Bicycle Facility Design Guidelines 5

Chapter Sections:

5.1 Design Principles

This chapter of the Durham Comprehensive Bicycle Plan is based on current state and national documents including the North Carolina Bicycle Facilities Planning and Design Guidelines (NCDOT Office of Bicycle and Pedestrian Transportation, January 2004) and the AASHTO Guide for Development of Bicycle Facilities (AASHTO, 1999). The recommended design guidelines of this plan use these documents as a baseline for minimum conditions, and are intended to facilitate creative solutions to a wide range of bicycle facility types. It is recognized that on facilities maintained by NCDOT, the State's design guidelines will apply, and that Durham has the potential to exceed these minimum guidelines where conditions warrant within their jurisdiction.

The following are key principles for these guidelines:

1. Durham will have both a complete network of greenways trails, and a complete network of on-street bicycling facilities. These two systems will be interconnected to make it possible for all destinations in Durham to be accessible by bicycle.

2. All roads in Durham are legal for the use of bicyclists, (except those roads designated as limited access facilities which prohibit bicyclists). This means that most streets are bicycle facilities, and will be designed and maintained accordingly.

3. Bicyclists have a range of skill levels, from "Type B/C" inexperienced/ recreational bicyclists (especially children and seniors) to "Type A" experienced cyclists (adults who are capable of sharing the road with motor vehicles). These groups are not always exclusive – some elite level athletes still like to ride on shared-use paths with their families, and recreational bicyclists will sometimes use their bicycles for utilitarian travel.

4. At a minimum, facilities will be designed for the use of Type "A" cyclists, with a goal of providing for Type "B" cyclists to the greatest extent possible. In areas where specific needs have been identified (for example, near schools) the needs of appropriate types of bicyclists will be accommodated.

5. Design guidelines are intended to be flexible and can be applied with professional judgment by designers. Specific national and state guidelines are identified in this document, as well as design treatments that may exceed these guidelines.

5.2 National and State Guidelines

The following is a list of references and sources utilized to develop design guidelines for Durham's Comprehensive Bicycle Master Plan. Many of these documents are available online and are a wealth of information and resources available to the public.

AASHTO Guide
Guide for the Development of Bicycle Facilities, 1999.
American Association of State Highway and Transportation Officials, Washington, DC.
www.transportation.org

AASHTO Green Book
Policy on Geometric Design of Streets and Highways, 2001.
American Association of State Highway and Transportation Officials, Washington, DC.
www.transportation.org

NCDOT
The North Carolina Bicycle Facilities Planning and Design Guidelines, 1994
NCDOT Division of Bicycle and Pedestrian Transportation
http://www.ncdot.org/transit/bicycle/projects/resources/projects_facilitydesign.html

MUTCD
Manual on Uniform Traffic Control Devices, 2003.
Federal Highway Administration, Washington, DC.
http://mutcd.fhwa.dot.gov

PBIC / APBP
Bicycle Facility Selection: A Comparison of Approaches
Michael King, for the Pedestrian and Bicycle Information Center
Highway Safety Research Center, University of North Carolina – Chapel Hill, August 2002
http://www.bicyclinginfo.org/pdf/bikeguide.pdf

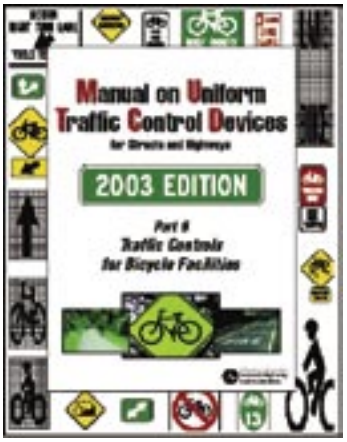


Figure 5.1 - Manual on Uniform Traffic Control Devices (MUTCD)

Bike Lane Design Guide (City of Chicago)
http://www.bicyclinginfo.org/pdf/bike_lane.pdf

Bicycle Parking Design Guidelines
http://www.bicyclinginfo.org/pdf/bikepark.pdf

Durham Trails and Greenways Master Plan
http://www.durhamnc.gov/departments/planning/plans.cfm

Durham Development Guide
http://www.durhamnc.gov/departments/works/handbook/

Durham Pedestrian Plan Design Standards
http://www.durhamnc.gov/durhamwalks/pdf/dw_sec06.pdf

5.3 Bicycle Facility Classification Descriptions

Design Designation	Width	Surface	Treatment	Function
Bike Lane	5'-6'	Asphalt	On-street lane striped and signed to NCDOT standards	For bicyclists on roadways.
Signed shared roadways	varies	Asphalt	May either be a low volume (less than 3000 cars per day) roadway with traffic calming and signage to create a safe shared use environment, OR a higher volume roadway with wide (14') outside lanes.	Used for designated bicycle routes; can include signage and pavement markings
Bicycle Boulevard	varies	Asphalt	Multiple traffic calming treatments combined with bike lanes and or signed shared roadways to create priority streets for bicyclists	Provides a continuous facility on streets with varying widths, volumes and speeds
Shared Curb Lane	9 - 12'	Asphalt	Common facility type in low-speed and low-volume street types.	Utilitarian cycling on streets which are not otherwise designated as elements of the bicycle network
Wide Curb Lane	12- 14'	Asphalt	Smooth pavement, bicycle compatible storm grates	For skilled bicyclists who are capable of sharing the road with motor vehicles
Shared Use Path	10'-14'	Asphalt, concrete or other smooth hard surface	Designed to NCDOT standards. Separated from roadway by planting strip or vertical curbing.	Typical application for regional trail and some community pathways and bikeways. Accommodates bicycles, pedestrians, wheelchairs. Minimizes potential trail crossing conflicts with autos.

Figure 5.2 - Bicycle Facility Classification Description Chart

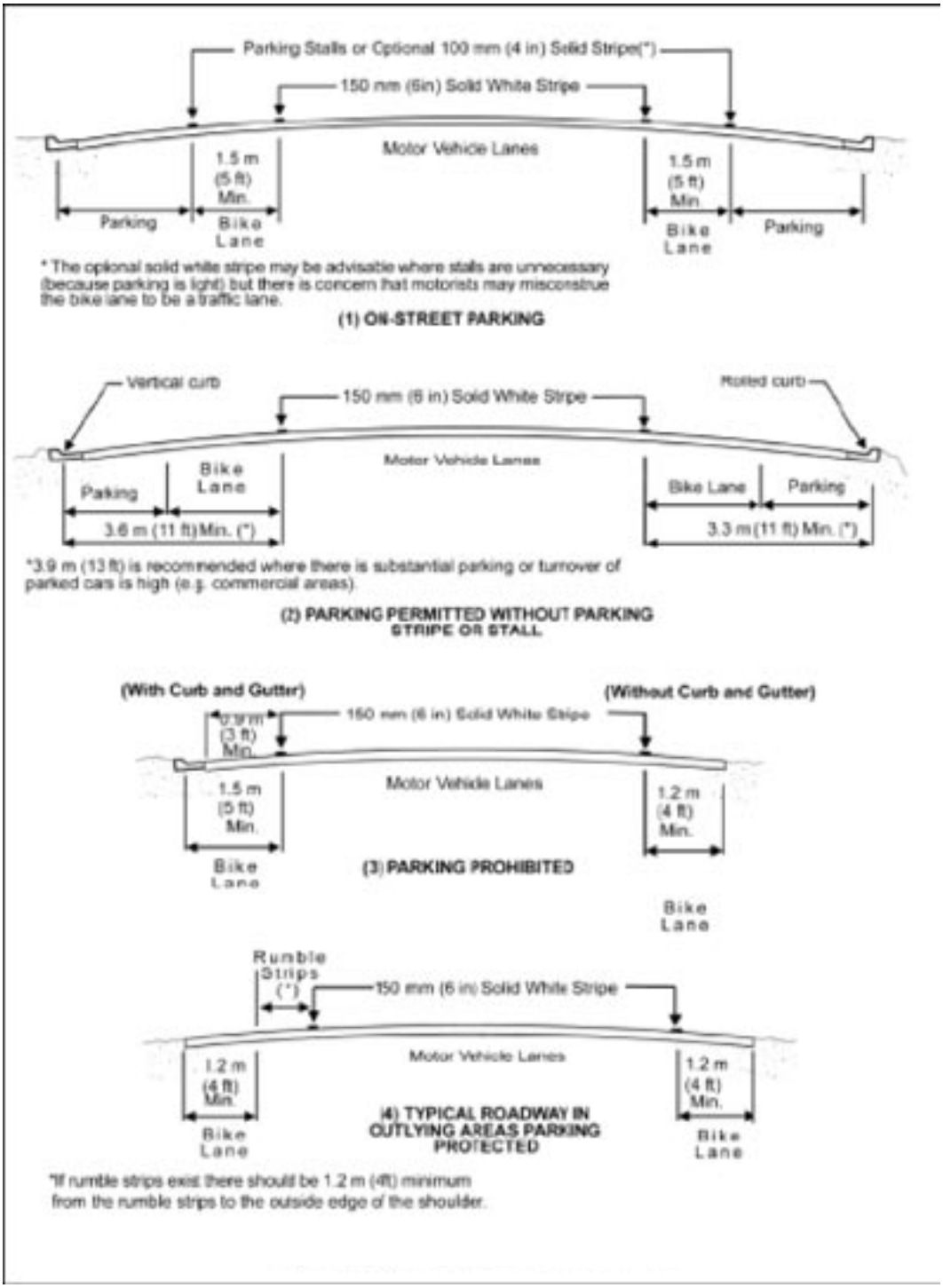


Figure 5.3 - Typical Bike Lane Cross Sections, AASHTO Bicycle Guide, 1999

5.4 Bicycle Facility Selection Criteria

The appropriate bicycle facility for any particular roadway whether new or existing should be primarily dictated by vehicle volume and speed of the roadway. Figure 5.4 below is a summary graphic combining bikeway dimension standards for ten different communities in North America. This figure is taken from Michael King's research, "Bicycle Facility Selection: A Comparison of Approaches" for the Pedestrian and Bicycle Information Center and Highway Safety Research Center, University of North Carolina – Chapel Hill in August 2002. The goal of this study was to survey the varying requirements available and provide a best practices approach for providing bicycle facilities. The table below provides a matrix for evaluating bicycle facilities. Along the left side are total traffic volumes per day and along the bottom is the speed of travel lane. The different colors represent the type of bikeway facility prescribed given the volume and speed of the travel lane.

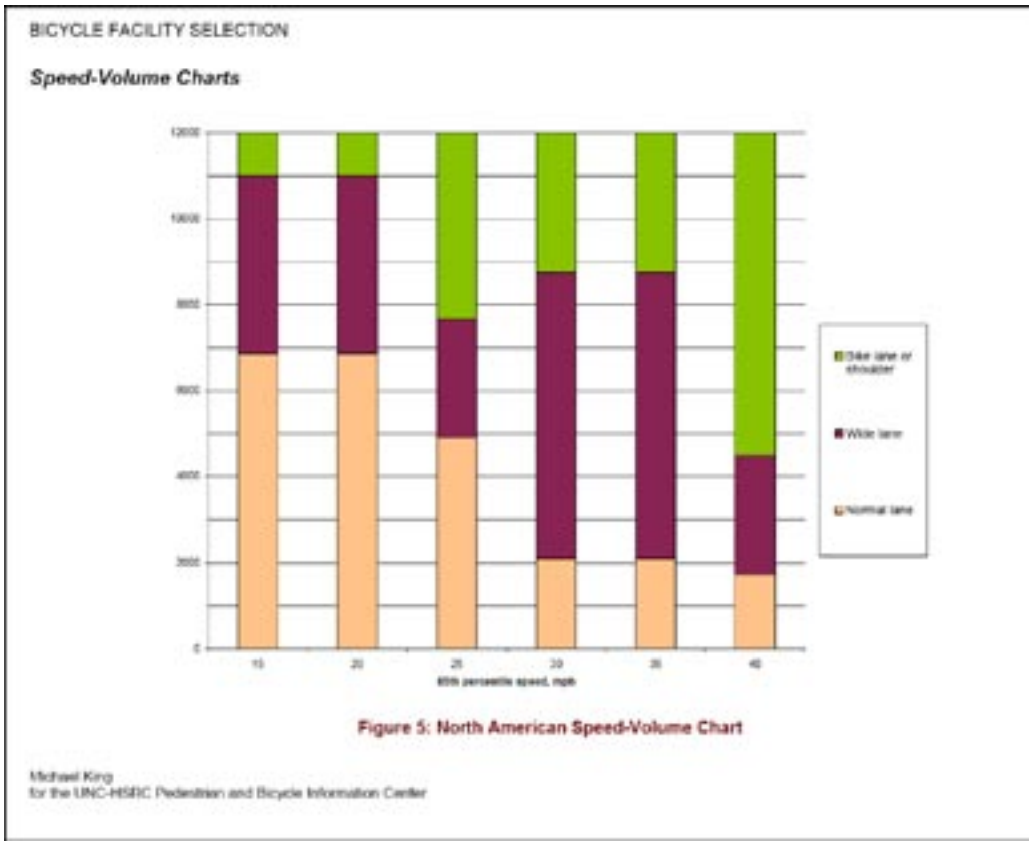


Figure 5.4 - North American Speed-Volume Chart. Illustrates prescribed bikeway facilities appropriate for streets of varying speeds and traffic volumes.

The tables below represent four different versions of the bicycle facility selection parameters based on the matrix shown in Figure 5.4. These alternatives incorporate the variables based on the local conditions identified in the King / UNC study.

