution for retrofitting streets with bike lanes. The most common roadway conversion is the restriping of two-way streets with four travel lanes to two travel lanes, a two-way center turn lane, and bike lanes, as illustrated in Figure A-14. While controversial, these types of roadway conversions have been implemented with success in a number of communities throughout the U.S. and Canada on roadways with 10,000 to 25,000 ADT. Experience with these conversions has shown that on roadways

[3] FHWA approval is needed for use of 10- foot travel lanes if the project is federally funded.

with significant turning movements, the 3-lane design provides a more uniform traffic flow, and reduces speeding, conflicts, and crashes. Much of the traffic capacity of the road can be maintained by providing turn lanes at intersections.[4]

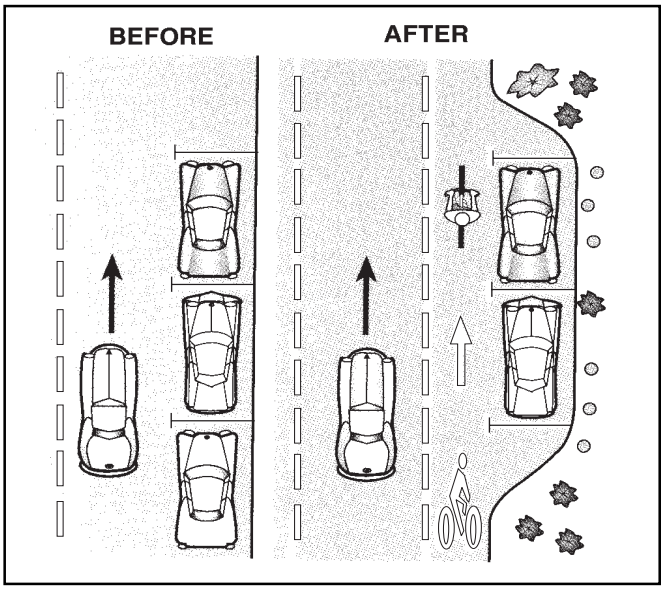

Figure A-13 Maintaining parking when there are no reasonable alternatives
Source: Oregon Bicycle and Pedestrian Plan (1995)

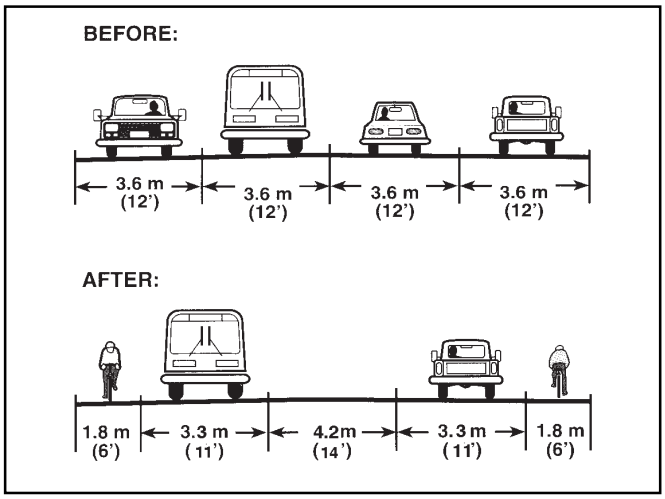

Figure A-14 Travel lanes reduced from 4 to 2, with center turn lane
Source: Oregon Bicycle and Pedestrian Plan (1995)

Paved Shoulders on Rural Roadways

A shoulder is the portion of a roadway contiguous to the travel lane on rural roadways without curbs and gutters. Paved shoulders are provided for a variety of safety, operational, and maintenance reasons. These include the following:

- Provision of space for motorists to stop out of traffic in case of an emergency.
- Provision of space to make evasive maneuvers to escape potential crashes.
- Provision of a recovery area to regain control of a vehicle.
- Improvement of highway capacity (e.g., by providing space for turning traffic).
- Provision of space for maintenance operations, such as snow removal.
- Provision of structural support to the pavement, reducing maintenance costs.

Adding or widening paved shoulders on rural roadways with few intersections is also a cost-effective way to accommodate bicyclists. Bicyclists are permitted to use shoulders under state law.

Width Standards

Paved shoulders should be at least 4 feet wide to accommodate bicyclists. However, where this width cannot be achieved, any additional paved shoulder width is helpful, especially if there is no joint between the travel lane and shoulder. A paved shoulder width of 5 feet is recommended from the face of guardrail, curb, or other roadside barriers. A pavement edge line should be striped separating the travel lane from the paved shoulder.

Paved shoulder on rural roadway.

[4] For more information, see Dan Burden and Peter Lagaerwey, "Road Diets: Fixing the Big Roads," Walkable Communities, Inc. (March 1999).

