CHAPTER 4

On-Road Bicycle Facilities

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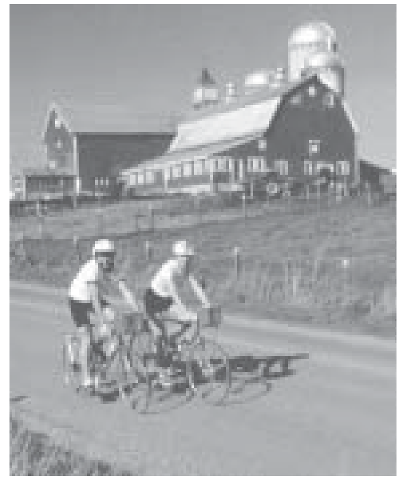
4.1 Introduction

This chapter covers on-road bicycle facilities — bicycle lanes, wide curb lanes, paved shoulders, and shared lanes — as well as related improvements and enhancements. Bicycle facilities that are well separated from the roadway such as shared use paths are discussed in Chapter 5, Shared Use Paths. Guidance on rail-trail conversions and rails-with-trails is provided in Chapter 6, Rail Trails.

Monkton



4.1.1 Application

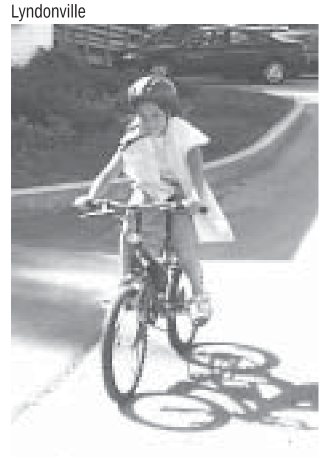
Most bicycling occurs on existing streets and roads because these facilities connect all destinations directly. Bicycle use is allowed on all roads in Vermont except for limited access highways where bicycles are legally prohibited. Therefore, all highways, except those where bicyclists are legally prohibited, should be designed and constructed under the assumption that they will be used by bicyclists. Bicycles should be considered in all phases of transportation planning, new highway design, highway reconstruction, and capacity improvement and transit projects.

Rutland

The most effective way to improve conditions for bicyclists and integrate them into the transportation system is to accommodate bicycle travel on all new and existing highways. Even if it were desirable to create a system of bikeways separated from the highway it would not be practical or affordable. Shared use paths and rail trails should be thought of as a complementary system of off-road routes for bicyclists and others that serves as an extension to the roadway network. Separated facilities should not be used to preclude on-road bicycle facilities. Rather they should be used to supplement on-road bikeways.

In general, low volume rural roads satisfactorily accommodate large numbers of bicyclists annually and could better accommodate cycling through the implementation of marginal improvements. On higher volume rural roads, paved shoulders provide increased operating width for bicyclists and motorists as do bicycle lanes on major streets in downtown and village settings. Wide curb lanes and shared roadways are used where width constraints prevent the development of separate lanes or paved shoulders of adequate width to serve bicyclists.

Lyndonville



Accommodating bicycles begins with the understanding that bicyclists vary greatly in age, skill, dimensions and needs.

4.2 Design Considerations

4.2.1 Bicycle and User Characteristics

Bicycle Characteristics

Bicycle Styles and Dimensions. The three most popular styles of multi-geared adult bicycles available today are: the road bike (also called a touring or racing bike), the mountain bike (characterized by wide, fat smooth or knobby tires) and the hybrid bike (which blends the agility of the road bike and the durability and upright riding position of the mountain bike).

Variations of these styles abound with regard to gearing, passenger and baggage carrying capability, and rider position.

Use the following criteria and the dimensions illustrated in Figure 4-1 to determine typical requirements for facility design and storage details:

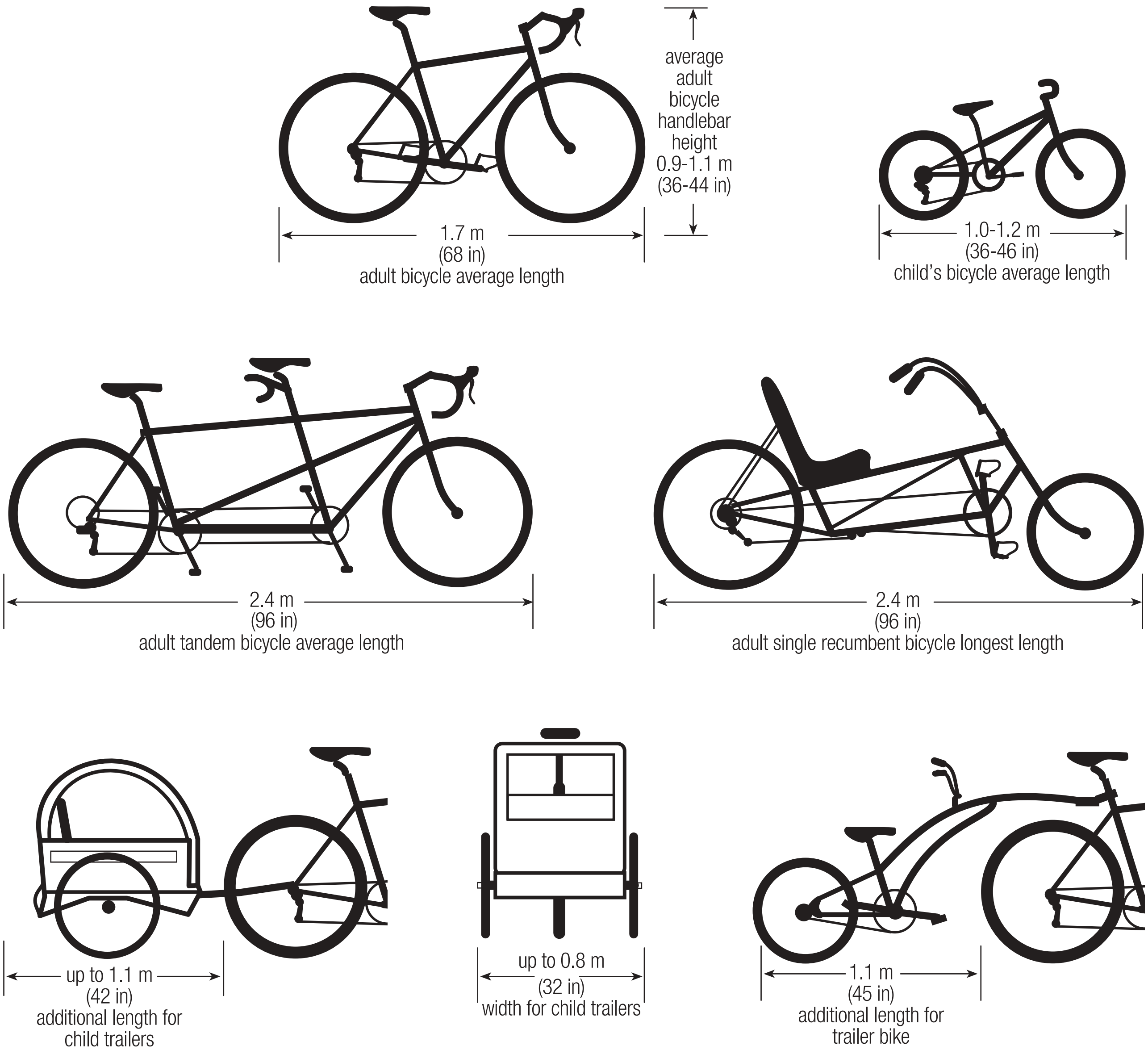


Figure 4-1.
Bicycle Styles and Dimensions.

An adult tandem bicycle averages 2.4 m (96 in) in length and can easily attain a speed in excess of 50 km/h (30 mph) on even a modest downhill.

Wheels and tires. The wheels and tires of a bicycle are narrow and sensitive to variations, imperfections and debris in the riding surface. In addition, the pressure in bicycle tires is high compared to other, larger vehicles. This makes bicycle tires more susceptible to damage and punctures from potholes, small pieces of glass, sharp stones and pieces of metal. Sensitive to these characteristics, bicyclists sometimes must suddenly swerve to avoid an obstacle in their path, a maneuver that may appear unpredictable or erratic to a motorist sharing the same lane.

Design considerations include:

- Minimal tire surface contact with the ground (as little as 2 sq cm or 0.3 sq in.).
- Road shock transmitted directly through the bicycle to the rider (many bicycles

do not have suspensions systems).

- Sand, mud, algae, snow, wet or icy leaves, metal utility covers and decking, and skewed railroad tracks can precipitate a crash.
- Longitudinal seams and cracks (as narrow as 6 mm or 0.25 in) can cause loss of control.
- Surface edges and objects higher than 12 mm (0.5 in) can damage some rims or cause a crash.
- Underlying concrete roadways, which are common in Vermont, often create longitudinal cracks that wander on and off the shoulder and pose a significant hazard to bicyclists.

Brakes and braking.

Design considerations include:

- Reaction and braking times vary widely among users (allow 2.5 sec normal reaction time, allow 3.0 sec more for a surprised reaction time).
- Application of the brake and mechanical delay can account for 1.5 sec of additional braking time.
- Maximum deceleration for a bicycle is 17 km/s^2 (11 mph per sec).
- When rims are wet or coaster brakes are used, performance is 50 to 80 percent less efficient.

Steering. Bicyclists maintain balance by steering the front wheel of the bicycle under the combined center of gravity of both bicycle and rider.

Consequently, emergency or evasive steering maneuvers cannot be accomplished quickly by most bicyclists. The initiation of an intentional sudden turn is counter-intuitive (i.e., the rider must sharply steer the front wheel out from under the center of gravity in the opposite direction he or she intends to go to set up the sudden turn).

Design considerations include:

- Emergency turns cannot be accomplished as quickly on a bicycle as in an automobile.
- To initiate a turn the operator must first steer the bicycle in the opposite direction to set up a counter lean (precipitating a controlled fall).
- Allow 1.5 sec to set up a normal turn.
- Bicycles steer more slowly when heavily loaded.
- The lower the center of gravity the more stable the bicycle (high loads such as rider-mounted backpacks and bicycle-mounted child seats raise the center of gravity and make a bicycle less stable).