	Facility	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph
N	Narrow lane	all	<200	--	--	--	--
W	Wide lane	--	200-600	--	--	--	--
B	Bike lane or shoulder	--	3000-10000	3000-20000	3000-40000	20000-40000	20000-40000
S	Separated lane or path	--	--	--	--	--	--

Center for Livable Communities Matrix

LEVEL OF SERVICE Speed-Volume Matrices

	Facility	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph
N	Narrow lane	--	--	--	--	--	--
W	Wide lane	--	--	--	--	--	--
B	Bike lane or shoulder	--	--	--	--	--	--
S	Separated lane or path	--	--	1600-3250	1600-2000	--	--

Bicycle Compatibility Index - LOS A Matrix

	Facility	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph
N	Narrow lane	--	--	--	--	--	--
W	Wide lane	--	--	--	--	--	--
B	Bike lane or shoulder	--	--	1600-3250	1600-2000	--	--
S	Separated lane or path	--	--	3250-18000	2000-18000	1600-18000	1600-18000

Bicycle Compatibility Index - LOS B Matrix

	Facility	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph
N	Narrow lane	--	--	--	--	--	--
W	Wide lane	--	--	1600-3000	--	--	--
B	Bike lane or shoulder	--	--	3000-11000	1600-10000	1600-8500	1600-7000
S	Separated lane or path	--	--	11000-18000	10000-18000	8500-18000	7000-18000

Bicycle Compatibility Index - LOS C Matrix

Michael King
for the UNC-HSRC Pedestrian and Bicycle Information Center

Figure 5.5 - Tables from "Bicycle Facility Selection: A Comparison of Approaches"

5.5 Complete Streets: Integrating Bikeways Into the Roadway System

The concept of a complete street is based on the principal that all streets should include basic amenities that facilitate the use of all forms of transportation not just motor vehicles. Additionally, amenities such as four foot landscaped median strips should be constructed to buffer and separate vehicle traffic from pedestrians, creating a furniture zone for facilities such as bicycle racks or lockers.

Figure 5.6 - A complete street in Amsterdam includes wide sidewalks with landscaping and bicycle parking, bicycle lanes, transit lanes and vehicle lanes

Community pathway and bikeway designs will vary according to the functional classification of the facility as well as the average daily traffic (ADT) on the adjacent roadway. Durham's minimum design requirements for public and private streets are included in the City of Durham Public Works "Reference Guide for Development". Based on Figure 5.4 the appropriate bicycle facility for a typical Durham "Collector Street" with no parking, speed limit of 35 mph and 2500-4000 ADT should include a separated bicycle lane or path. The following are vehicle volume and speed appropriate street configurations supported by research conducted in the "Bicycle Facility Selection: A Comparison of Approaches" study. These figures also illustrate the application of community pathways and bikeways on High Volume Roadways and Low Volume Roadways.

5.5.1 High Volume Roadways

On roadways with 3,000 or more ADT, bicycle lanes should be used to improve bicyclist safety and comfort. A buffer or curb must separate the shared use path or sidewalk from the roadway for pedestrian safety. The width of the bicycle lane, buffer, and sidewalk or path should appropriately reflect the volume and speed of the vehicles using the roadway.

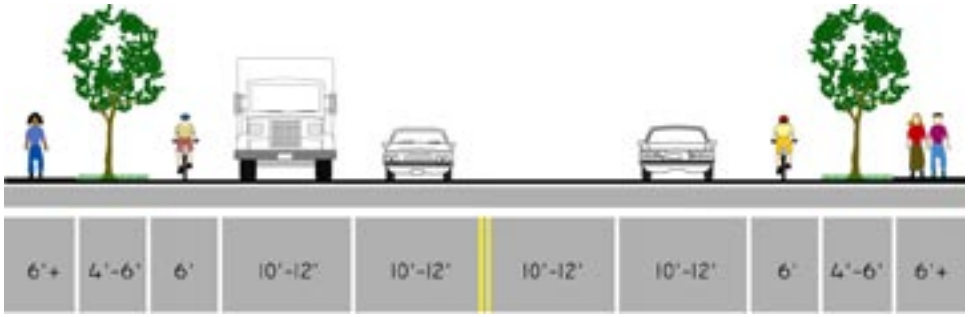


Figure 5.7 - Option 1: High-Volume, High-Speed Roadway

Figure 5.7 illustrates typical bicycle accommodation in urbanized areas. The minimum bike facility width is 4 ft. on open shoulders and 5 ft. from the face of a curb, guardrail, or parked cars, with 6 ft. being the preferred width in urbanized areas. AASHTO specifies that the national standard for bicycle lane width 5 ft.

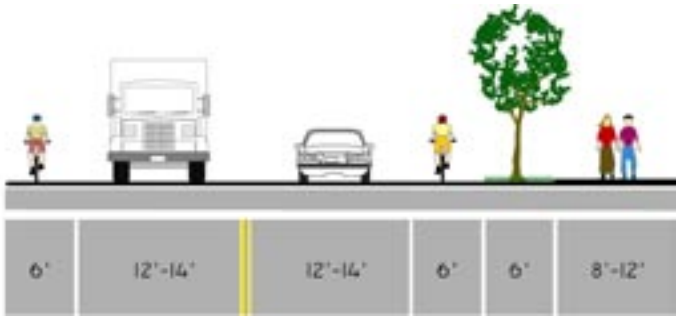


Figure 5.8 - Option 2: (Shared Use Path with Bike Lanes) on a High-Volume, High-Speed Roadway

Some arterials and major collectors can accommodate a shared use path on one side of the roadway and on-street bicycle lanes for more experienced bicyclists (Figure 5.8). This configuration correlates with the "Street Trail" typology cited on page III-2 of the Durham Trails and Greenways Master Plan. The "Street Trail" is described as a portion of a Greenway or Trail which is constituted of a standard five foot sidewalk adjacent to a roadway with a striped bicycle lane. The shared use path provides a comfortable walking space for pedestrians and enables children and recreational bicyclists to ride without the discomfort of riding in a busy street. It is recommended that sidewalk components of the "Street Trail" be upgraded to a width of 10' wide and preferably 12-15' in higher traffic areas. This configuration works best along roadways with limited driveway crossings and with services primarily located on one side of the roadway, or along a riverfront or other natural feature.

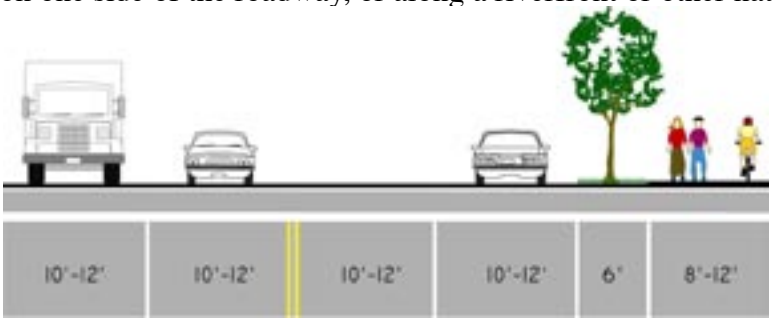


Figure 5.9 - Option 3 (Shared Use Path) on a High-Volume, High Speed Roadway

Sometimes a shared use path can provide full bicycle and pedestrian accommodation on high-volume, high-speed roadways (Figure 5.9). This type of trail works best in corridors where there are limited driveway/intersection crossings and more desirable destinations along one side of the roadway, or where no roadway space is available to provide bike lanes, yet the road travels past a number of desirable locations. The trail should be at least 10' wide (preferable 12-15') with a 6' or greater vegetated buffer where possible. Option 3 corresponds to the "Sidewalk Trail" typology within the Greenways Master Plan which calls for 8 - 10 foot sidewalks adjacent to a roadway. A local example is the Downtown Trail along Blackwell Street and around Central Park.

5.5.2 Moderate Volume Roadway with On-Street Parking

On moderate volume roadways, such as minor collectors, on-street parking is often permitted. Where on-street parking is permitted, and a bike lane is provided, the bike lane must be between parking and the travel lane. Appropriate space must be allocated to allow passing cyclists room to avoid open car doors.

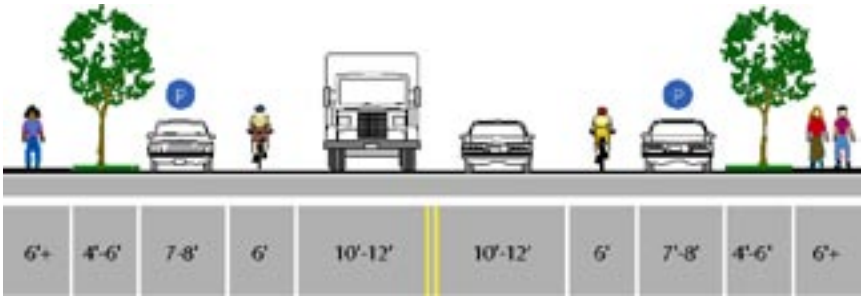


Figure 5.10 - Option 1: Bike Lane with On-Street Parking

5.5.3 Moderate Volume Roadway with Wide Outside Lanes

Additionally, if no bicycle lane is striped, the outside travel lane in either direction may be widened to provide enough roadway space so that bicyclists and motor vehicles can share the roadway without putting either in danger.

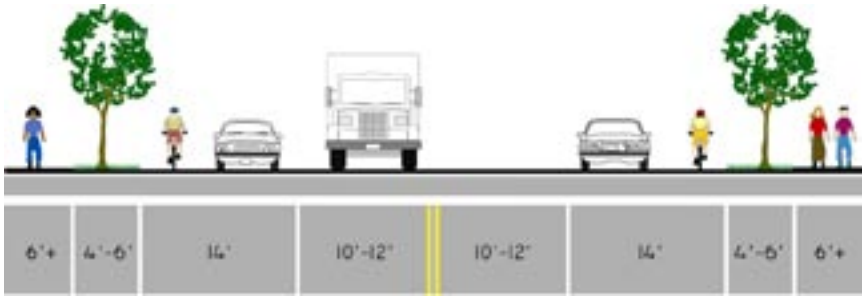


Figure 5.11 - Option 2: Wide Outside Lane on Moderate Volume Roadway

5.5.4 Low Volume Roadways

On a low volume, low speed roadway (i.e. residential or neighborhood streets); many bicyclists can safely share the road with vehicles. Pedestrians should be separated from the roadway with a buffer or a curb. A landscaped buffer is an excellent way to provide a separated trail environment. A curb must be present if there is insufficient space for a buffer. The width of the sidewalk or trail should depend on the traffic volume and speeds of the adjacent roadway.

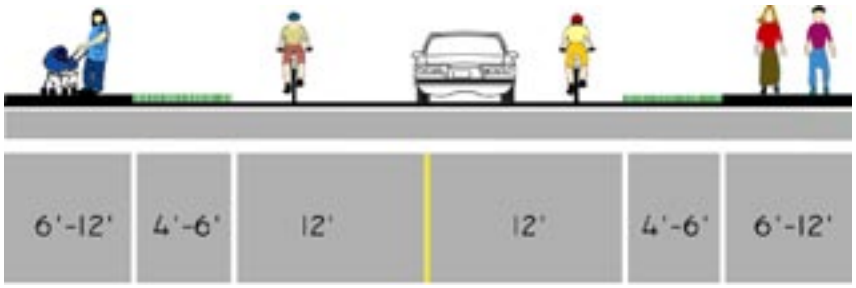


Figure 5.12 - Low Volume, Low Speed Roadway

INNOVATIVE TREATMENTS

Bicycle Boulevards

To further identify preferred routes for bicyclists, the operation of lower volume roadways may be modified to function as a through street for bicycles while maintaining local access for automobiles. Traffic calming devices reduce traffic speeds and through trips while limiting conflicts between motorists and bicyclists, as well as give priority to through bicycle movement.