It is desirable to increase the width of paved shoulders to 5-6 feet on roadways with high traffic volumes (e.g., over 5,000 ADT) and/or a high percentage of trucks, buses, and recreational vehicles (e.g., over 5%). A wider paved shoulder is also desirable on steep grades, as bicyclists need more room for maneuvering. Other factors that should be considered in determining the desired shoulder width are the average travel speed (whether above 50 mph), roadway location (e.g., whether within 1-3 miles of an urban area), adjacent land use, and current and projected use by bicyclists.

Due to the buildup of debris and the trapped condition a bicyclist faces, paved shoulders on bridges are especially important. Bridge shoulder width should, at a minimum, match the approaching roadway shoulder width. Bridges exceeding a 3% grade benefit from wider shoulder widths.

It is best to add or widen paved shoulders in conjunction with pavement overlays in order to ensure a smooth, seamless joint, reduce costs, and minimize traffic disruptions. When paved shoulders are provided as part of new road construction, the pavement structural design should be the same as that of the roadway. If paved shoulders need to be added on a roadway that isn't scheduled for an overlay project in the near future, it should be done with use of a saw cut joint, pavement grinder, or asphalt feathering. (For more information, see Design Standards for Shoulder Bikeways in the *1995 Oregon Bicycle and Pedestrian Plan*)

Wherever a roadway is constructed or widened, paving of gravel driveways and intersecting streets should be considered for a sufficient distance to prevent loose gravel from spilling onto the shoulders.

Shared-Use Paths

A shared-use path is a bicycle facility that is physically separated from motor vehicle traffic by distance or a barrier. Shared-use paths are sometimes referred to as "trails," however this term is best used to refer to unimproved, recreational facilities for mountain bicycling. Shared-use paths are almost always two-way facilities, often paved, and are typically used by pedestrians, runners, and in-line skaters, as well as bicyclists.

Capital City Trail through the Nine Springs E-way.

Shared-use paths can be advantageous in a number of circumstances, such as the following:

- To serve areas not well served by the roadway system (e.g., only served by limited access highways or with few intersecting roadways).
- To create short cuts through a residential neighborhood or urban park and/or link urban or suburban destination and origin points.
- To make use of continuous greenbelts such as rivers, shorelines, drainages, and rail corridors. Those may serve both as elements of regional or community transportation and recreational trail plans (e.g., when located in a park).

Shared-use paths should be thought of as extensions of the highway system that are intended for the exclusive or preferential use of bicyclists and pedestrians similar to the way freeways are intended for the exclusive or preferential use of motorists. Shared-use paths should *not* be used to preclude on-street bicycle facilities, but rather to complement the on-street bicycle facility network.

Shared-use paths should generally *not* be placed directly adjacent to roadways, because this creates a number of safety problems. For example, unless paired, bicycle paths require one direction of bicycle traffic to ride against motor vehicle traffic, contrary to the rules of the road. At intersections and driveways, motorists entering or crossing the roadway often do not notice bicyclists coming from their right, as they are not expecting vehicles coming from that direction. Even bicyclists coming from the left often go unnoticed, because motorists' attention is directed at crossing motor vehicle traffic on the street at the intersection. Also,

Shared use path skirting the convention center.

bicyclists tend to travel on the wrong side of the road against traffic when approaching or leaving the path.

Shared-use paths may be considered along roadway corridors under the following conditions:

- The path will generally be separated from motor vehicle traffic.
- There is a desire to provide path continuity throughout the corridor.
- There are few at-grade intersections or driveways.
- The path connects at each end onto streets with good bicycle and pedestrian facilities, or onto another safe, well-designed path.
- There is adequate access to local cross-streets and other facilities along the route.
- Any needed grade separation structures do not add substantial out-of-direction travel, and are comfortable to users.

Shared-use paths are used by others besides bicyclists.

- Bicycle and pedestrian use is expected to be high.
- The total cost of providing the path is proportionate to the need.

Width and Clearance: The minimum recommended width for a two-way shared-use path is 10 feet.[4] A width of 12 feet, or even 14 feet, is desirable in areas with heavy use by bicyclists, pedestrians, runners, and in-line skaters. One-way paths are discouraged, because they are often used as two-way facilities. If necessary, one-way paths should be at least 6 feet wide and designed and signed appropriately.

A minimum two-foot wide graded area on each side of an off-street path is necessary for safe operation. A distance of 4 feet or more is generally desirable to provide clearance from trees, fences, and other obstructions. A distance of 6 feet or more is desirable from any steep embankments (3:1 slope or greater); otherwise a safety railing should be installed. The recommended clearance to overhead obstructions is 10 feet, with a minimum of 8 feet. For paths adjacent to a roadway, a minimum separation of 5 feet is recommended between the path and the edge of the roadway. Otherwise, a physical barrier of sufficient height (4 ½ feet) should be installed. Signage along paths should be 4-7 feet high.