Tracking widths and grades. Due to steering wobble, bicyclists may track over a 1.0 m (40 in) width. An increase in climbing grade can generate more wheel wobble due to the slower speed, requiring even more operating width. Also, extra operating width on descents can allow bicyclists to more safely avoid debris or surface hazards at higher speeds. Therefore, where practicable, it is desirable to provide a paved shoulder or bicycle lane at least 1.8 m (6 ft) in width on uphill and downhill grades that exceed 5 percent to provide bicyclists with additional space for maneuvering.

With multi-geared bicycles, many bicyclists can comfortably manage 10 percent grades for short distances. Experienced bicyclists can accomplish steeper grades for much longer distances (e.g., the 13 percent grade on Vermont Route 132 between

South Strafford and Sharon). Grades of 5 percent are the more common limit, with grades of 4 percent or less preferred by the majority of bicyclists.

Design considerations include:

- Average operating width on level terrain is 1 m (40 in).
- Average operating width over hilly terrain is 1.2 to 1.4 m (4 to 6 ft).
- Preferred grade is 4 percent (1:25) or less.
- Acceptable grades over limited distances range from 6 to 10 percent (1:16 to 1:10).

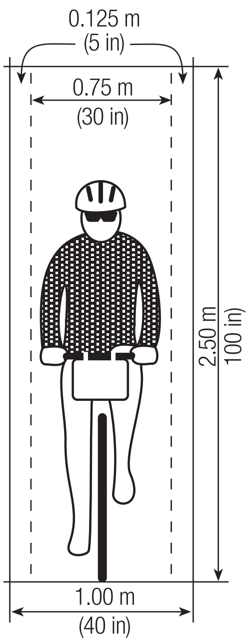


Figure 4-2.
Bicyclist's Operating Space

User Characteristics

Although riders vary greatly in age, skill, dimensions and needs, the characteristics below encompass virtually all bicyclists:

Table 4-1.
User Characteristics and Speeds.

User Characteristics	Metric	English
Design viewing height	1.35 m	54 in
Center of gravity (adult, child varies)	0.84-1.02 m	33-40 in
Speeds (by age)	**Metric**	**English**
Child (4-8 years)	10-14 km/h	6-9 mph
Youth (9-12 years)	11-17 km/h	7-11 mph
Young adult (13-18 years)	13-24 km/h	8-15 mph
Adult	13-24 km/h	8-15 mph
Proficient adult	19-38 km/h	12-24 mph
Senior adult	13-24 km/h	8-15 mph
Cycling club pace lines	24-50 km/h	15-30 mph
Design speeds	**Metric**	**English**
Design speed (crossing intersections)	15 km/h	10 mph
Design speed (level terrain — paved)	30 km/h	20 mph
Design speed (unpaved)	24 km/h	15 mph
Design speed (downhill)	50 km/h	30 mph
Design speed (uphill)	8-19 km/h	5-12 mph

The slender profile of bicyclists may make them difficult for motorists to see, especially in complex visual situations.

Profile and visibility. Most motorists involved in car-bicycle crashes report they did not see the bicyclist before the crash. Their slender profile (and sometimes low height) of bicyclists may make them difficult to see, especially in complex visual situations. The problem is even worse in low light conditions or at night. Bicyclists can improve their own visibility by making sure their bicycles are properly equipped with reflectors, wearing bright clothing, using retro-reflective fabrics, using flashing tail lights at night, and using headlights at night. However, motorists need to be on the lookout for bicyclists. Ultimately, increased bicycle use will result in increased motorist awareness.

Considerations for design include:

- Bicyclists exhibit a thin or low profile.
- Their curbside location can reduce their being seen by overtaking, turning or parked motorists.
- Signs and stripes can warn motorists to expect increased bicycle use.
- Even when using lights, bicyclists are extremely difficult to detect under low light conditions or at night time.
- Motorists should be trained and expected to detect bicyclists more readily.

4.2.2 Bicycle Crash Types

Approximately 900 bicyclists are killed each year in motor vehicle crashes nationwide. This is but a fraction of the injuries that occur from car-bike crashes. According to *Pedestrian and Bicycle Crash Types of the Early 1990s (1996)*, 1991 data from the General Estimates System indicated that an additional 67,000 bicyclists reported injuries as a result of colliding with a motor vehicle. Many more injuries go unreported. A study by Stutts, et al. (1990) showed that fewer than two-thirds of bicycle-motor vehicle crashes were serious enough to require emergency room treatment.

In 1996, NHTSA sponsored additional research to further refine and update crash type distributions. This research resulted in a study, *Pedestrian and Bicycle Crash Types of the Early 1990s*, that identified 85 individual crash types, although, through assimilation, all crash types could be grouped into just three crash type groups: 1) specific circumstances; 2) the bicycle and motor vehicle on parallel paths; and 3) the bicycle and motor vehicle on crossing paths.

The **specific circumstances** group accounted for 7 percent of all crashes. Accident sub-types in this group were:

Table 4-2.
Bicycle Crash Types, Specific Circumstances Group.