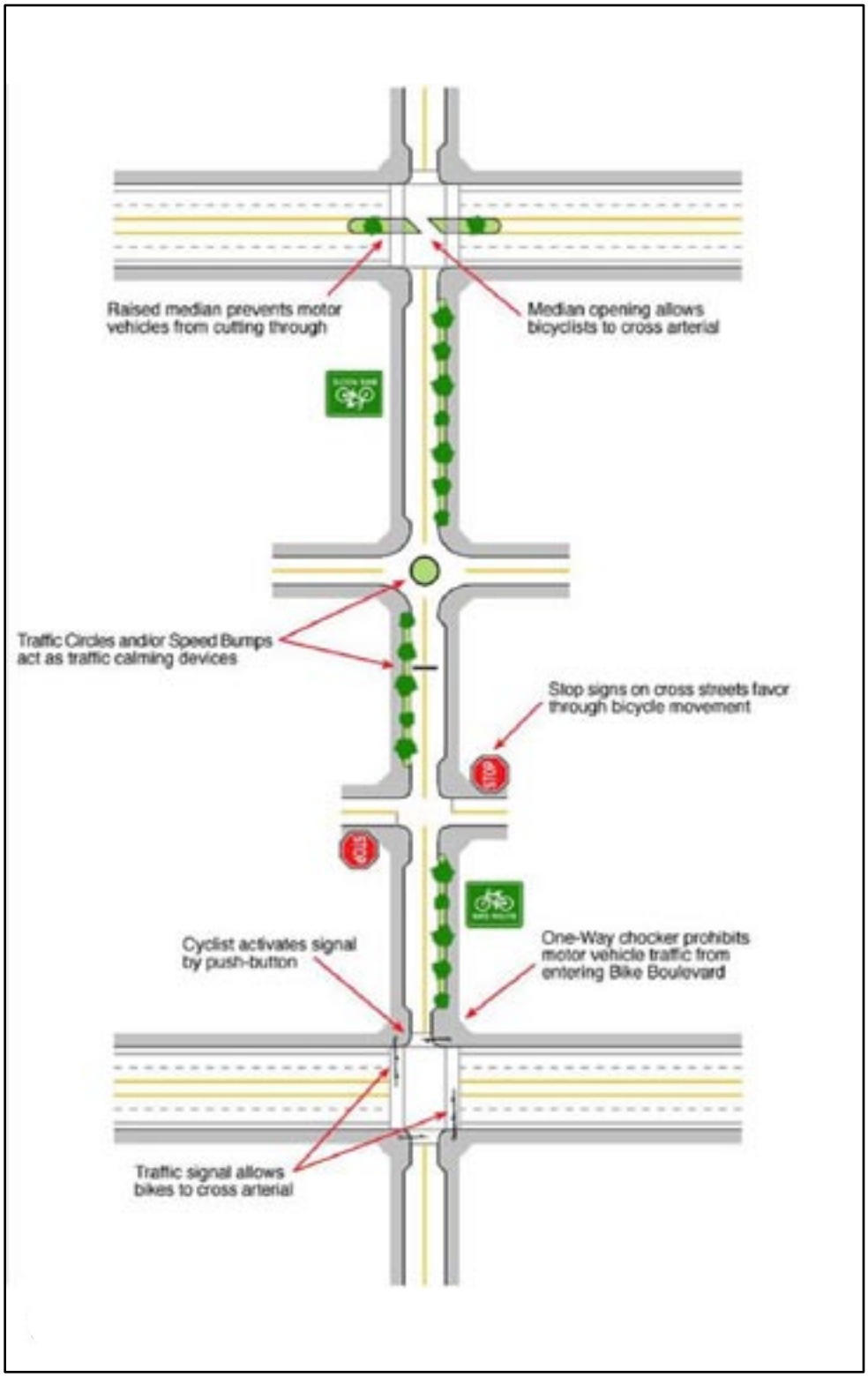


Figure 5.13 - Bicycle Boulevard Lane Configuration

Shared Bus/Taxi/Bicycle Lane
An example of a multi-use bicycle lane within the street is shown to the right. This innovative bikeway treatment is utilized in Phoenix, AZ, Philadelphia, PA, and Toronto, Canada, among other cities in the US and abroad.

Potential Applications include:

- Auto-congested streets, moderate or long bus headways
- Moderate bus headways during peak hour
- No reasonable alternative route
- Limited ROW space for any other bicycle facility

INNOVATIVE BICYCLE SUPPORT FACILITIES

Affordable and Accessible Bicycle Maintenance
This bicycle repair stand shown at left is a fixture within the Cambridge, UK, town marketplace. The U.S. equivalent would be a farmer's or public market which is a center for activity, easily accessible by foot or bicycle. Local bike shops in Durham could provide similar services. The presence of smaller scale operations that primarily provide maintenance and repair functions within semi-permanent structures like the tent and tarp shown below allow for a lower cost operation, thereby passing on savings to the customer in terms of lower repair and maintenance costs.

Car-Free Town Centers
Cambridge, UK prohibits vehicles from entering the heart of town, allowing controlled and specialized access for designated permit holders. The car free environment benefits both bicyclists and pedestrians. Many cities are implementing car free days to allow the public to experience their environment without cars. This innovation is particularly cost effective in that no permanent infrastructure is necessary to experiment with the arrangement. These events could be coordinated with health and environmental promotions, as well as parades and other special events in Durham.

Bicycle Facilities on Buses and Trains

Integrating bicycle facilities with transit modes allows bicyclists to greatly expand their range of travel or "trip chain". Integration of facilities with transit modes allows cyclists to use their bicycles on one or both ends of their daily commute, allowing greater flexibility. Below are examples of commuter trains and bus services with customized facilities allowing for simple and secure storage of bicycles without hindering or impeding other passengers.

Figure 5.14 - Instructions on how to load a bicycle onto a bus equipped with a bicycle rack, developed for a bicycle user map by Fremont, CA

Figure 5.15 - This bike lane protects bicyclists from right turning automobiles at the intersection

5.6 Bicycle-Friendly Intersections

Intersections represent one of the primary collision points for bicyclists. Generally, the larger the intersection, the more difficult it is for bicyclists to cross. On-coming vehicles from multiple directions and increased turning movements sometimes may make it difficult for motorists to see non-motorized travelers. Most intersections do not provide a designated place for bicyclists. Bike lanes and pavement markings often end before intersections, causing confusion for bicyclists. Loop and other traffic signal detectors, such as video, often do not detect bicycles. Bicyclists wanting to make a left turn can face quite a challenge. Bicyclists must either choose to behave like motorists by crossing travel lanes and seeking refuge in a left-turn lane, or they may act as pedestrians and dismount their bikes, push the pedestrian walk button located on the sidewalk, and then cross the street in the crosswalk. In some situations bicyclists traveling straight may have difficulty maneuvering from the far right lane, across a right turn lane, to a through lane of travel. Furthermore, motorists often do not know which bicyclist movement to expect. Figure 5.16 is an example of an intersection that provides bike lanes at critical locations. Figures 5.17 to 5.20 further illustrate intersection treatments.

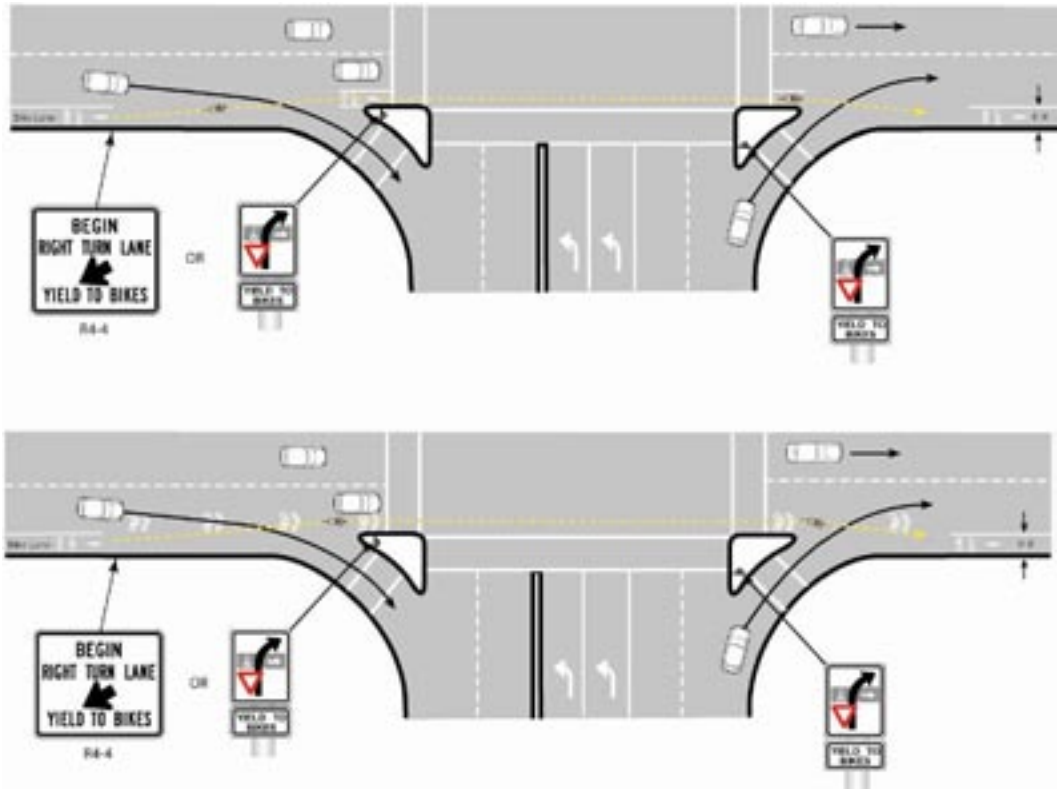


Figure 5.16 - Bike lane through RIGHT TURN ISLAND intersection with free right-turn lanes.

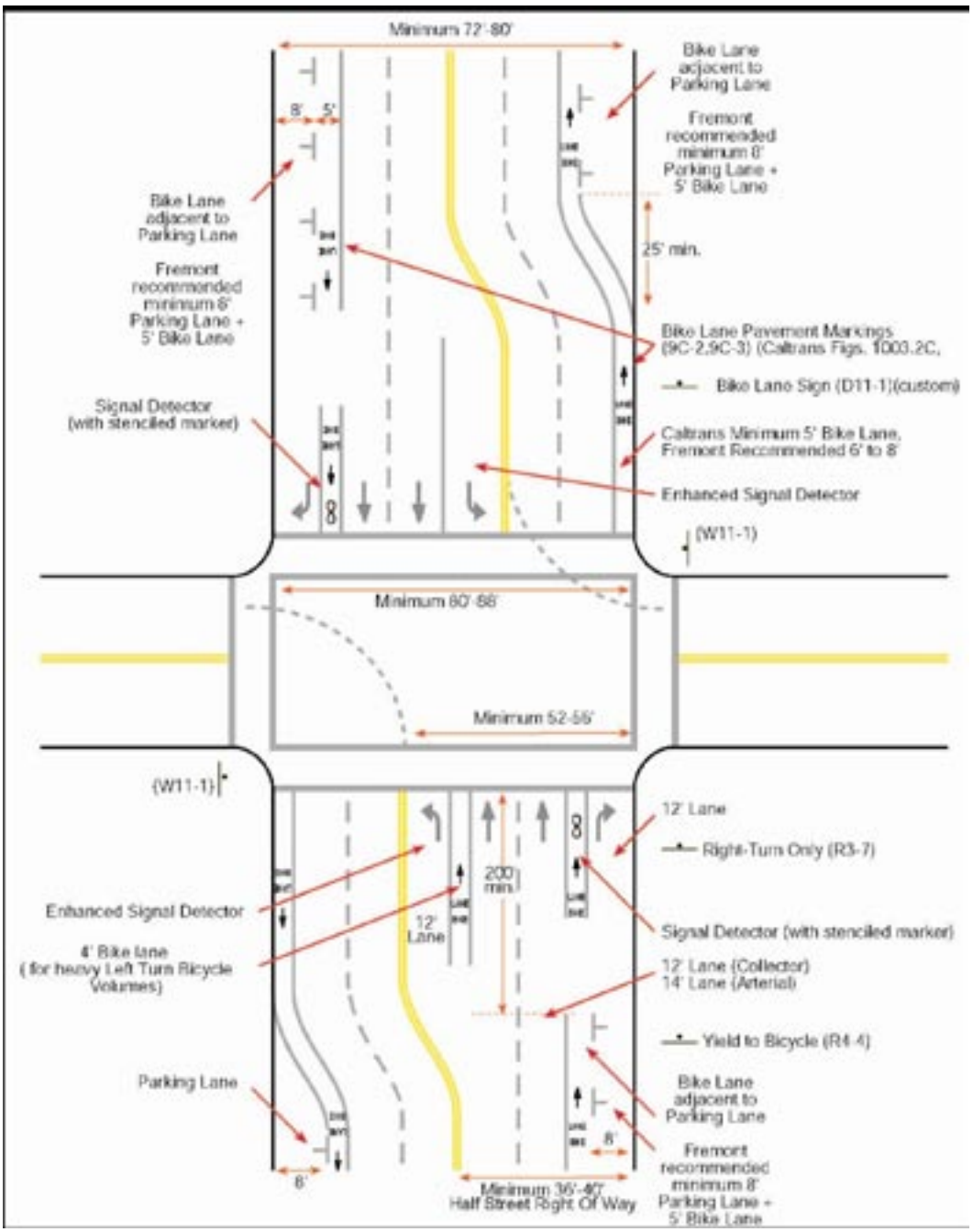


Figure 5.17 - Bicycle lane configurations at intersections adopted by Fremont, CA.

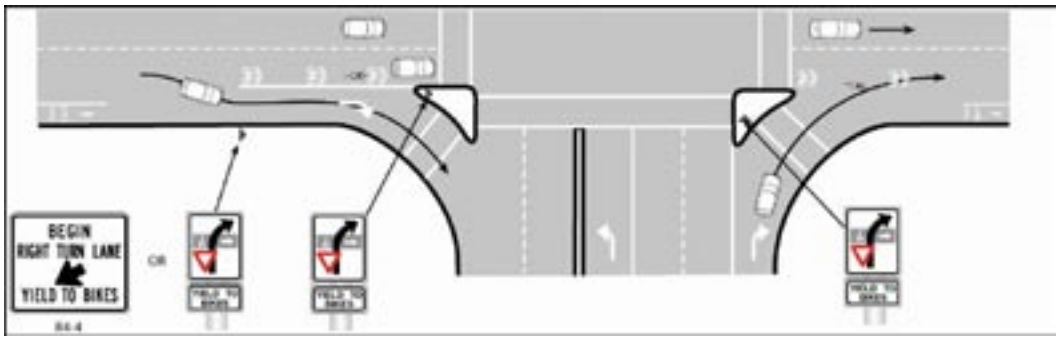


Figure 5.18 - Shared travel lane through right turn island intersection with exclusive right turn lanes.