Design Speed, Radii, and Grades: Shared-use paths should generally be designed for the preferred speed of the faster bicyclists. The AASHTO Guide recommends a design speed of 20 miles per hour (30 mph when the downgrade exceeds 4 percent). However, paths should not be designed to encourage speed. Paths are used by bicyclists with vastly different skill levels as well as pedestrians, in-line skaters, and others. Paths designed to encourage higher speeds may

[4]In some instances, a reduced width of 8 feet can be adequate.

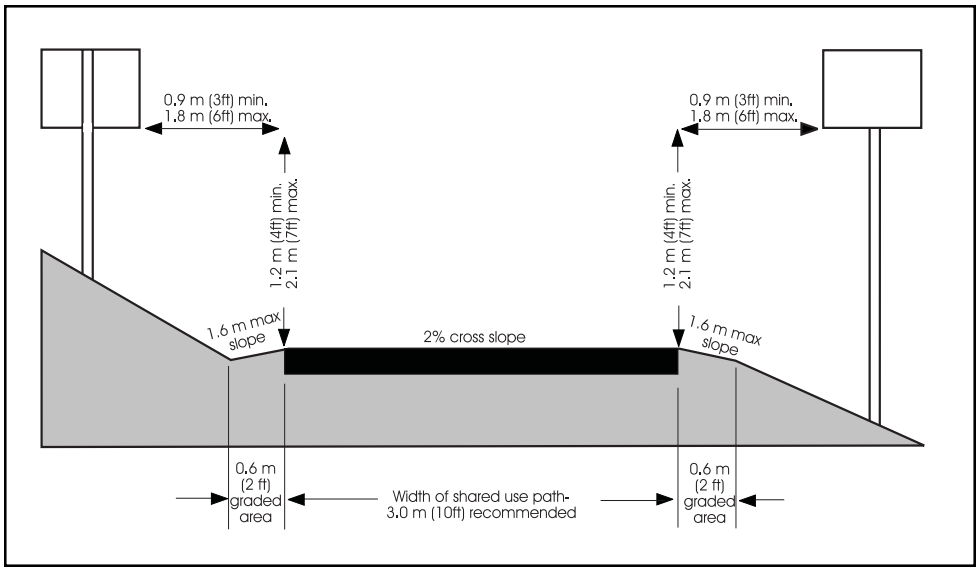

Figure A-15 Shared use path cross-section
Based on AASHTO Guidelines (1999)

create too great of an operating speed differential between families and high speed bicyclists. The need to work within the natural terrain and provide an attractive path experience must also be considered. Just as roads can be overbuilt, so too can paths.

The AASHTO Guide recommends a minimum radius of curvature of 100 feet for bicycle paths with a design speed of 20 mph. Adequate stopping sight distances should also be provided at curves and intersections. When substandard radius curves and stopping sight distances must be used because of right-of-way, topographical or other considerations, standard curve warning signs and/or supplemental pavement markings (yellow center stripe) should be installed in accordance with the MUTCD. Widening the pavement through the curve should be considered in such situations.

Grades on shared-use paths should be kept to a minimum, especially on long inclines. The maximum desirable grade is 5%, although steeper grades may be needed and are acceptable for short distances of up to 500 feet. The width of bicycle paths should be increased on steep slopes, where feasible. Grades steeper than 3% may not be practical for paths with crushed stone surfaces.

Pavement Structure and Drainage: A crushed stone surface is adequate for purely recreational paths in rural areas. However, in urban areas it is recommended that paths be paved to provide a higher level of service, improve accessibility, and allow for year-round use. Pavement structures should be machine laid and constructed of asphaltic or portland cement concrete. Paths should be designed with sufficient structural depth to sustain without damage loads of occasional emergency, maintenance, and other motor vehicles that can be expected to use or cross the path. Special consideration should be given to the location of motor vehicle wheel loads on the path.

For adequate drainage, a minimum pavement cross slope of 2% is recommended. Sloping in one direction instead of crowning is preferred and generally simplifies the drainage and surface construction. A smooth surface is essential to prevent water ponding and ice formation in the winter.

Curb Cuts: Curb cuts for bicycle access to shared-use paths should be designed so that the bottom of the curb cut matches the gutter grade without an elevated lip. The bottom width of the curb cut should be the full width of the bikeway, generally 10 feet wide. Additional width may be necessary on downhill grades.

In some situations, mid-block curb cuts for paths are desirable to allow bicyclists to enter the road prior to an intersection. This allows bicyclists to get in proper position to make a left turn instead of having to cross two streets (pedestrian style).

Mid-block curb cut for bicycle path.

Path-Roadway Intersections: Intersections with roadways must be carefully considered in bicycle path design. If alternate locations for a shared-use path are available, the one with the most favorable intersection conditions should generally be selected. For crossings of high-speed, high-volume arterial roads and highways, grade separation may be the only practical treatment. Unless bicycles are prohibited from the intersecting highway, providing for turning movements at at-grade intersections must be considered.