Specific circumstances group	Percent
Crashes in parking lots and other non-roadway areas	3.7
Other “weird” types	3.2
Group total	6.9

The **bicycle and motor vehicle on parallel paths** group accounted for 36 percent of all crashes. Accident sub-types in this group were:

Table 4-3.
Bicycle Crash Types, Bicycle and Motor Vehicle on Parallel Paths Group.

Bicycle and motor vehicle on parallel paths group	Percent
Motorist turned or merged into path of bicyclist	12.1
Bicyclist turned or merged into path of motorist	7.3
Either operator on wrong side of street	2.8
Motorist overtaking bicyclist	8.6
Bicyclist overtaking motorist	2.7
Motorist loss of control	0.6
Bicyclist loss of control	1.8
Group total	35.9

The **bicycle and motor vehicle on crossing paths** group accounted for 57 percent of all crashes. Accident sub-types in this group were:

Table 4-4.
Bicycle Crash Types, Bicycle and Motor Vehicle on Crossing Paths Group.

Bicycle and motor vehicle on crossing paths group	Percent
Bicyclist did not clear intersection	1.4
Motorist failed to yield	21.7
Bicyclist failed to yield, midblock rideout	11.7
Bicyclist failed to yield, intersection rideout	16.8
Motorist turning	0.7
Bicyclist turning	0.7
Crash occurred at intersection	4.1
Group total	57.1

Major findings of this study include:

- Driveways and other junctions account for 3 out of 4 crashes. Design facilities with this in mind.
- Young bicyclists under the age of 15 (and particularly 10 to 14) are over-represented in crashes with motor vehicles. Bicyclists older than 44 are over represented with regard to serious and fatal injury.
- Crashes with motor vehicles result in serious and fatal injuries 18 percent of the time.
- Two-thirds of bicycle-motor vehicle crashes occur during late afternoon and evening hours. Exposure is high during this period and visibility can be a problem.
- Two-thirds of the crashes occurred in urban areas.
- About 60 percent of road-related crashes occurred on two-lane roads.
- Roads with narrow lanes and higher speed limits are over-represented with regard to serious and fatal injury.

As a result of the study, the researchers concluded that a system-wide approach — including engineering, education and enforcement — is needed if the goals of the National Bicycling and Walking Study (refer to VTrans Bicycle Policy) are to be met.

4.2.3 Types of On-Road Bikeway Facilities and Treatments

The types of on-road bicycle treatments include:

- *Bicycle lane*. A portion of the roadway that has been designated by signs and pavement markings for preferential or exclusive use by bicyclists.
- *Wide curb lane*. A wider than normal travel lane that better accommodate bicycles and motor vehicles in the same lane while providing enough space for motorists to overtake and pass bicyclists without changing travel lanes.
- *Paved shoulder*. –The paved portion of the highway contiguous with the outside travel lane of the roadway that can be used by bicyclists as well as for the accommodation of pedestrians, stopped vehicles, emergency use and the lateral support of sub-base, base and surface courses.
- *Shared lanes*. Travel lanes with no additional width provided for bicyclists.
- *Incremental improvements*. Any change in infrastructure that benefits bicyclists.

including bicycle-safe drainage grates, minimal additional width, signing, pavement markings, etc.

In addition, traffic calming techniques can effectively reduce the speed of motor vehicles along a roadway (refer to Chapter 7, Traffic Calming) and signs and pavement markings may be used to alert motorists of increased bicycling activity in certain locations, designate routes and convey information to bicyclists (see Chapter 8, Signs, Pavement Markings and Signals).

4.2.4 Selecting Appropriate Bicycle Facilities

The wide variation in ability, needs and desires among bicyclists can make it difficult to plan and design facilities that meet all the needs of these users.

Indeed, no one type of bicycle facility or highway design will suit all bicyclists and no bicycle facility can overcome a lack of bicycle operator skill. It is important to recognize that the choice of any one particular design will affect the type of rider that will be attracted to a facility, the level of use along the facility, and the level of access and mobility that will be afforded to bicyclists.

Design users. Accommodating bicyclists begins with the understanding that not all bicyclists are alike. The characteristic that best differentiates bicyclists is ability, which may be defined as a combination of skills, knowledge and judgment.

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The Bicycle Federation of America estimates that one out of three people (100 million) in the United States own a bicycle, yet it is believed that fewer than 5 percent of these bicycle owners qualify as experienced or highly skilled bicyclists. Therefore, the vast majority of bicycle riders may be considered intermediate and novice bicyclists.

Group A bicyclists include experienced riders who have a level of comfort operating in traffic conditions.

The 1994 FHWA report, *Selecting Roadway Design Treatments to Accommodate Bicyclists*, identified three general categories of bicycle user types (A, B and C) to assist highway designers in choosing different facility types for different roadway conditions for different types of bicyclists. AASHTO recognizes the same bicycle user types in their *Guide for the Development of Bicycle Facilities*.

The three general bicycle user types are:

Group A — Advanced Bicyclists

These bicyclists exhibit the following characteristics:

- Experienced riders.
- Have a level of comfort operating in traffic conditions.
- Use existing roadway system.
- Operate at maximum speed with minimum delay.
- Require minimal operating space on the roadway or shoulder to reduce the need for either the bicyclist or the motor vehicle operator to change position when passing.