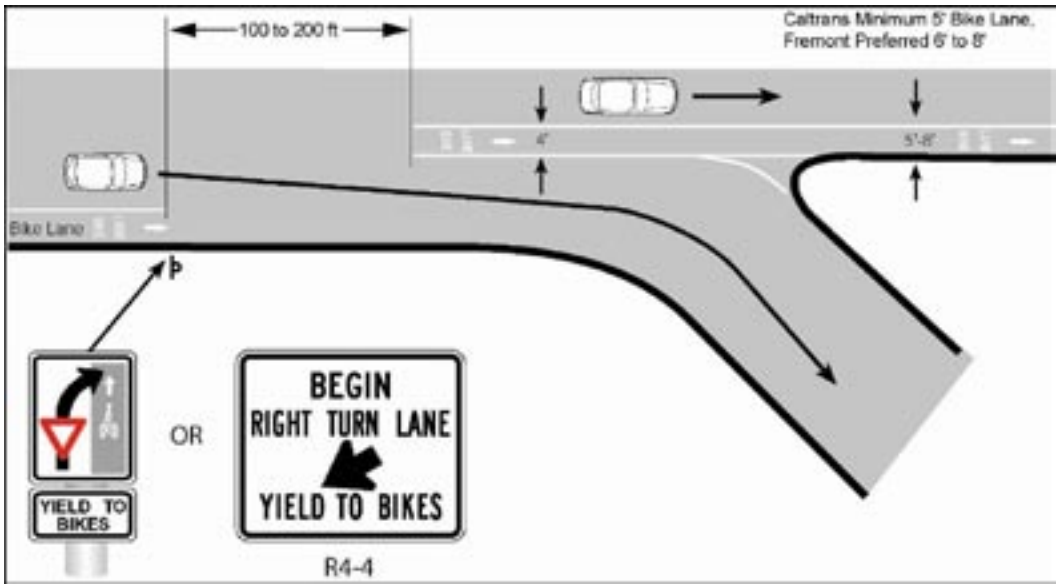


Figure 5.19 - Bicycle lane through a freeway ramp. (See Figure 5.32 for additional treatment options)

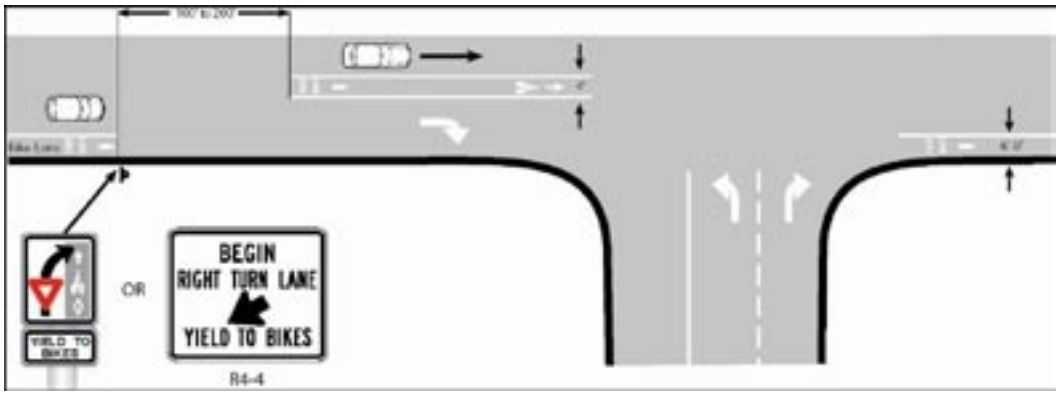
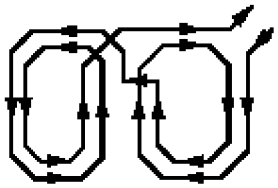


Figure 5.20 - Bicycle lane adjacent to a right turn only lane.

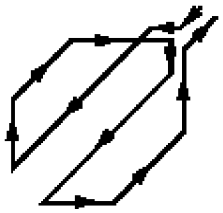
BICYCLE ACTIVATED DETECTOR LOOP

Changing how intersections operate can help make them more "friendly" to bicyclists. Improved traffic signal timing for bicyclists, bicycle-activated loop detectors, and camera detection make it easier and safer for cyclists to cross intersections. Bicycle-activated loop detectors are installed within the roadway to allow the weight of a bicycle to trigger a change in the traffic signal. This allows the cyclist to stay within the lane of travel and avoid maneuvering to the side of the road to trigger a push button, which ultimately provides extra green time before the light turns yellow to make it through the light. Current and future loops that are sensitive enough to detect bicycles should have pavement markings to instruct cyclists on how to trip them.

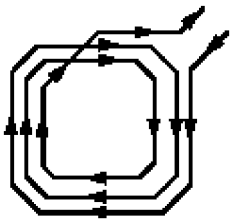
Quadruple Loop
- Detects most strongly in center
- Sharp cut-off sensitivity
- Used in bike lanes



Diagonal Quadruple Loop
- Sensitive over whole area
- Sharp cut-off sensitivity
- Used in shared lanes



Standard Loop
- Detects most strongly over wires
- Gradual cut-off
- Used for advanced detection



From: *Implementing Bicycle Improvements at the Local Level*, FHWA, 1998, p. 70.

Figure 5.21 - Common Loop Detector Types

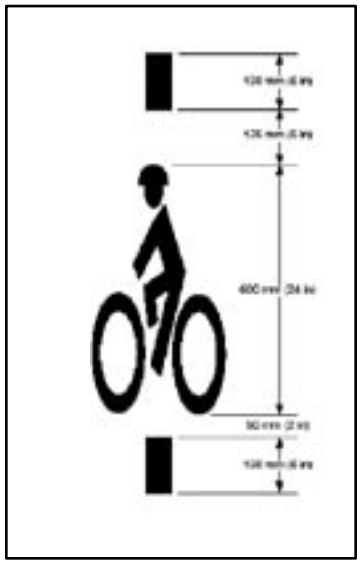


Figure 5.22 - Appropriate pavement marking to aid bicyclists in locating loop detectors at intersections

BICYCLE SPECIFIC TRAFFIC CONTROL SIGNALS

A bicycle signal is an electrically powered traffic control device that may only be used in combination with an existing traffic signal. Bicycle signals direct bicyclists to take specific actions and may be used to address an identified safety or operational problem involving bicycles. A separate signal phase for bicycle movement will be used. Alternative means of handling conflicts between bicycles and motor vehicles shall be considered first. When bicycle traffic is controlled, green, yellow or red bicycle symbols are used to direct bicycle movement at a signalized intersection. Bicycle signals shall only be used at locations that meet Department of Transportation Bicycle Signal Warrants. A bicycle signal may be considered for use only when the volume and collision, or volume and geometric warrants have been met:

1. Volume. When W = B x V and W > 50,000 and B > 50.
Where:
W is the volume warrant.
B is the number of bicycles at the peak hour entering the intersection.
V is the number of vehicles at the peak hour entering the intersection.
B and V shall use the same peak hour.

2. Collision. When 2 or more bicycle/vehicle collisions of types susceptible to correction by a bicycle signal have occurred over a 12-month period and the responsible public works official determines that a bicycle signal will reduce the number of collisions.

3. Geometric.
(a) Where a separate bicycle/multi use path intersects a roadway.
(b) At other locations to facilitate a bicycle movement that is not permitted for a motor vehicle.

From: MUTCD 2003 and MUTCD 2003 California Supplement (May 20, 2004), Sections 4C.103 & 4D.104 - http://www/dot.ca.gov/hq/traffopps/signtech/mutcdsupp/

Figure 5.23 - Bicycle traffic signal used to bring bicycles leaving the UC Davis campus back into the road network.

BIKE BOX / ADVANCE STOP LINE

A bike box is a relatively simple innovation to improve turning movements for bicyclists without requiring cyclists to merge into traffic to reach the turn lane or use crosswalks as a pedestrian. The bike box is formed by pulling the stop line for vehicles back from the intersection, and adding a stop line for bicyclists immediately behind the crosswalk. When a traffic signal is red, bicyclists can move into this "box" ahead of the cars to make themselves more visible, or to move into a more comfortable position to make a turn. Bike boxes have been used in Cambridge, MA; Eugene, OR; and European cities.

Potential Applications:

- At intersections with a high volume of bicycles and motor vehicles
- Where there are frequent turning conflicts and/or intersections with a high percentage of turning movements by both bicyclists and motorists
- At intersections with no right turn on red (RTOR)
- At intersections with high bicycle crash rates
- On roads with bicycle lanes
- Can be combined with a bicycle signal (optional)

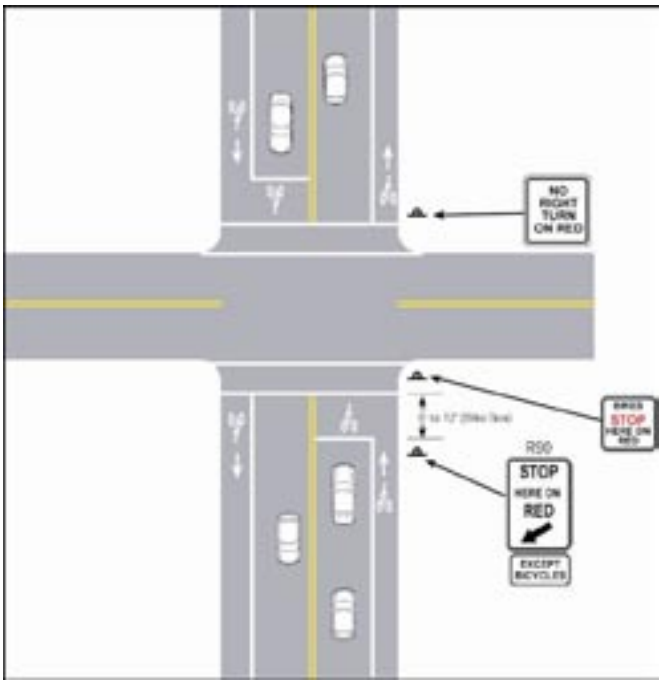


Figure 5.24 - Plan View of the Bicycle Box.

Figure 5.25 - Bicycle box in Eugene, OR. (Photo: Evaluation of an Innovative Application of the Bike Box, FHWA, 2000.)

Figure 5.26 - Bike box in England filled in with color to emphasize allocation of space to bicycle traffic

5.7 Pavement Markings

The Manual on Uniform Traffic Control Devices (MUTCD) provides guidance for lane delineation, intersection treatments, and general application of pavement wording and symbols for on-road bicycle facilities and off-road paths (http://mutcd.fhwa.dot.gov/pdfs/millennium/12.18.00/9.pdf). In addition to those presented in the MUTCD, the following experimental pavement markings may be considered.

BIKE LANES

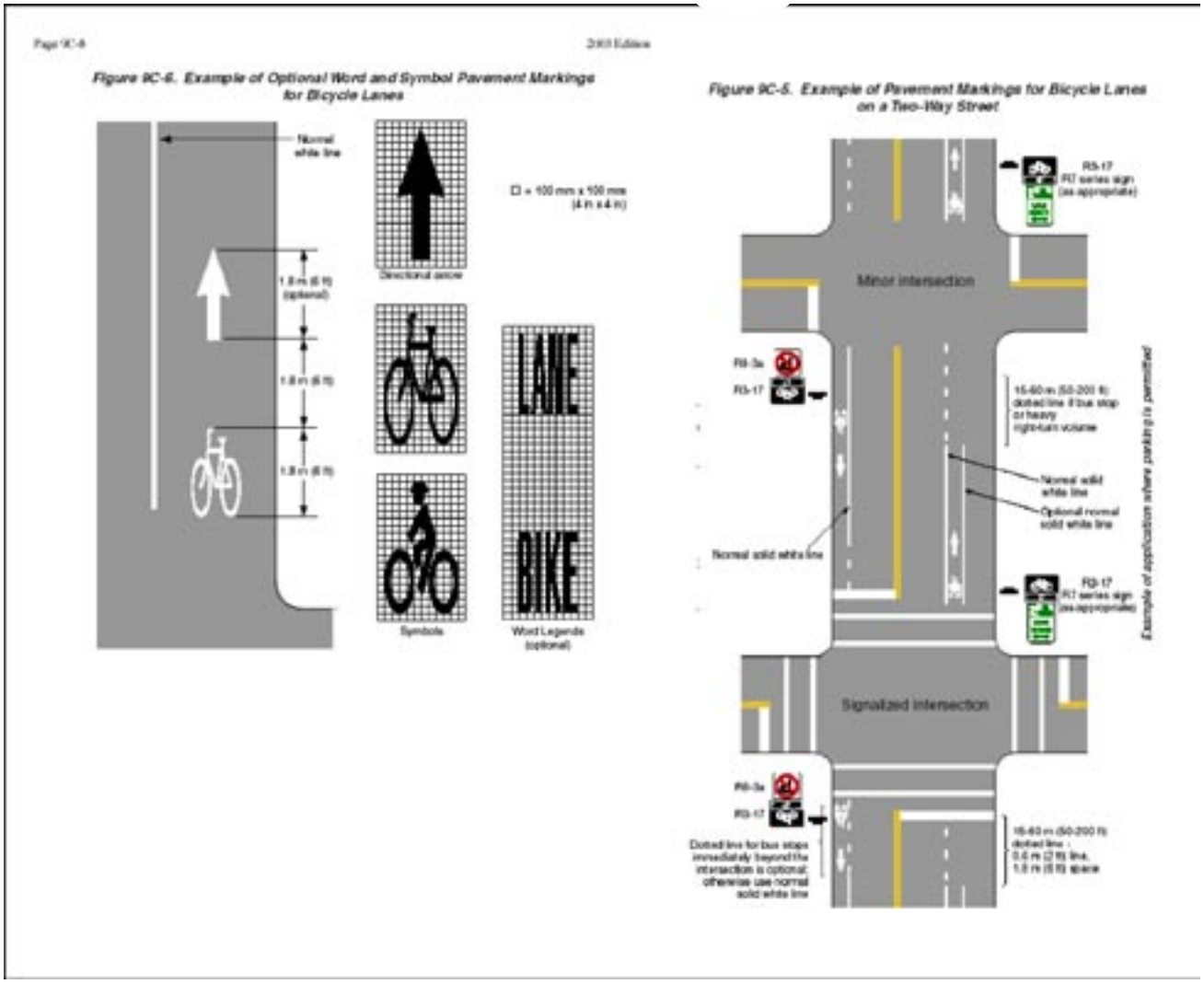


Figure 5.27 - MUTCD examples of optional word and symbol pavement markings for bicycle lanes

BIKE ROUTE "SHARROW" STENCIL

San Francisco has created a bicycle shared lane arrow (or "sharrow" stencil for use on designated on-road bicycle facilities where lanes are too narrow for striping designated bike lanes. The stencil can serve a number of purposes, such as making motorists aware of bicycles potentially traveling in their lane, showing bicyclists the appropriate direction of travel, and, with proper placement, reminding bicyclists to bike further from parked cars to prevent "dooring" collisions. Traditionally "sharrow" markings are used on roadways with on-street parallel parking. See Figure 5.28 for placement guidelines.