For at-grade mid-block intersections, a major consideration is establishment of right-of-way. Right-of-way is normally assigned based upon: (1) heavier volume of traffic; (2) higher speed traffic; and (3) higher classification of roadway. In the case of path-roadway intersections, the unique behavioral characteristics of bicyclists and motorists must also be considered. For example, bicyclists have a strong desire to maintain momentum, while motorists tend to assume that bicyclists will or should always yield.

Path-street crossing with curb and crosswalk marking.

It should not be assumed that just because bicyclists are the ones who may be injured in the event of a crash, they should always be required to stop at intersections. This can lead to unsafe practices and increase the potential for a serious crash. Four-way stops should generally be avoided, as they lead to confusion. A common approach to path intersections with low-speed, low-volume streets is to leave them uncontrolled. If bicyclists are given the right-of-way, use of a raised crosswalk and/or a flashing signal may be needed in addition to stop or yield signs in order to alert motorists to their need to slow down and stop or yield.

For mid-block crossings, the type of traffic control to be used (e.g., yield sign, stop sign, signal) and location should be provided in accordance with the MUTCD. Care should be taken to ensure adequate stopping sight distances at intersections and adequate warning to permit bicyclists to stop, especially on downgrades. Advance warning signs of all crossings should be on the roadway in advance of the intersecting path as prescribed in the MUTCD. For path crossings of busy roads, a refuge island or signal may be required. The refuge island width should be 8 feet at a minimum, with 10 feet preferred. Where a signal is needed, bicycle-sensitive loop detectors in the pavement should be used. Techniques to slow motor vehicle traffic approaching the bicycle path crossing (e.g., speed hump, curb extension) should be considered, particularly on roads with traffic speeds greater than 25 mph.

Path crossing is integrated close to the signalized street intersection.

For adjacent path crossings, where the path crosses a roadway at an existing intersection between two roadways, it is usually preferable in urban situations for the crossing to be integrated close to the intersection. This allows motorists and path users to recognize each other as intersecting traffic. See photo above. Traffic controls, such as no right-turn on red or an all-red signal phase may be necessary for these types of crossings where the intersecting and/or parallel roadways have high traffic volumes. There are times, particularly in rural areas, when it is preferable that the path crossing of a roadway be located away from the intersection with another roadway. Path-roadway crossings should be at right angles whenever possible.

Undesirability of Sidewalk Bikeways: While in rare instances they may be necessary, sidewalk bikeways are not recommended. Bicyclists are safer when they are allowed to function as roadway vehicle operators, rather than as pedestrians. Sidewalk bicycle paths create conflicts between pedestrians and bicyclists. Conflicts with fixed objects (e.g., utility poles, sign posts, etc.) are also common. Unsafe conditions are created at intersections and driveways. Bicyclists on sidewalks are often not visible to motorists, and motorists are not expecting them. While some sidewalk bicycle use is expected (e.g., young children riding in residential areas) and often legally permitted by local ordinance (if bicyclists yield to pedestrians), it is inappropriate to sign a sidewalk as a bicycle path.

D. Traffic Signals

At signalized intersections, the timing of the traffic signal cycle and the method of detecting the presence of bicyclists needs to be considered.

Signal Timing

At signalized intersections, traffic signal clearance intervals should be timed to provide bicyclists with sufficient time to react, accelerate, and pass through the intersection on the clearance interval. An all-red phase is not required, but can be used to allow bicyclists that enter the intersection during the yellow interval to clear the intersection. Normally, a bicyclist can cross an intersection under the same signal phasing arrangement as motor vehicles. However, special consideration of bicyclists may be needed for on multi-lane crossings and acute angle intersections, which require longer crossing times for bicyclists. To check the clearance interval, a bicyclist's speed of 6-8 mph and a perception/reaction/braking time of 2.5 seconds should be used. (See AASHTO Guide for additional guidance on determining minimum green time)

Demand-Actuated Signals

Traffic detector loops for demand-actuated signals should be designed to detect bicycles and should be located in the bicyclist's expected path, including bike lanes/paved shoulders and left-turn lanes. This is crucial both for bicyclists' safety and compliance with traffic laws. Special accommodation may be needed on the right side of the rightmost through lane in order to ensure bicycle detection. Quadrupole and diagonal-type loop detectors generally provide for bicycle detection. Dipole and rectangular loops can also detect bicycles if the detector sensitivity is adjusted.

Traffic detector loop in bike lane.

Detector loops are usually not installed across the entire lane, and it is therefore possible that a bicycle on the far right side of the travel lane or road will not be detected. Pavement markings that indicate to bicyclists the area of the loop where they will be detected, preferably the right side of the travel lane, should be considered. Figure A-16 shows the standard pavement symbol to use to notify bicyclists where to stop. The symbol would typically be used on side streets crossing major streets and left-turn lanes. Florida has recently been testing use of the sign shown in Figure A-17 in conjunction with the symbol to explain its purpose.