Group A bicyclists are best served by:

- Wide outside lanes on urban arterials and collectors.
- Usable shoulders on rural highways.

Group B bicyclists are less confident of their ability to operate in traffic without special provisions for bicycles.

Group B — Basic Bicyclists

Group B bicyclists exhibit the following characteristics:

- Casual or new adult or teenage riders.
- Less confident of their ability to operate in traffic without special provisions for bicycles.

- Some will become advanced bicyclists, most will remain basic riders.
- Prefer low-speed, low traffic-volume streets or designated bicycle facilities.

Group B bicyclists are best served by:

- Extra operating space when riding on the roadway.
- Ensuring low speeds on neighborhood streets.
- Network of designated bicycle facilities (bicycle lanes, side-street bicycle routes and shared-use paths.
- Usable shoulders on rural highways.

Group C — Children

The bicycle riders that comprise Group C share these traits:

Group C bicycle riders include children and pre-teens who may not comply with traffic regulations.

- Children, usually pre-teen riders.
- Roadway use initially monitored by parents.
- May not comply with traffic regulations.
- They (and their parents) prefer residential streets with low motor vehicle volumes and speed limits, and well-defined separation of bicycles and motor vehicles or separate pathways.

Group C bicycle riders are best served by:

- Ensuring low speeds on neighborhood streets.
- Extra operating space when riding on the roadway or facilities separated from motor vehicle traffic.
- Network of designated bicycle facilities (bicycle lanes, paved shoulders, side-street bicycle routes, shared use paths, and rail trails.
- Riding on a sidewalk where pedestrians are not endangered or when pedestrian activity is low.

The design values in this chapter are aimed at meeting the needs of all bicyclists including Group B and C riders.

As a goal, a particular bicycle facility design should be chosen to encourage use by the lowest caliber bicyclist expected to frequently use the facility. For basic adult and child bicyclists (Groups B and C), bicycle lanes, wide curb lanes and paved shoulders — facilities that provide extra operating space on a roadway — or an alternate route using neighborhood streets, or shared use paths and rail trails are the design treatments that are favored.

As a goal, a particular bicycle facility design should be chosen to encourage use by the lowest caliber bicyclist expected to frequently use the facility.

Often, physical constraints are encountered that prevent consideration of these types of facilities. Therefore, design treatments that consume less width may have to be considered. At a minimum, facilities that accommodate the needs of the more skilled Group A bicyclists — shared lanes, paved shoulders and wide curb lanes — should be used as a guide to selecting the minimum design treatment for *any* roadway on which accommodations for bicycles are provided.

Marginal improvements (refer to Section 4.7, Marginal Improvements) should be considered for all roadways on which bicycle use is not prohibited.

Supplemental Guidance

Two resources that can aid designers in the selection of appropriate on-road bicycle facilities are AASHTO's *Guide for the Development of Bicycle Facilities* and FHWA's *Selecting Roadway Design Treatments to Accommodate Bicycles*.

4.3 Bicycle Lanes

Bicycle lanes, also called "bike lanes," are defined in the MUTCD as "a portion of a roadway that has been designated by signs and pavement markings for preferential or exclusive use by bicyclists." They are most commonly used in urban or village settings where a designated bike facility will aid the orderly flow of motorist and bicyclist traffic. These settings typically include numerous driveways, turning movements or other potential conflicts that indicate that bike lanes are a good design option. Refer to VTrans Standard Drawings for design details.

South Burlington

Bicycle lanes, designated by signs, stripes and symbols, are intended for the preferential or exclusive use of bicyclists.

Features of Bicycle Lanes

- Are not physically separated from travel lanes.
- Designated by signing and pavement markings (including lane striping <u>and</u> lane symbols).
- Intended for preferential or exclusive use of bicyclists.
- Provides increased operating width for bicyclists.
- Provides for more predictable movements of motorists and bicyclists.
- Motorists and bicyclists are less likely to veer out of their own lanes.
- Vary in width depending on conditions.

4.3.1 Design Considerations

- Bicycle lanes should be one-way facilities.
- Bicycle lanes should carry bike traffic in the same direction as adjacent traffic (i.e. on the right side of the street or road).
- Bicycle lanes should never be placed between a parking lane and the curb.
- Pavement surfaces should be level and smooth.
- Where drain inlets and utility covers are present in bicycle lanes, they should be bicycle-safe and adjusted flush with the roadway surface.
- Delineate bicycle lanes from motor vehicle lanes with a 150 mm (6 in) solid white stripe. For added distinction, a 200 mm (8 in) solid white stripe may be used.
- Bicycle lanes should be delineated from parking lanes with a 100 mm (4 in) solid white stripe where no parking lane stripes or tick marks exist.
- Short distance, two-way lanes may be considered where the need to make a double crossing of a busy street or use of a sidewalk might otherwise be required.
- Where bicycle lanes exist in advance of a roundabout terminate bicycle lane striping at the pedestrian crosswalk. See Sections 7.2.3 and 7.2.4 for additional design considerations at roundabouts.