Denver and San Francisco have effectively used this treatment for several years. Other cities, such as Portland, Los Angeles, Gainesville, Cambridge, Oakland, Paris, Brisbane, Zurich, and Buenos Aires have begun to utilize this new treatment as well. The "sharrow" treatment is currently being considered for inclusion in the MUTCD.

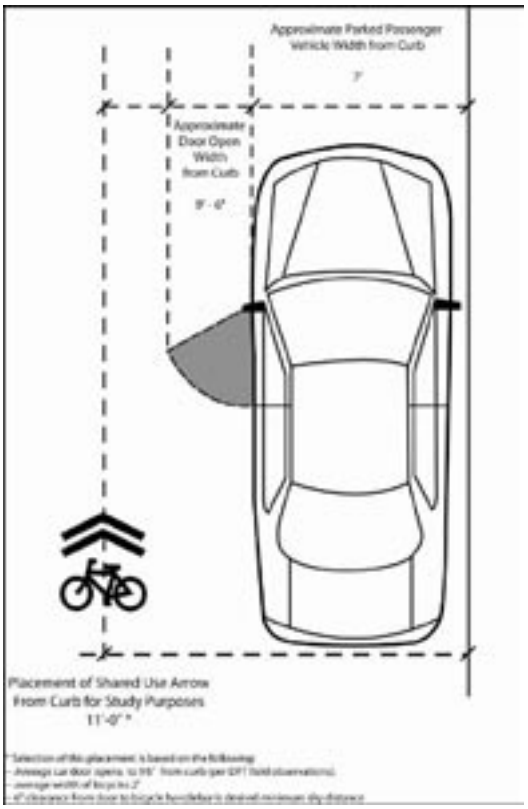


Figure 5.28 - San Francisco Sharrow Dimensions

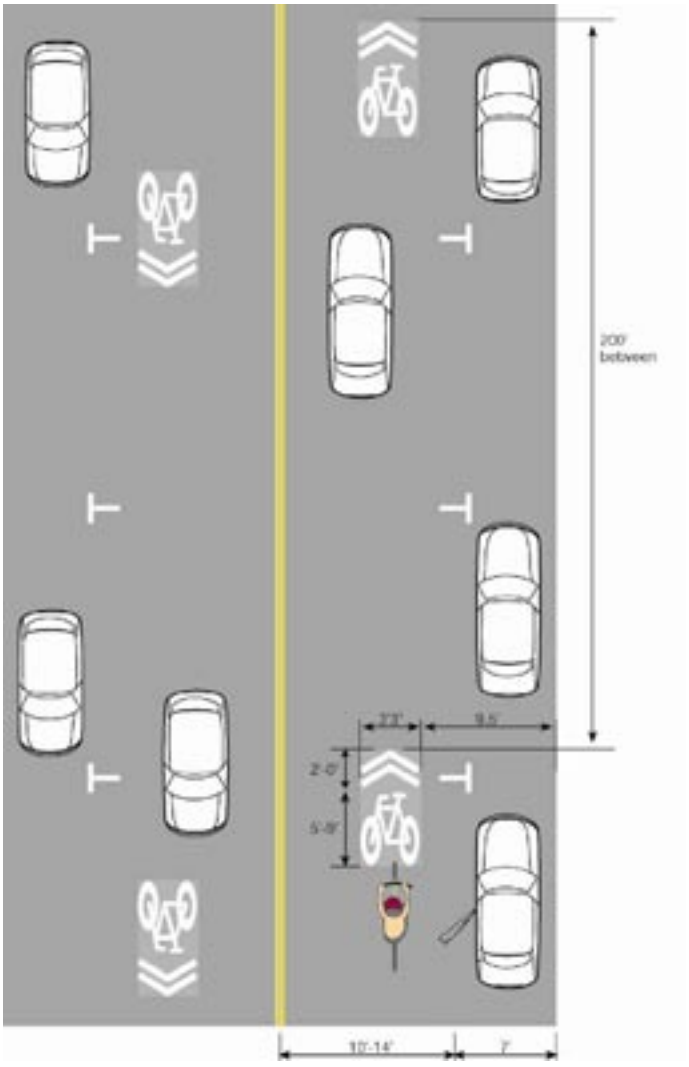


Figure 5.29 - Sharrow installed on Market Street, San Francisco

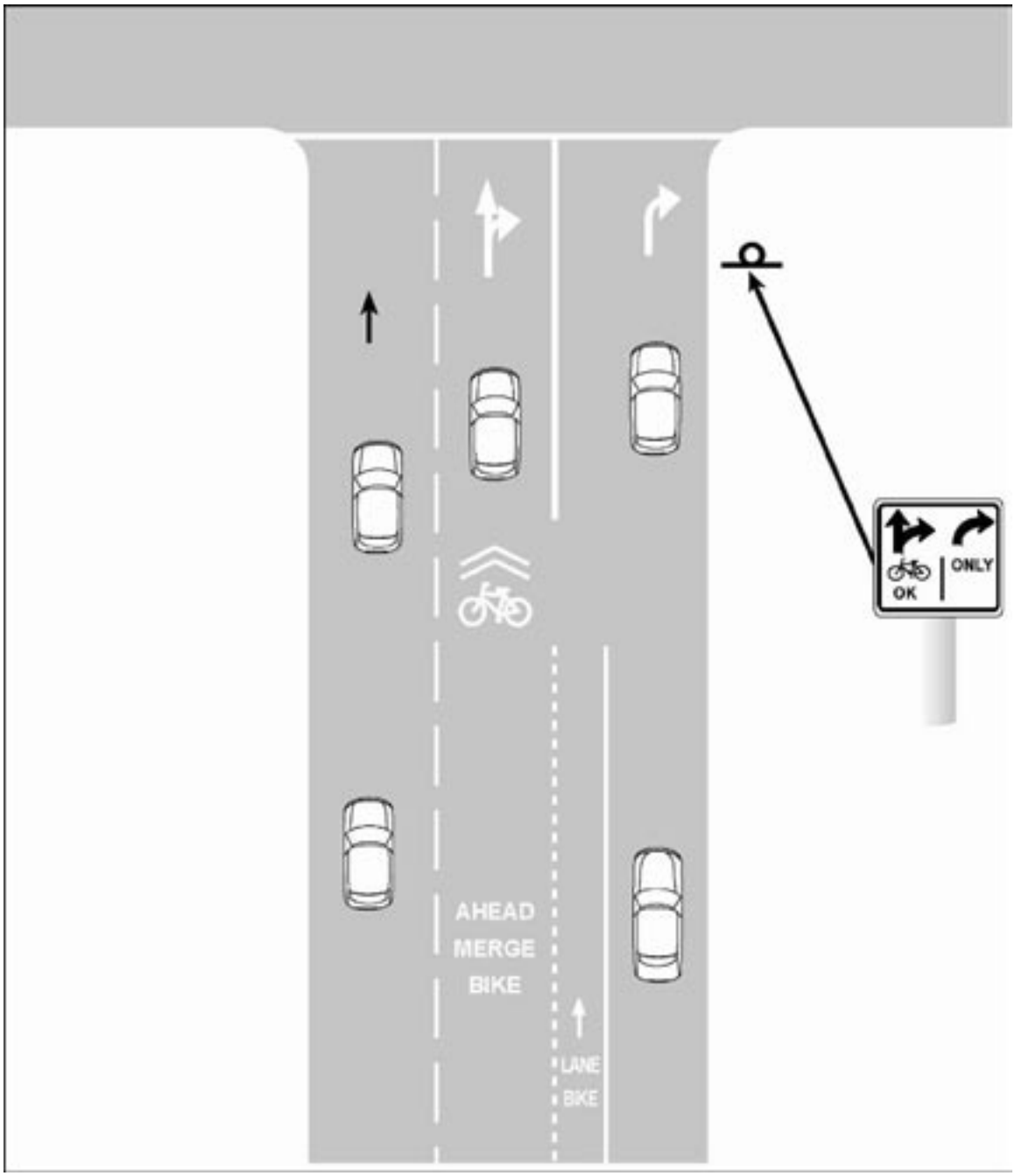


Figure 5.30 - Plan view of sharrows integrated with a double turn lane.

COLORED BIKE LANES

European countries have used colored pavement – red, blue, yellow, and green - in bike lanes that tend to have a higher likelihood for vehicle conflicts. Examples of such locations are freeway on- and off-ramps and where a motorist may cross a bike lane to move into a right turn pocket. In the United States, the City of Portland has experimented with blue bike lanes and supportive signing with favorable results. Studies after implementation showed more motorists slowing or stopping at the blue lanes and more motorists using their turn signals near the blue lanes.

Figure 5.31 - This blue bike lane in Portland is used to warn motorists approaching the on-ramp that bicyclists have a through lane.

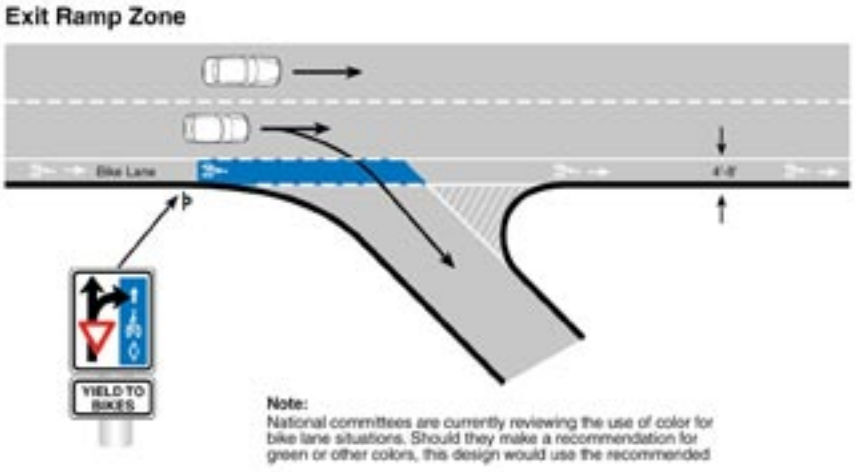
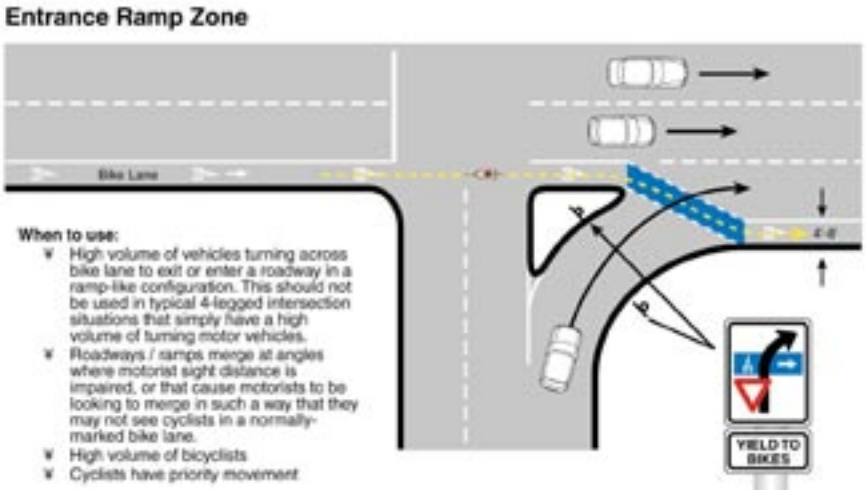


Figure 5.32 - Colored bicycle lane treatment through conflict area.

Figure 5.33 - Blue bicycle lane use in Denmark.



CONTRA FLOW BICYCLE LANES

The contra-flow bicycle lane provides a striped lane going against the flow of automobile travel. The lanes should be separated by a double-yellow line, preferably with a concrete or landscaped divider. University Avenue in Madison, Wisconsin is a example of such a facility.