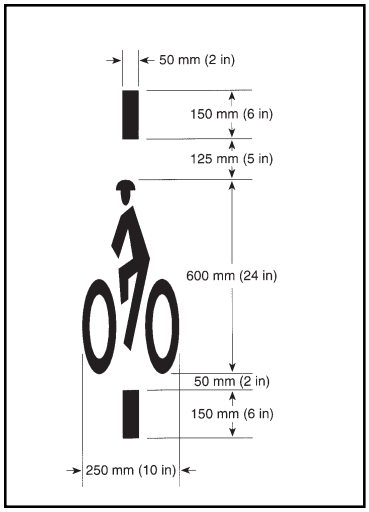

Figure A-16 Pavement symbol to notify bicyclists where to stop to activate traffic signal

Source: AASHTO Guidelines (1999)

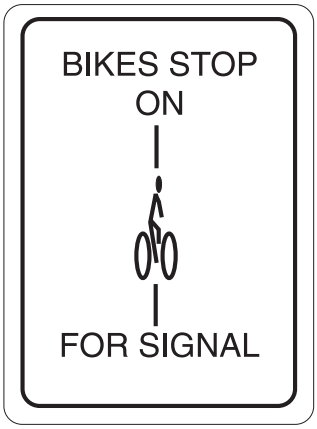

Figure A-17 ***Sign that can be used with pavement symbol to explain purpose***

Source: ***Florida Bicycle Facilities Planning and Design Handbook (2000)***

Programmed Visibility Signals

Where programmed visibility signal heads are used, which are designed to have a finite field of view, they should be checked to ensure they are visible to bicyclists who are properly positioned on the road. If the programmed signals cannot be aimed to serve bicyclists, separate signals should be provided.

E. Additional Design Considerations

Road Hazards

In addition to road debris, there are a variety of other hazards to bicyclists that should either be avoided or eliminated, or kept outside the travel path of bicyclists. The following are the most common.

Drainage Grates and Utility Covers: Drainage grates and utility underground access and handhole covers should be located outside the travel path of bicyclists. Drainage inlets in the curb face, shown in photo below, are preferable to street-surface designs and save space by allowing a one foot wide gutter pan. Bicycle-safe drainage grates should always be used. Otherwise, a bicycle wheel may fall into the slots of parallel bar grates, causing the bicyclist to fall. It is also important that grates and utility covers be adjusted flush with the road surface. As a last and temporary resort, identifying an unsafe grate with a pavement marking visible at night could be done.

Drainage inlets in curb face keep grates out of bicyclists' path.

At-Grade Railroad Crossings: Railroad crossings can present a hazard to bicyclists if not properly designed. Where possible, the rails should cross the road or bicycle path at or near a right angle to minimize the potential for a bicyclist's front wheel becoming trapped in the flangeway and causing loss of steering control. If the crossing angle is less than 45 degrees, the outside lane, shoulder, or bicycle lane should be widened, where possible, to improve the angle of approach. Pavement markings directing the bicyclist toward the best crossing angle are also a good idea.

Outside lane widened to allow bicyclists to cross RR tracks at safe angle.

It is also important that the roadway or path surface be at the same elevation as the rails. Rubberized railway crossing mats or concrete panels (vs. asphalt or timber) are recommended for their smoothness and durability. See photo on next page. The width of the open flange area between the

rail and the roadway surface should be kept to a minimum. Warning signs and pavement markings should be installed in accordance with the MUTCD.

Rubberized rail crossing mats provide smooth crossings for bicyclists. An even better alternative is concrete panels.

Paths should be paved an extra two feet on both sides at railroad crossings in order to maintain the necessary clearance space for safe operation.

Rumble Strips: Rumble strips are sometimes provided continuously in the paved shoulder area of 4-lane divided highways to alert motorists that they are wandering off the travel lanes onto the shoulder. They are also sometimes used in the travel lanes on rural 2-lane highways prior to a controlled intersection to alert motorists of the upcoming intersection. In either case, the rumble strips should not be placed across the entire width of the paved shoulder or travel lane. Rather, a 4-foot or greater smooth surface for bicyclists should be provided on the outside half of the paved shoulder or travel lane.

Lighting

The presence of fixed-source lighting on streets is important to help bicyclists see road surface conditions and avoid potential obstacles, particularly during low light conditions. The needs of bicyclists should be considered when designing lighting for streets. Adequate lighting should also be provided for off-street bicycle paths, through underpasses and tunnels, and at bicycle path and street intersections.

Urban paths should have lighting for safe use during hours of darkness.

Structures

Roadway Bridges: Roadway bridges often present obstacles to bicyclists because of high traffic volumes, narrow widths, open grate decking, and expansion joints. Safe accommodation of bicycles on roadway bridges is important to provide access across major barriers and to assure bicycle facility network continuity. Bicycle-safe decking and expansion joints should be used on all bridge decks. The width of new bridges should equal the width of the approach

Bike lane continues across bridge.