Bicycle Lane Symbols

General design considerations and recommendations

- Designate bicycle lanes by signing, lane striping <u>and</u> lane symbols:
- Either a bicycle symbol (preferred) or a word legend (optional) may be used as a lane symbol.
- A directional arrow must be used in combination with the bicycle symbol or word legend.
- Center symbols in the bicycle lane.
- Place symbols on the far side of each intersection to alert drivers and bicyclists of the exclusive or preferential nature of the bicycle lane. Symbols shall be placed

no closer than 20 m (65 ft) from the intersection or cross road. Supplementary symbols may be placed on the near-side of an intersection to warn bicyclists not to enter a bicycle lane on the wrong side of the road.

- Place additional symbols periodically along uninterrupted sections of the bicycle lane at the following rate:

  For metric calculations
  Multiply speed in km/h times 7 (e.g., 60 km/h X 7 = approx. 420 m);

  For English calculations
  Multiply speed in mph times 40 (e.g., 35 mph X 40 = approx. 1400 ft).

- In order to increase longevity of the symbol, do not place symbols in areas such as driveways where motor vehicles are expected to travel over the symbol.

The preferred bicycle lane symbol is as shown in Figure 4-3.

Refer to Section 8.3.2, Markings, in Chapter 8, Signs, Pavement Markings and Signals, for additional guidance on approved designs and placement of pavement markings and signs for bicycle lanes.

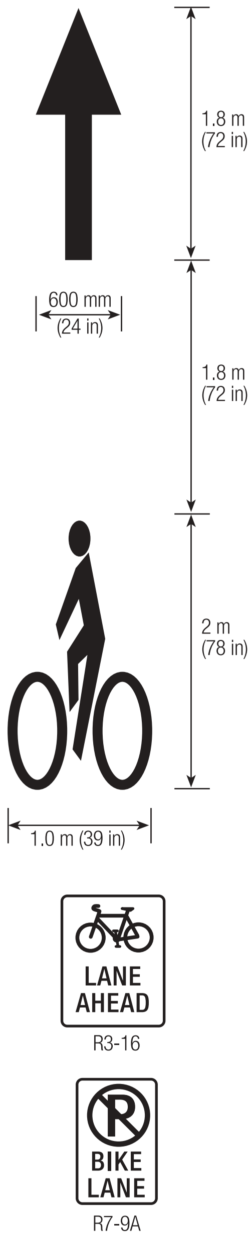


Figure 4-3
Bicycle Lane Symbol and Signs

4.3.2 Width

The widths for bicycle lanes in village centers and urban environments appear in Tables 4-6 through 4-9. Greater widths may be required where higher traffic volumes, traffic speeds, heavy vehicles or limited sight distances exist. Also, the width of a bike lane may need to be adjusted where curbing, adjacent on-street parking or other features from which a bicyclist may shy away exist.

Additional bike lane width is recommended where there are 30 or more overtaking heavy vehicles per hour in a single outside lane. Use the following formula to calculate this from existing traffic data.

How to Calculate the Number of Overtaking Heavy Motor Vehicles per Hour in a Single Outside Lane.

Heavy vehicle volume is usually expressed in percent AADT. However, use of these percentages alone can be misleading. For example, as much as 25 percent of the traffic using a particular roadway may consist of heavy vehicles. But if the total traffic volume is low, fewer than 30 heavy or large vehicles may overtake a bicyclist within an hour's time. To compute the number of heavy vehicles that will overtake a bicyclist in one hour, use the formula below:

$$HV_{OT} = \frac{[AADT \times SP_V]}{[SP_T \times L]} \times \frac{[R_{HV} - R_B]}{[R_{HV}]} \times HV\%$$

Where:

HV_{OT} = Number of overtaking heavy vehicles per hour
AADT = Total traffic volume (both directions)
SP_V = Percent share of the traffic volume per study period (typically 0.4 or 40 percent)
SP_T = Length of study period in hours (typically 7 hours from 9 a.m. to 4 p.m.)
L = total number of travel lanes in both directions (typically 2 as trucks tend to travel in outside lanes)
R_{HV} = Rate of the faster moving heavy vehicle (in miles per hour)
R_B = Rate of slower moving bicycle vehicle (typically 10 miles per hour)
HV% = Percentage of heavy vehicles (expressed in a percentage of AADT)