Potential Applications:

- Provides direct access to key destinations
- Improves safety
- Infrequent driveways on bike lane side
- Bicyclists can safely and conveniently re-enter traffic at either end
- Sufficient width to provide bike lane
- No parking on side of street with bike lane
- Existing high bicycle usage of street
- Less than three blocks in length
- No other reasonable route for bicyclist
- One way streets

Figure 5.34 - Contra-Flow bicycle lanes utilized in Scotland

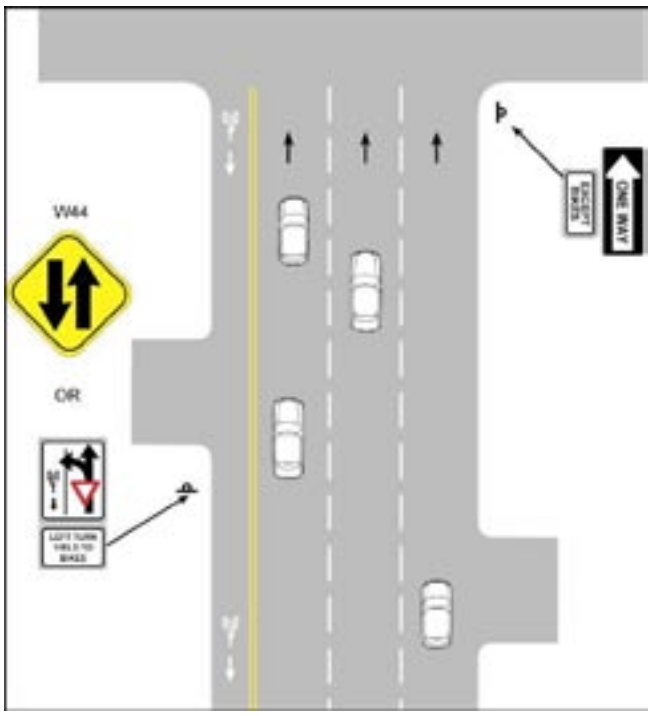


Figure 5.35 - Plan view of a contra-flow bicycle lane

5.8 Innovative Roadside Treatments

Filter strips and bio-swales are innovative ways to retain and treat storm water from impervious surfaces and work well with roadside trails. The design guidelines for filter strips and swales are similar; both methods use grassy vegetation or aggregate to remove sediment from storm water runoff. Use of filter strips and swales can be limited in retrofit situations due to slope, soil, and right-of-way conditions. Existing underground utility conflicts may increase cost and complexity.

FILTER STRIPS

Filter strips (Figure 5.32 and Figure 5.33) are gently sloped grassy and aggregate areas that are used to treat small quantities of sheet flow runoff. They are often used to pretreat storm water flow of minimal depth as it passes from an impervious area, like a parking lot or roadway, into a swale or infiltration area. Sidewalk width illustrated is a minimum.

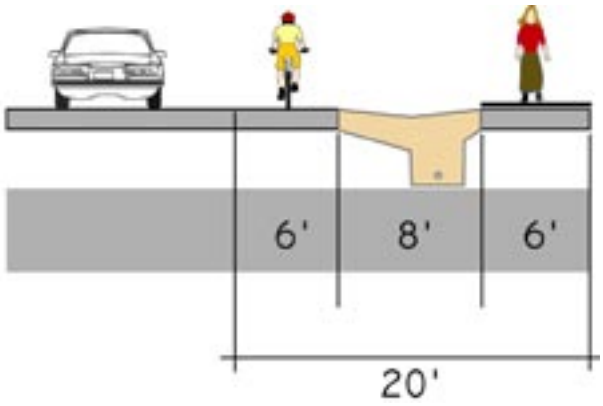


Figure 5.36 - Aggregate Filter Strip

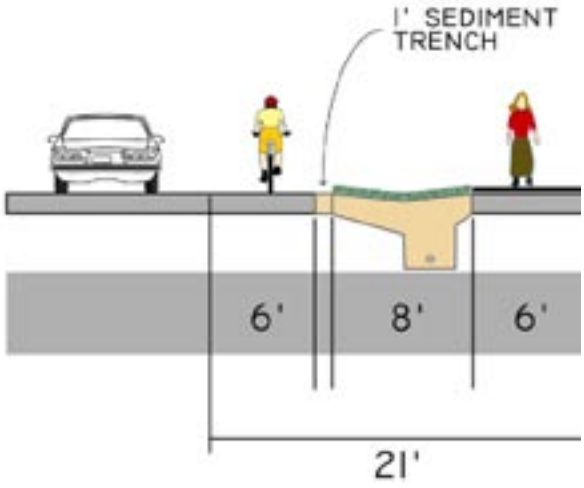


Figure 5.37 - Grass Filter Strip

SWALES

Swales (Figure 5.38) are shallow, wide depressions adjacent to roadways and trails that direct storm water runoff over vegetation to slowly settle sediments and particulate matter. The pollutants are filtered out, settled, or removed by plants, causing fewer pollutants to enter ecologically sensitive water bodies. For more information and further design guidelines for swales and other Green Street concepts, consult Metro's "Green Streets" guidebook (www.metro-region.org).

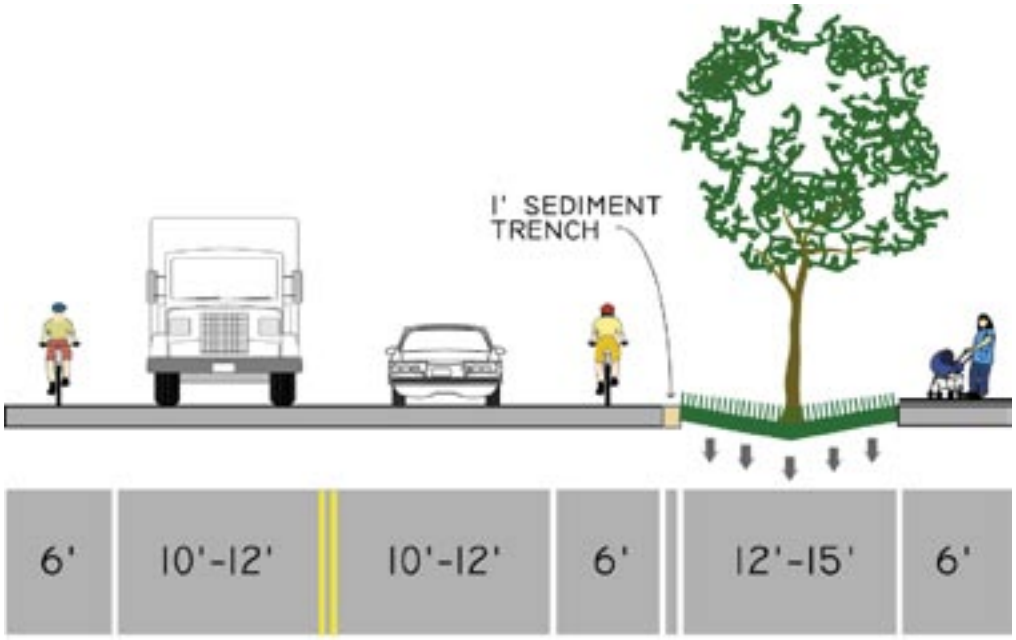


Figure 5.38 - Bio-Swale

Figure 5.39 - Bio-Swale along a multiuse path

Bio-Swale Guidelines
(Metro, "Green Streets")

Optimal Length	200-250 ft
Slope of sides (optimal)	1% - 2%
Slope of sides (minimum, maximum)	1%, 6%
Optimal water depth	3 inches
Optimal width	12 ft

Source: www.metro-region.org

5.9 Signage

This section applies to signed designated bikeways that exist as part of the roadway network. This includes bike lanes, bike routes, and shared use paths. Locations that have been identified as bicycle lanes will be striped and maintained by the County/ City of Durham or NCDOT, depending on ownership of roadway and maintenance responsibility as defined by contract. Bicycle lane striping should follow standards established in this plan, supported by standards from the AASHTO Guide to Bicycle Facilities and the Manual on Uniform Traffic Control Devices (MUTCD). Bike lanes and bike routes should also have additional on-road symbols where appropriate as established in the standards mentioned earlier. Signage is also an important part of the bicycle network. Figure 5.36 shows a number of different signs and markings, both on poles and on the roadway, that the City of Portland has adopted for their new bicycle signage program. The signs have been approved by the Oregon DOT, and will be installed around Portland in the near future. Wayfinding signs such as these improve the clarity of travel direction while illustrating that destinations are only a short ride away. The signs below are provided only as a point of reference for the purposes of these guidelines and are not being adopted by Durham.

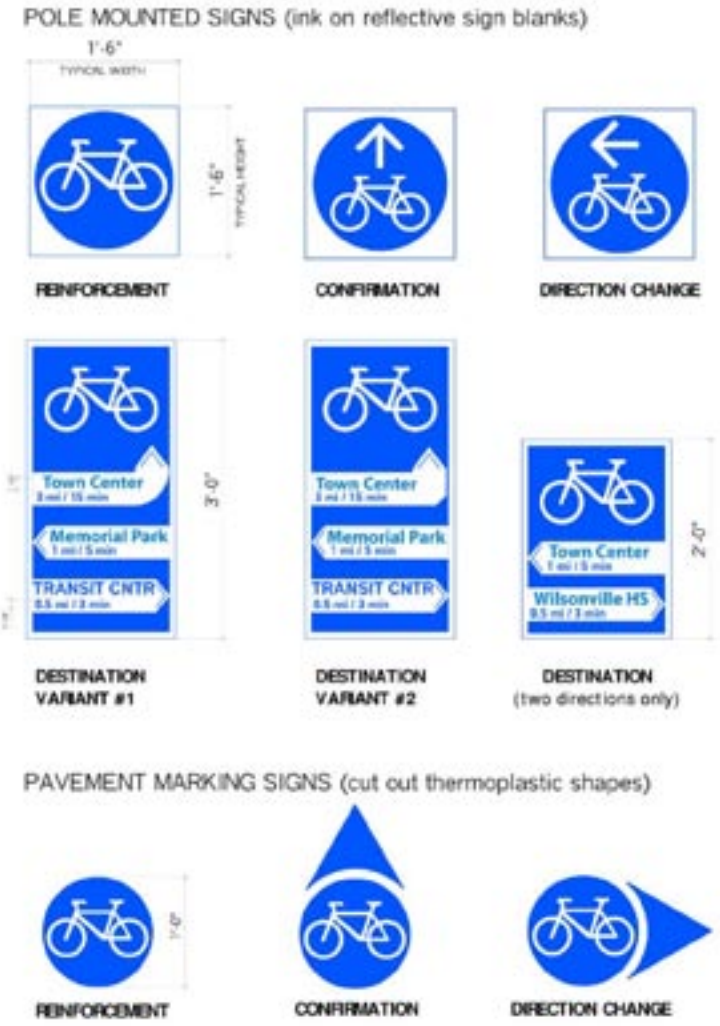


Figure 5.40 - Innovative On-Road Facilities Signage used in Portland

ROUTE SYSTEM SIGNAGE

Implementing a well-planned and attractive system of signing can greatly enhance bikeway facilities by signaling their presence and location to both motorists and existing or potential bicycle users. Effective signage can encourage more bicycling by leading people to city bikeways, and by creating a safe and efficient transportation option for local residents and visitors to the county, .

All bikeway signage should conform to the Manual on Uniform Traffic Control Devices (MUTCD). This document gives specific information on the type and location of signage for the primary bike system. A list of bikeway signs from the MUTCD is shown in Figure 5.41.

Item	Location	Color	MUTCD Designation
No Motor Vehicles	Entrances to trail	B on W	R5-3
Use Ped Signal / Yield to Peds	At crosswalks where sidewalks are being used	B on W	R9-5, R9-6
Bike Lane Ahead; Right Lane Bikes Only	At beginning of bike lanes	B on W	R3-16, R3-17
STOP, YIELD	At trail intersections with roads	W on R	R1-1, R1-2
Bicycle Crossing	For motorists at trail crossings	B on Y	W11-1
Bike Lane	At the far side of all arterial intersections	B on W	D11-1
Hazardous Condition	Slippery or rough pavement	B on Y	W8-10
Turns and Curves	At turns and curves which exceed 20-mph design specifications	B on Y	W1-1, W1-2, W1-4, W1-5, W1-6
Trail Intersections	At trail intersections where no STOP or YIELD required, or sight lines limited	B on Y	W2-1, W2-2, W2-3, W2-4, W2-5
STOP Ahead	Where STOP sign is obscured	B, R on Y	W3-1
Signal Ahead	Where signal is obscured	B, R, G	W3-3
Bikeway Narrows	Where bikeway width narrows or is below 8'	B on Y	W5-4
Downgrade	Where sustained bikeway gradient is above 5%	B on Y	W7-5
Pedestrian Crossing	Where pedestrian walkway crosses trail	B on Y	W11A-2
Restricted Vertical Clearance	Where vertical clearance is less than 8'6"	B on Y	W11A-2
Railroad Crossing	Where trail crosses railway tracks at grade	B on Y	W10-1
Directional Signs	At intersections where access to major destinations is available	W on G	D1-1b(r)[], D1-1-c
Right Lane Must Turn Right; Begin Right Turn Here, Yield to Bikes	Where bike lanes end before intersection	B on W	R3-7, R4-4
Trail Regulations	All trail entrances	B on W	N/A
Multi-purpose Trail: Bikes Yield to Pedestrians	All trail entrances	N/A	N/A
Bike: Reduce Speed & Call Out Before Passing	Every 2,000 feet	B on W	N/A
Please Stay on Trail	In environmentally sensitive areas	N/A	N/A
Caution: Storm Damaged Trail	Storm damaged locations	B on Y	N/A
Trail Closed: No Entry Until Made Accessible & Safe for Public Use	Where trail or access points closed due to hazardous conditions	N/A	N/A
Speed Limit Signs	Near trail entrances, where speed limits should be reduced from 20 mph	B on W	N/A
Trail Curfew 10PM – 5 AM	Based on local ordinance	R on W	N/A

Figure 5.41 - Recommended Signing and Marking

In general, the sizes of signs used on bicycle paths are smaller than those used on roadways. Table 9B-1 of the MUTCD lists minimum sign sizes for both bicycle facilities. If the sign applies to drivers and bicyclists, then the larger size used for conventional roads shall apply.