Pedestrian/bicycle overpass provides access across freeway.

roadway, including bicycle lanes, gutter pan, and sidewalks. Even where the approach roadway does not have bike lanes or paved shoulders, space for bicyclists and pedestrians should generally be provided. If bicyclists must be directed to use the sidewalk, sidewalks should be provided on both sides of the street and should be widened to a minimum of 8 feet, with 10 feet preferred. A wider bicycle-pedestrian way may be desirable under some circumstances, such as steep grades and/or heavy use.

Shared-Use Path Over/Underpasses: Separate over- or underpasses for shared-use paths are necessary to provide access across barriers, such as rivers, freeways, and railroads. In selecting an over- or underpass, the advantages and disadvantages of each should be considered. For example, underpasses provide an opportunity to reduce or eliminate approach grades, since the required clearance is less than an overpass of a highway. However, underpasses sometimes present security problems or concerns and may require drainage. Overpasses are more open, but require longer approaches to achieve the standard clearance (17 feet over highways and 23 feet over railroad tracks).

The minimum total width of shared-use path over- or underpasses should be the same as the approaching paved bicycle path (generally 10 feet), plus a minimum of 2 feet clear distance on both sides, for a total of 14 feet. Access by emergency and maintenance vehicles should be considered in establishing the design clearances of bicycle path structures. An overhead clearance of 10 feet is desirable, where possible. Approaches to overpasses and underpasses should have good visibility. Grades of 5% or less are desirable, if possible. Grades should not exceed requirements set by the Americans with Disabilities Act (generally 8%).

Railings or other barriers on both sides of a shared-use path bridge should be a minimum of 3½ feet high. Adequate, vandal-resistant lighting should be provided for both bridges and underpasses for safety and personal security reasons.

Traffic Calming Devices: Considerations for Bicyclists

Speeding on local neighborhood streets is a problem in some areas, in part due to street design that accommodates high-speed travel. Older neighborhoods also sometimes have problems with speeding and cut-through traffic. Well-designed traffic calming devices can effectively reduce traffic speeds and volumes while maintaining local access to neighborhoods. These measures are generally complementary to (or at least not detrimental to) bicycle use. However, consideration should be given to bicyclists to ensure the design doesn't compromise their safety. Street lighting should be used with traffic calming devices, because bicycle lighting requirements are for visibility of the bicyclist, not for the bicyclist to detect hazards. The following other bicyclist-related design issues for these devices should be considered, particularly for identified bicycle routes.

Speed Humps: Speed humps should generally be constructed with a longitudinal length of 12-22 feet with a raised area 3-4 inches high. Where a series of humps are used, they are typically spaced between 300 and 600 feet apart. This will slow motor vehicles while providing a smooth ride for bicyclists. Signing and marking of the humps is essential and they should be visible at night (e.g., through use of lighting).

Speed humps slow motor vehicles down while providing a smooth ride for bicyclists.

Medians: Medians are most useful to accommodate bicyclists and pedestrians at crossings of major multi-lane roadways. They can be either raised or flush with the roadway surface. If raised, they should include an area at least 10-12 feet wide that is ramped or flush with the road for bicyclists. The minimum central refuge width for safe use by bicyclists should be 8 feet. Used in isolation, roadway medians do not have a significant impact on reducing vehicle speeds.

Traffic Circles: Traffic circles are circles of varying diameter formed by curbs that are placed in the intersection of local streets to reduce motor vehicle speeds. The traffic circle should be designed to incorporate adequate deflection on each approach to enforce appropriate entry speed for motor vehicles and discourage a motorist form trying to overtake a bicyclist in the intersection.

Traffic circles slow motor vehicles on residential streets.

Street Closures and Diverters: Traffic diverters and street closures should preserve bicycle turning and through movement options, unless overriding safety concerns exist. Bicycle "cut-throughs" or gaps at diverters and street closures should be wide enough (five feet) to accommodate a bicycle trailer. They should also be designed to permit good visibility of adjacent roads and to minimize the risk of obstruction by parked vehicles. Painting a bicycle symbol and other directional markings in front of the gap can help in minimizing the risk of obstruction by parking vehicles.

This street is closed to through motor vehicle traffic, but provides bicycle access to the neighborhood.

Curb Extensions: Motor vehicles can safely pass bicyclists at an intersection with a curb extension, if the street does not have a centerline stripe. On streets with a centerline stripe, the curb extension should be placed so that a minimum 14-foot outside lane is left on the roadway to allow bicyclists to pass through the intersection safely. Alternatively, motorists should be encouraged to let bicyclists through first by using complementary traffic calming techniques such as speed tables and cautionary signing.

Bicycle Network Continuity During Construction or Other Travel Disruptions

Through bicycle and pedestrian movement must be maintained during construction projects and other activities disrupting travel (e.g., special events), particularly on bridges. Bicyclists and pedestrians are most susceptible to disruptions in their normal routes, because of their slower speeds

Bicycle and pedestrian access access should be maintained through construction zones.

and exposure to noise, dirt, and fumes. Temporary lane restrictions, detours, and other traffic control measures instituted during construction or other traffic disruptions should be designed to accommodate non-motorized travelers, if at all possible.