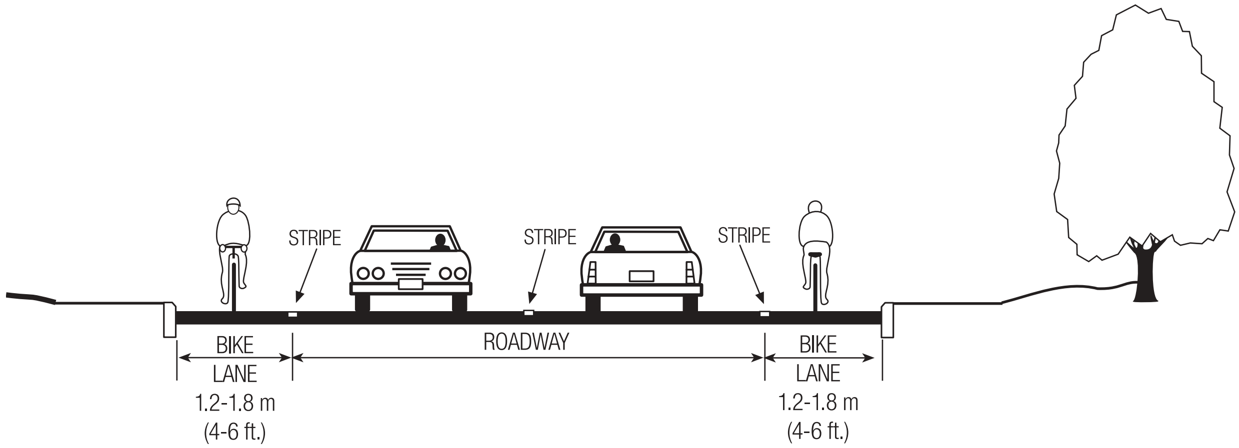


Figure 4-4.
Bicycle Lane, Curbed Street, No Parking.

Table 4-5.
Bicycle Lane, Curbed Street, No Parking

Minimum[(a)(b)]	Conditions
1.2 m (4 ft)	Urban or village curbed street where parking is not permitted and bicycle lanes are provided next to the curb
Preferred[(b)]	**Conditions**
1.8 m (6 ft)	Where bicycle use is high, where in-line skaters are expected, or along grades over 5 percent.

[(a)] Add 0.3 m (1 ft) on bridges or where there are 30 or more overtaking heavy vehicles per hour in a single outside lane.

[(b)] Width measured from the curb face to the center of the bike lane stripe.

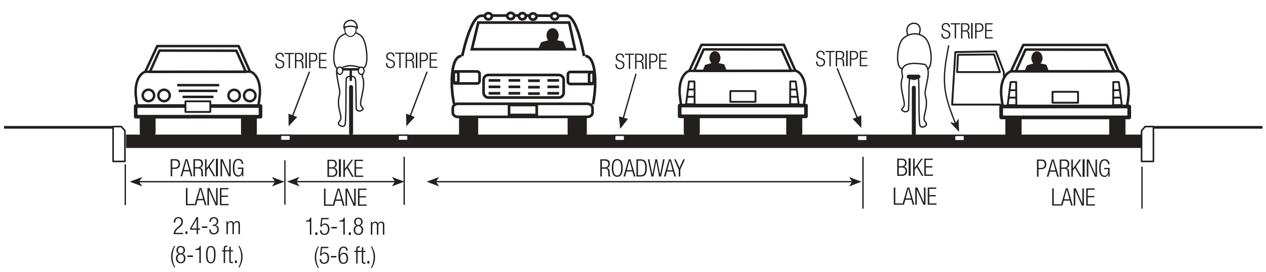


Figure 4-5.
Bicycle Lane, Curbed Street, with Parking.

Table 4-6.
Bicycle Lane, Curbed Street, with Parking

Minimum[(a) (b)]	Conditions
1.5 m (5 ft)	Urban or village curbed street where a delineated parking lane is provided.
Preferred[(b)]	**Conditions**
1.8 m (6 ft)	Urban or village curbed street where a delineated parking lane is provided, where bicycle use is high, where in-line skaters are expected or along grades over 5 percent.

[(a)] Add 0.3 m (1 ft) on bridges or where there are 30 or more overtaking heavy vehicles per hour in a single outside lane.

[(b)] Width measured from the curb face to the center of the bike lane stripe.

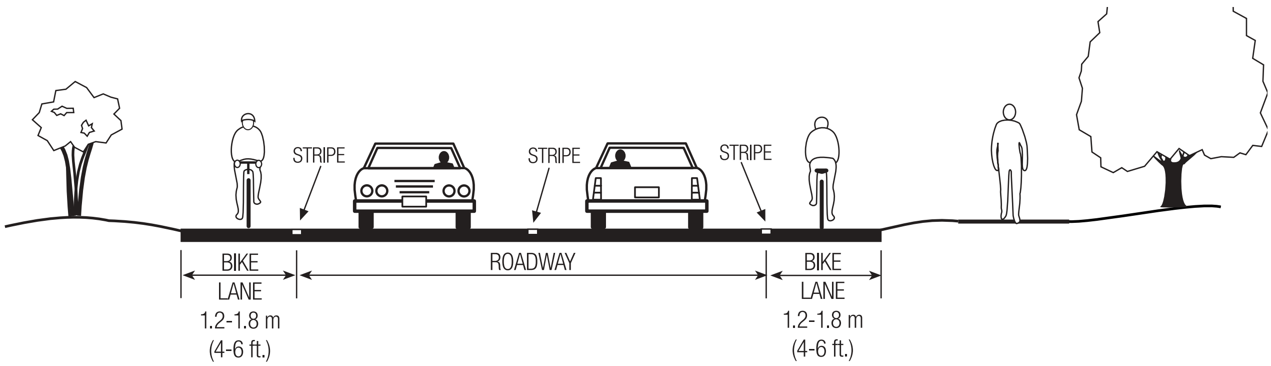


Figure 4-6.
Bicycle Lane, Street or Highway, No Curb, No Parking.