Figure 5.42 - MUTCD Standard Bicycle Signage

Figure 5.43 - Potential Durham Bikeway Signage -
Local, Regional and State Levels of Bikeway Route Signage

5.10 Special Purpose Signage

Innovative signage is often developed to increase bicycle awareness and improve visibility. Signs to be installed on public roadways in North Carolina must be approved by NCDOT's Traffic Control Devices Committee and/or the City of Durham. New designs can be utilized on an experimental basis with NCDOT approval.

In California, San Francisco was the first city to use the approved customized bike route logo sign, similar to Example 1 below. Jurisdictions may choose a graphic of their choice for the upper portion of the sign, and a numbering system, similar to the highway numbering system, can be used in the lower portion. The "Share the Road" sign (Example 2), is designed to advise motorists that bicyclists are allowed to share and have the right to cycle on narrow roadways with motor vehicles.

Example 1
North Carolina cities can use similar customized logo signs to define bike routes.

Example 2
Share the Road signs remind motorists that bicyclists have the right to ride on the roadway

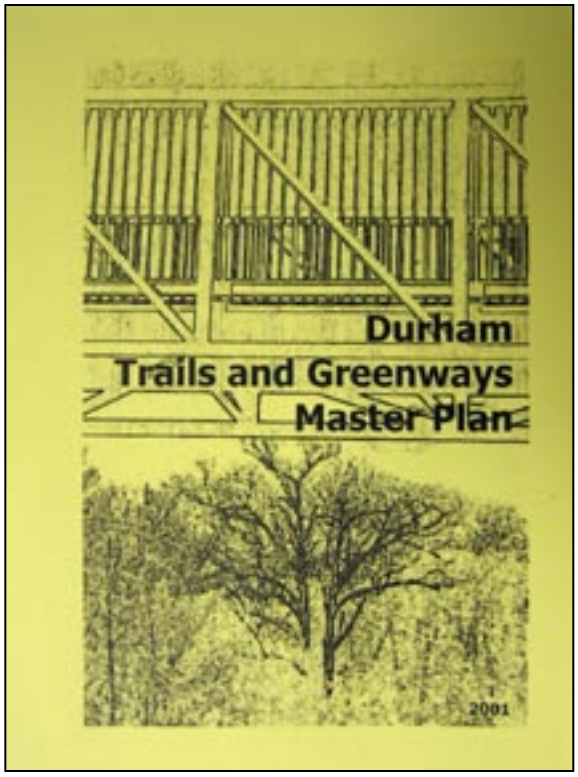
Example 3
The "Bikes Allowed Use of Full Lane" sign is currently used on an experimental basis in several cities.

Figure 5.44 - Examples of Special Purpose Signage

5.11 Shared Use Paths, Greenways and Trails

The Durham Trails and Greenways Master Plan (http://www.durhamnc.gov/departments/planning/plans.cfm) identifies an extensive network of trails and greenways planned for the region. Durham is home to an impressive number of greenways that provide a network for recreation, commuting and safe access to major recreational destinations. One of the key elements of designing these trails and greenways is to safely integrate off-street facilities into vehicle traffic. Part of this includes crossing features for all roadways include warning signs both for vehicles and trail users. The type, location, and other criteria are identified in the Manual for Uniform Traffic Control Devices (MUTCD).

The Bicycle Network (Chapter 4) developed for this Plan is designed to integrate and complement existing and future trails and greenways in Durham. Providing connections between on-street and off-street facilities is a vital link and valuable resource for the area. Sidewalk Trails and Street Trails defined by the Trails and Greenways Plan are correlated with the on-street bicycle facility cross sections identified in the section on Complete Streets. Greenways, Trails fall within umbrella of Shared Use Paths as they are intended for all non-motorized modes of transportation and not just bicycles. Definitions for terms described above are provided in the glossary.



In addition to dimensional standards, the following is a discussion of special design considerations unique to Shared Use Paths. Adequate warning distance is based on vehicle speeds and line of sight. Signage should be highly visible; catching the attention of motorists accustomed to roadway signs may require additional alerting devices such as a flashing light, roadway striping or changes in pavement texture. Intersection signage for trail users must include a standard stop sign and pavement marking, sometimes combined with other features such as bollards or a kink in the trail to slow bicyclists. Care must be taken not to place too many signs at crossings lest they overwhelm the user and lose their impact.

Figure 5.45 - Shared Use Path Crossing of local street.

Directional signage may be useful for trail users and motorists alike. For motorists, a sign reading "Bicycle Trail Xing" along with a Durham trail emblem or logo helps both warn and promote use of the trail itself. For trail users, directional signs and street names at crossings help direct people to their destinations.

The directional signing should impart a unique theme so trail users know which trail they are following and where it goes. The theme can be conveyed in a variety of ways: engraved stone, medallions, bollards, and mile markers. A central information installation at trail heads and major crossroads also helps users find their way and acknowledge the rules of the trail. (Figure 5.47) They are also useful for interpretive education about plant and animal life, ecosystems, and local history.

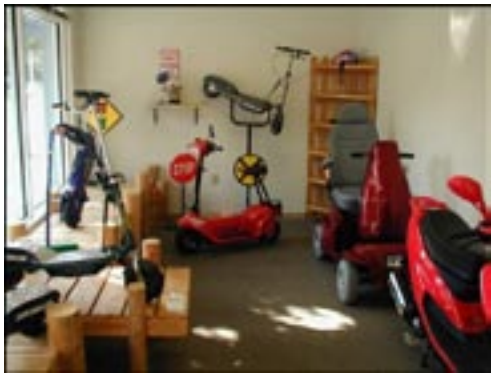


Figure 5.46 - As the City of Medicine, Durham could lead the way in designing an alternative transportation network that accommodates mobility needs of an aging population.

A number of striping patterns have emerged over the years to delineate trail crossings. A median stripe on the trail approach (Figure 5.45) will help to organize and warn trail users. The actual crosswalk striping is a matter of local and State preference, and may be accompanied by pavement treatments to help warn and slow motorists. The effectiveness of crosswalk striping is highly related to local customs and regulations. In communities where motorists do not typically yield to pedestrians in crosswalks, additional measures may be required.

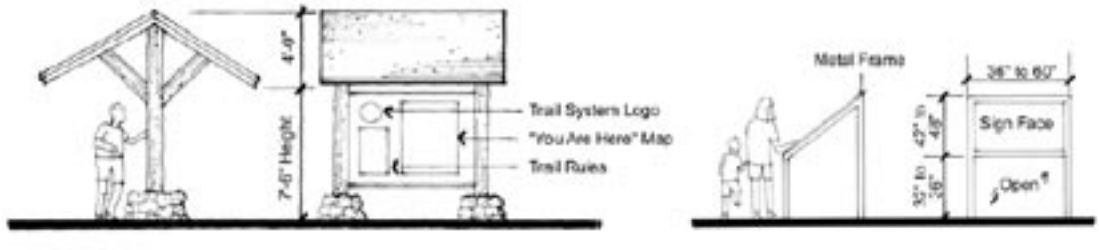


Figure 5.47 - Trailhead Information Installation Examples

Figure 5.48 illustrates a typical shared use path design, which is the most common design for Durham's trail and greenway network. This path is designed to accommodate two-way bicycle and pedestrian traffic, typically has its own right-of-way, and can accommodate maintenance and emergency vehicles. This type of trail is typically paved (asphalt or concrete) but can also be crushed stone or another smooth surface, as long as it meets ADA requirements. Wider soft shoulders should be provided for runners/joggers if space allows.

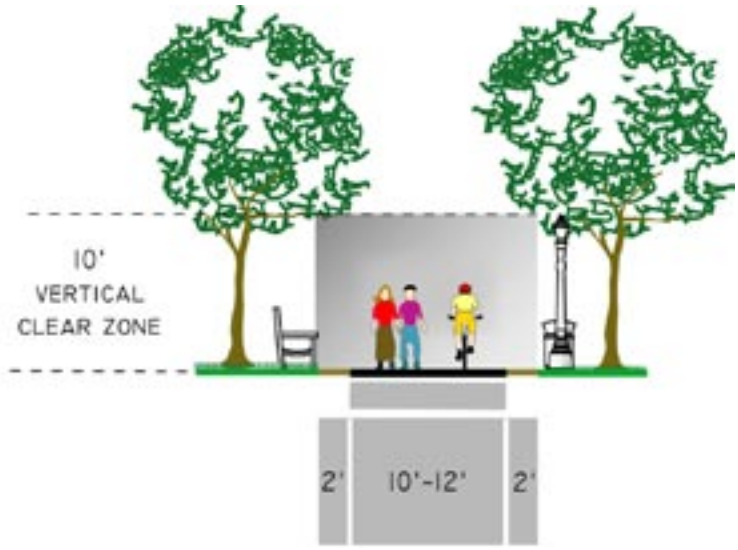


Figure 5.48 - Typical Shared Use Path Design

LOCAL NEIGHBORHOOD TRAIL

Neighborhood trails provide access for most, if not all, trail users within neighborhoods, parks, greenspaces, and other recreational areas. They are similar to regional trails in that they typically have their own right-of-way and serve only non-motorized users. These trails should be at least 8' wide if bicycle use is anticipated. All efforts should be made so that at least one ADA accessible trail is available and serves the most desirable parts of the area (i.e., picnic areas, viewpoints, playground equipment, etc.) Neighborhood and homeowner association groups are encouraged to identify connector trails, and complete a "new trail request form" through the City or fund a new trail through neighborhood dues to expedite the process.

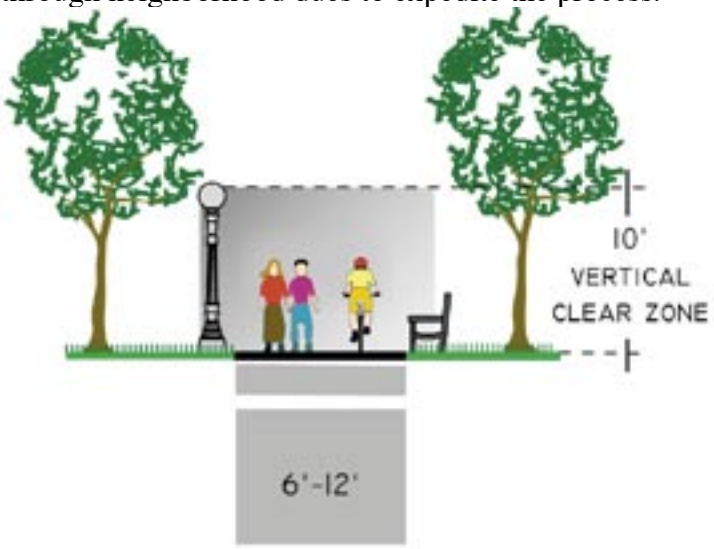


Figure 5.48 - Paved Neighborhood Trail

LOCAL TRAIL: ACCESSWAY

Accessways provide direct connections for trail users to schools, parks, community centers, retail areas, neighborhoods, and other trails. They are intended to be short, direct connections to reduce unnecessary out-of-direction travel for bicyclists and pedestrians. Accessways in parks, greenways, or other natural resource areas may have a 5' wide gravel path with wooden, brick or concrete edgings.

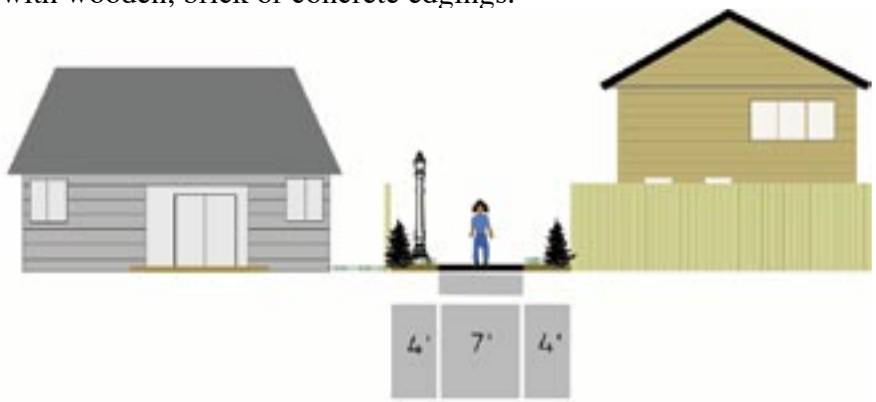


Figure 5.49 - Bicycle and Pedestrian Accessway

INNOVATIVE ACCESSWAYS

There are also other innovative ways to provide direct access, particularly in topographically constrained areas (i.e., on steep hills, over waterways, etc.) Stairs, alleyways, bridges, and elevators can provide quick and direct connections throughout the city and can be designed so they are safe, inviting, and accessible to most trail users. For example, stairways can have wheel gutters so that bicyclists can easily roll their bicycles up and down the incline and boardwalks can provide access through sensitive wet areas and across small waterways.