It is recommended that local communities develop and implement bicycle and pedestrian access policies for street and building construction zones. Compliance with the policies can be achieved through training in-house staff and incorporating the policies into contractor agreements and building permits.

On low-volume rural roadways or through short street construction zones, standard traffic control practices are generally adequate. On roadways with heavier traffic or longer construction zones, a wide outside lane or temporary bicycle lane should be provided for motor vehicles to safely pass bicyclists. A detour route for bicyclists may be advisable on highways with very heavy traffic volumes and high speeds. In urban areas, bicyclists should not be routed onto sidewalks, unless no other reasonable alternative exists. If through travel on a designated bicycle route is disrupted, a reasonable detour should be established and signed. Debris from construction activity should be swept to maintain a reasonably clean riding surface in the bike lane/paved shoulder or outer area of the roadway.

Other considerations for construction-related street disruptions include the following:

- Metal plates create a slick and dangerous surface for cyclists, and are not easily visible at night. If they are used to accommodate traffic, the plates should not have a vertical edge greater than one inch without a temporary asphalt lip to accommodate bicyclists. They should also not have knobs on top for lifting.
- Construction holes or depressions should never be left without physical barriers, which prevent bicyclists from running over them.
- The placement of advance construction signs should obstruct neither the pedestrian's nor bicyclist's path.
- Information regarding construction and route changes should be communicated to the public via the local media. Project managers should also notify and consult with affected groups (e.g., PTAs, businesses) and transportation policy committees.

F. Maintenance

Streets and bicycle paths should be adequately maintained to allow safe use, protect the investment of public funds in bicycle facilities, and guard against legal liability. Street maintenance crews should be trained to spot conditions that are hazardous to bicyclists, and bicycle facility users should be encouraged to report problems (e.g., through use of facility improvement forms). A regular maintenance schedule should be established and sufficient funds budgeted for the work. Special attention should be given to signed bicycle routes and other high-volume bikeways.

Pavement Surfaces

Street and paved bicycle path surfaces should be smooth and free from major surface irregularities. Care should be taken to promptly repair cracks, potholes, and other physical problems, particularly in the bicycle travel path. Patching and pavement overlays should be done to a high standard (e.g., not leaving a ridge, sweeping away loose materials, etc.).

Removal of Debris

Routine maintenance programs should be established to remove sand, gravel, glass, and other debris from streets and bicycle paths. Bicycle lanes and paved shoulders tend to collect debris and need extra attention. Special attention should also be given to the areas of roadways between the typical paths of turning and through motor vehicle traffic. These areas also tend to fill with debris and are in the usual travel path of bicyclists. Poor drainage may cause a reoccurring debris problem in some areas, and should be corrected.

Snow and Ice Removal

Bicycle lanes and bicycle paths should be kept clear of snow and ice.

Signs, Stripes, Legends

Signs, striping, and legends should be kept in a readable condition, including those directed at motorists.

Encroaching Vegetation

Bushes and tree branches adjacent to bicycle paths should be trimmed back to allow a minimum of two feet of clearance, particularly at curves. Vegetation should be prevented from breaking up the edge of pavement and encroaching on the path surface.

G. Bicycle Parking

Bicycle parking facilities should be provided at both trip origin (e.g., multi-family housing developments) and likely trip destination points (e.g., employment center, commercial area). Bicycle parking areas should be accessible from driveways or ramps designed to accommodate bicycle travel, and should be located close to building entrances for convenience and added security.

Bicycle parking is generally grouped into two classes: long-term and short-term. Long-term parking facilities provide weather protection and a higher level of security. Covered

Bicycle lockers provide secure, protected parking.

Bicycle parking.

parking (via awning, roof overhang, etc.), bicycle lockers, or rooms in buildings are examples. At least some long-term parking should be provided at employment centers, schools, transit stops, and multi-family housing developments. Short-term parking provides a means of locking the bicycle frame and a wheel, but does not provide accessory security or weather protection. It is intended for situations where the bicycle will be left for a relatively short period of time and it is visible and convenient to the building entrance. Many sites need both types of parking; short-term for customers and long-term for employees.

Dimensions and Location

Bicycle parking spaces should be at least 6 feet long and 2 feet wide. Overhead clearance for covered spaces should be at least 7 feet. A 5-foot aisle should be provided behind each row of bicycle parking. (See Fig. 18) For double-sided rack, an access aisle is required on both sides of the rack. Some spaces should be large enough to accommodate bicycle trailers, particularly at grocery stores. Bicycle parking should be located in well lit, secure locations close to building entrances. Bicycle parking provided in the public right-of-way (e.g., in downtown, neighborhood commercial districts) should allow 6 feet for passage of pedestrians.