Figure 5.50 - Bicycle wheel gutters on stairs and boardwalk bridge

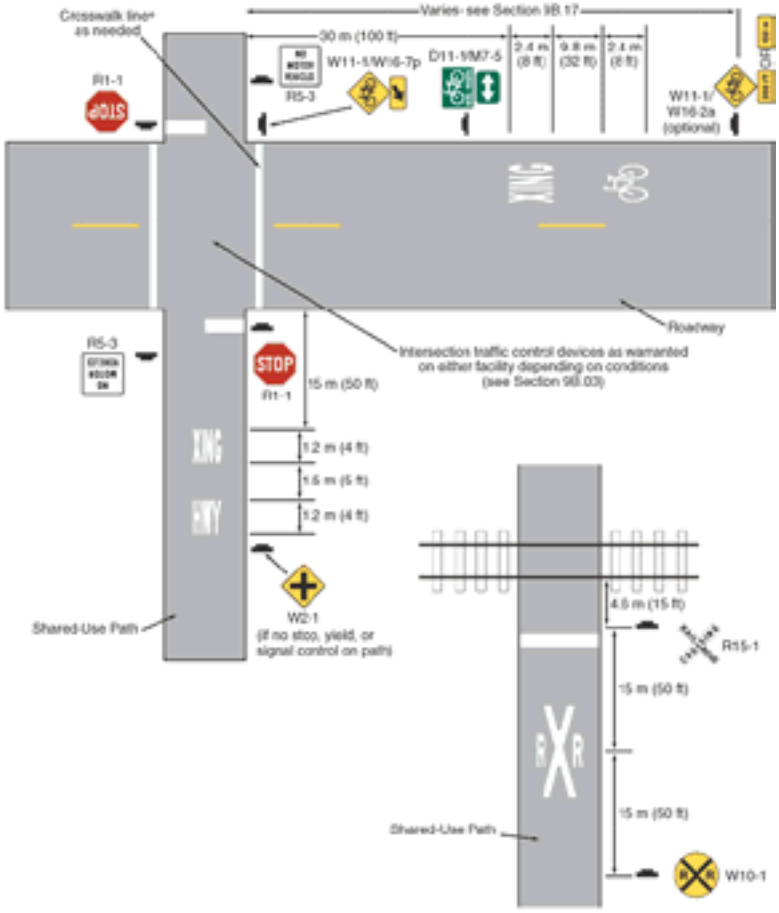


Figure 5.51 - MUTCD examples of signing and markings for shared use paths

Figure 5.52 - Multi-use trail approach towards an intersection

Figure 5.53 - Excellent existing Rocky Creek Trail directional and informational trail signage.

Wooden bollard with directional information

Inlaid medallions

Stone mileage marker

Figure 5.54 - Dual Purpose Bollard - Sign Hybrid Trail Markers

AMENITIES

There are a number of amenities that make a bicycle system inviting to the user. Below are some common amenities that make systems stand out.

Interpretive Installations

Interpretive installations and signs can enhance the users experience by providing information about the history of Durham. Installations can also discuss local ecology, environmental concerns, and other educational information.

Water Fountains and Bicycle Parking

Water fountains provide water for people (and pets, in some cases) and bicycle racks allow recreational users to safely park their bikes if they wish to stop along the way, particularly at parks and other desirable destinations.

Pedestrian-Scale Lighting and Furniture

Pedestrian-scale lighting improves safety and enables the facility to be used year-round. It also enhances the aesthetic of the trail. Lighting fixtures should be consistent with other light fixtures in the city, possibly emulating a historic theme.

Providing benches at key rest areas and viewpoints encourages people of all ages to use the trail by ensuring that they have a place to rest along the way. Benches can be simple (e.g., wood slates) or more ornate (e.g., stone, wrought iron, concrete).

Maps and Signage

A comprehensive signing system makes a bicycle and pedestrian system stand out. Informational kiosks with maps at trail heads and other pedestrian generators can provide enough information for someone to use the network with little introduction – perfect for areas with high out-of-area visitation rates, in addition to the local citizens.

Art Installations

Local artists can be commissioned to provide art for the trail system, making it uniquely distinct. Many trail art installations are functional as well as aesthetic, as they may provide places to sit and play.

5.12 Bicycle Parking

As more bikeways are constructed and bicycle usage grows, the need for bike parking will climb. Long-term bicycle parking at transit stations and work sites, as well as short-term parking at shopping centers and similar sites, can support bicycling. Bicyclists have a significant need for secure long-term parking because bicycles parked for longer periods are more exposed to weather and theft, although adequate long-term parking rarely meets demand.

When choosing bike racks, there are a number of things to keep in mind:

- The rack element (part of the rack that supports the bike) should keep the bike upright by supporting the frame in two places allowing one or both wheels to be secured.
- Install racks so there is enough room between adjacent parked bicycles. If it becomes too difficult for a bicyclist to easily lock their bicycle, they may park it elsewhere and the bicycle capacity is lowered. A row of inverted "U" racks should be installed with 15" minimum between racks.
- The inverted "U" shaped bicycle racks are preferential for short term parking due to their efficient use of space, ease of use and security, while bicycle lockers provide a safe and secure option for long term bicycle parking (Figure 5.62).
- Empty racks should not pose a tripping hazard for visually impaired pedestrians. Position racks out of the walkway's clear zone.
- When possible, racks should be in a covered area protected from the elements. Long-term parking should always be protected.

The table below provides basic guidelines on ideal locations for parking at several key activity centers as well as an optimum number of parking spaces.

Land Use or Location	Physical Location	Bicycle Capacity
City Park	Adjacent to restrooms, picnic areas, fields, and other attractions	8 bicycles per acre
City Schools	Near office entrance with good visibility	8 bicycles per 40 students
Public Facilities (city hall, libraries, community centers)	Near main entrance with good visibility	8 bicycles per location
Commercial, retail and industrial developments over 10,000 gross square feet	Near main entrance with good visibility	1 bicycle per 15 employees or 8 bicycles per 10,000 gross square feet
Shopping Centers over 10,000 gross square feet	Near main entrance with good visibility	8 bicycles per 10,000 gross square feet
Commercial Districts	Near main entrance with good visibility; not to obstruct auto or pedestrian movement	2 bicycles every 200 feet
Transit Stations	Near platform or security guard	1 bicycle per 30 parking spaces

Figure 5.55 - Recommended Guidelines for Bicycle Parking Locations and Quantities

Figure 5.56 - Bicycle parking sponsored by local merchants

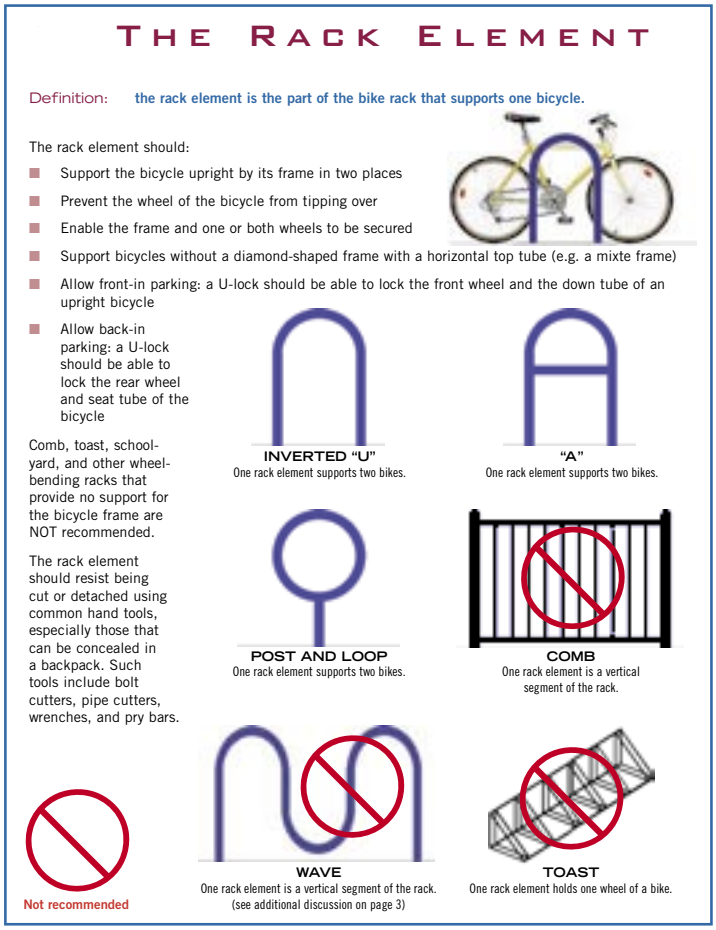


Figure 5.57 - Recommended bicycle parking facilities, Source: APBP (www.apbp.org)

Figure 5.58 - Example of a "U" shape bicycle rack.

Figure 5.59 - Example of a bicycle rack serving as a piece of utilitarian public art.

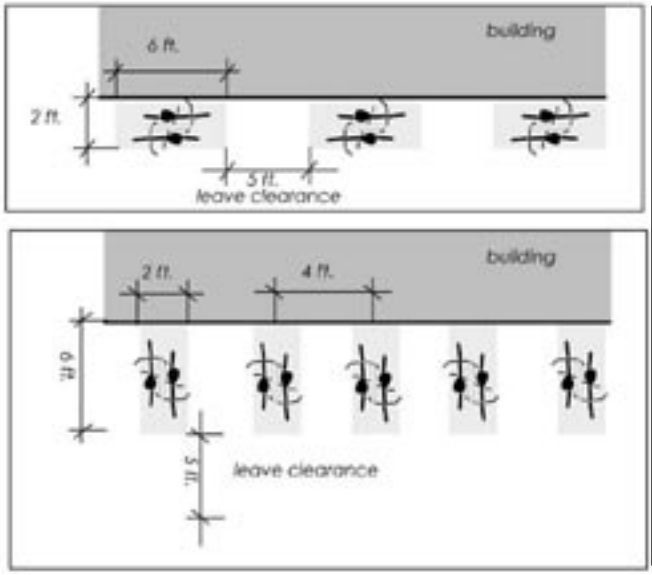


Figure 5.60 - Recommended bicycle parking spacing dimensions

Figure 5.61 - Although the bicycle rack illustrated in this case is not recommended, provision of shelter from rain greatly increases usefulness of this bicycle parking facility during inclement weather

Figure 5.62 - Bicycle lockers are a crucial component of the bicycle system. They offer safe and secure storage at transit centers and destinations. Parking rates are reasonable at about 3-5 cents an hour. (www.bikelink.org)

ATTENDED BICYCLE PARKING FACILITIES

Attended bike parking is analogous to a coat check – your bike is securely stored in a supervised location. An organization called The Bikestation Coalition is promoting enhanced attended parking at transit stations. The Bikestation concept is now in use in Palo Alto, Berkeley, San Francisco, Seattle, and Chicago. Bikestations offer secured valet bicycle parking near transit centers. What makes Bikestations distinctive are the other amenities that may be offered at the location – bicycle repair, cafes, showers and changing facilities, bicycle rentals, licensing, etc. Bikestations become a virtual one-stop-shop for bicycle commuters. Attended bicycle parking can be offered at some special events. For example, the Marin County Bicycle Coalition sponsors valet parking at many festivals in the county, the Sonoma County Bicycle Coalition sponsors valley parking at the downtown Santa Rosa Farmer's Market, and secured bicycle parking is offered at Pac Bell Park in San Francisco.

Figure 5.63 - Bikestation - Long Beach, California

FREE BIKE

Copenhagen, Denmark pioneered the concept of providing a fleet of bicycles for free public use throughout the urban center. The Danish free bikes are subsidized by advertising sales on the bicycles, and they require a coin or credit card deposit for use. The bicycles are single speed, durable and suitable only for short trips. Their design makes them less likely to be stolen. They can be picked up and dropped off at a variety of destinations – making them an easy choice for in-town travel by residents and visitors. A variety of similar programs utilize recycled bicycles or bicycles painted in a common color for free public use.

5.13 Bicycle Friendly Drainage Grates

Drainage grates usually occupy portions of roadways, such as bicycle lanes, where bicycles frequently travel. Often drainage grates are poorly maintained or are of a design that can damage a bicycle wheel or in severe circumstances, cause a bicyclist to crash. Improper drainage grates create an unfriendly obstacle a cyclist must navigate around, often forcing entrance into a motor vehicle lane in severe cases. Bicycle friendly drainage grates should be installed in all new roadway projects and problem grates should be identified and replaced.

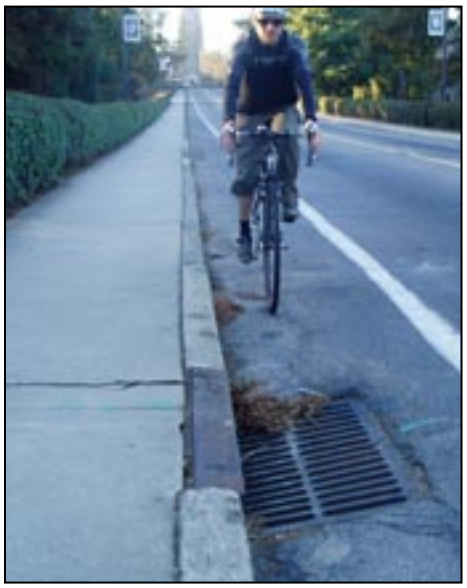


Figure 5.64 - Dangerous Drainage Grate Condition

Figure 5.65 - New Bicycle Friendly Drainage Grate on Martin Luther King Blvd in Durham

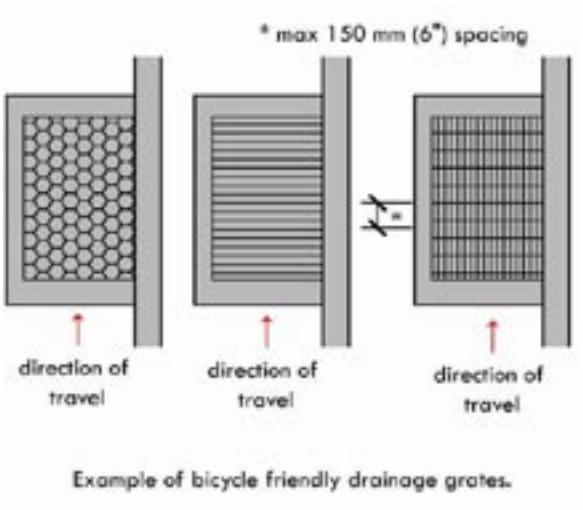


Figure 5.66 - Additional Bicycle Friendly Drainage Grate Designs