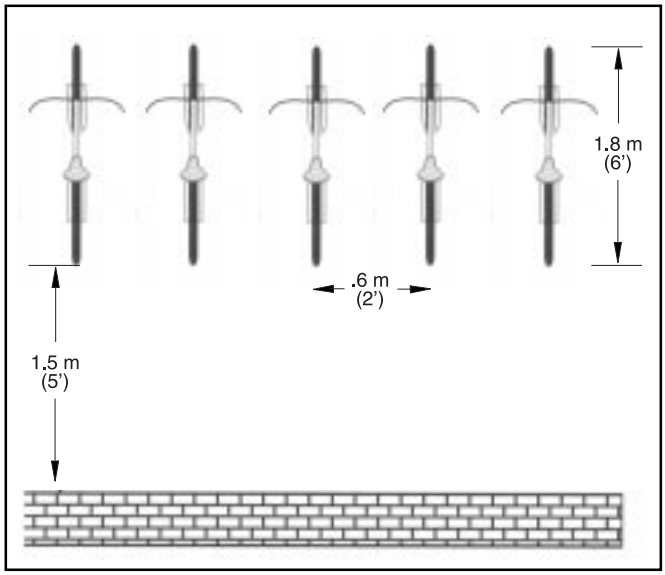

Figure A-18 Bicycle parking dimensions
Source: Oregon Bicycle and Pedestrian Plan (1995)

Number of Spaces

The amount of bicycle parking can be based on: (1) the number of employees, residents, students, etc.; (2) building square footage; and/or (3) number of motor vehicle spaces provided. For information purposes, the City of Madison's Off-Street Bicycle Parking Guidelines are provided in Figure A-20. Flexibility should be provided in the local ordinance to increase or decrease the required number of spaces,

Off-Street Bicycle Parking Guidelines	
Land Use	**Bike Space**
Dwellings/Lodging rooms	1 per dwelling unit or 3 lodging rooms
Clubs/lodges	1 per lodging room plus 3% of person capacity
Fraternities/sororities	1 per 3 rooms
Hotel/lodging houses	1 per 20 employees
Galleries/museums/libraries	1 per 10 auto spaces
Colleges/universities/junior and high schools	1 per 4 employees plus 1 per 4 students
Nursery/elementary schools	1 per 10 employees plus students above second grade
Convalescent and nursing homes/institutions	1 per 20 employees
Hospitals	1 per 20 employees
Places of assembly, recreation, entertainment and amusement	1 per 10 auto spaces
Commercial/manufacturing	1 per 10 auto spaces
Miscellaneous/other	To be determined by the Zoning Administrator based on the guideline for the most similar use listed above

Notes: 1) In all cases where bicycle parking is required, no fewer than two (2) spaces shall be required.
2) After the first fifty (50) bicycle parking spaces are provided, additional bicycle parking spaces required are 0.5 (one half) space per unit listed.
3) Where the expected need for bicycle parking for a particular use is uncertain due to unknown or unusual operating characteristics of the use, the Zoning Administrator may authorize that construction and provision of not more than fifty (50) percent of the bicycle parking spaces be deferred. Land area required for provision of deferred bicycle parking spaces shall be maintained in reserve. (Sec. 28.11(3)(1) 1. Cr. by Ord. 9426, 3-11-88)

Figure A-19 Off-street Bicycle parking guidelines
Source: City of Madison Zoning Ordinance

depending upon the area, type of business, and other factors. If the number of required bicycle parking spaces is reduced, space should still be required to be set aside for the parking if needed in the future.

Bicycle Racks

Bicycle racks should be securely anchored to the surface or a structure and should be designed so that the frame and front wheel of the bicycle can be locked to the rack with a standard high-security U-shaped lock. Racks must hold bicycles securely, supporting the frame so that the bicycle cannot be pushed or fall to one side. (See Appendix B "Bicycle Parking Rack Selection")

Consideration should also be given for provision of showers and changing facilities at office buildings and other locations (e.g., health clubs).

Front wheel of bicycle can be locked with high-security U-shaped lock.

Bicycle Facility Design References

Guide for the Development of Bicycle Facilities, American Association of State Highway and Transportation Officials, 1999.

Manual on Uniform Traffic Control Devices, U.S. Department of Transportation (see in particular Part 9 covering Traffic Controls for Bicycle Facilities)

Facilities Development Manual, Procedure 11-45-10, Wisconsin Department of Transportation (Feb. 1994)

Florida Bicycle Facilities Planning and Design Handbook, Florida Department of Transportation, July 1999, Revised April 2000.

Oregon Bicycle and Pedestrian Plan, Oregon Department of Transportation, 1995.

City of Portland (OR) Bicycle Master Plan, Office of Transportation, City of Portland, 1996.

FHWA DRAFT Course on Bicycle and Pedestrian Transportation, U.S. Department of Transportation, Federal Highway Administration, 2000.