Table 4-7.
Bicycle Lane, Street or Highway, No curb, No Parking

Minimum[a]	Conditions
1.2 m (4 ft)	Ideal conditions (i.e., where certain edge conditions do not dictate additional bicycle lane width).
Preferred[b]	Conditions
1.5 m (5 ft)	Highways without curbs; vehicle speeds are 56 km/h (35 mph) or less.
1.8 m (6 ft)	Highways without curbs; where vehicle speeds exceed 56 km/h (35 mph).
1.8 m (6 ft)	Where bicycle use is high, where in-line skaters are expected or along grades over 5 percent.

[a] Add 0.3 m (1 ft) on bridges or where there are 30 or more overtaking heavy vehicles per hour in a single outside lane.

[b] Width measured from the curb face to the center of the bike lane stripe.

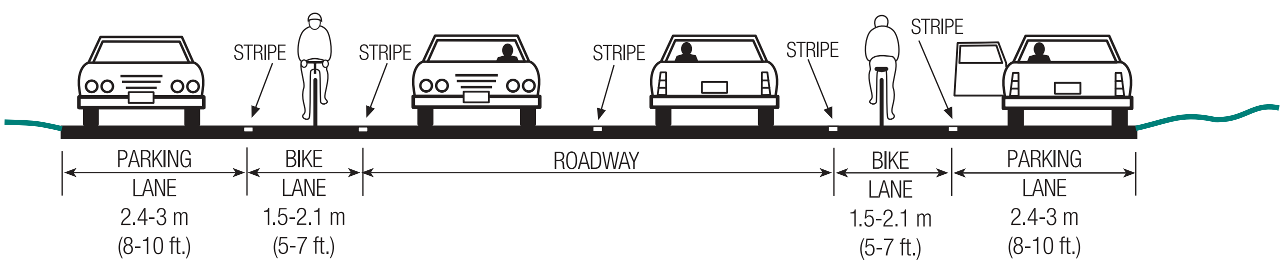


Figure 4-7.
Bicycle Lane, Street or Highway, No Curb, with Parking.

Table 4-8.
Bicycle Lane, Street or Highway, No Curb, with Parking

Minimum[a]	Conditions
1.5 m (5 ft)	Ideal conditions (i.e., where certain edge conditions do not dictate additional bicycle lane width).
Preferred[b]	Conditions
1.8 m (6 ft)	Highways without curbs; vehicle speeds are 56 km/h (35 mph) or less.
2.1 m (7 ft)	Highways without curbs; where vehicle speeds exceed 56 km/h (35 mph).
2.1 m (7 ft)	Where bicycle use is high, in-line skaters are expected or along grades over 5 percent.

[a] Add 0.3 m (1 ft) on bridges or where there are 30 or more overtaking heavy vehicles per hour in a single outside lane.

[b] Width measured from the curb face to the center of the bike lane stripe.

4.3.3 Practices to Avoid

Avoid the following unsafe designs:

Left-side bicycle lanes. Do not locate a bicycle lane on the left side of a one-way street because it creates unexpected conflicts at intersections. A rare exception is when the number of conflicts can be substantially decreased, such as may be created by heavy bus traffic or unusually heavy right-turning movements, angled on-street parking, or where there are a significant number of left-turning bicyclists.

Two-way bicycle lanes. Do not use two-way bicycle lanes. A rare exception occurs on the left side of a one-way street when the number of conflicts can be substantially decreased. Refer to Section 4.3.6, Contra-flow Bicycle Lanes.

Bicycle lanes on one side of a two-way street. Do not place a bike lane in only one direction of travel on a two-way street. This can lead to wrong-way riding as bicyclists may perceive the facility to be intended for two-way use. If limited road space is available, it may be preferable to have wide outside lanes in both directions rather than one bike lane in one direction. The exception is when there is only adequate space for one bike lane on a street with a severe grade. In that case, placing a single bike lane in the uphill direction addresses the slower operating speed and greater operating space that will be exhibited by uphill bicyclists.

Bicycle use on bridge sidewalks. Where bridge sidewalks are wide enough for bicycle use, ramps that provide a lateral transition from the roadway to the sidewalk should be provided, especially where motor vehicle volumes and speeds are high, the bridge is long and the outside lanes or shoulders on the bridge are narrow. Ramps should be a minimum of 2.4 m (8 ft) in length and have flared edges as shown in Figure 4-8.

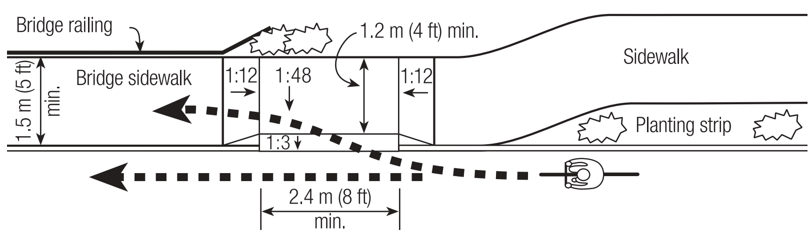


Figure 4-8.
Lateral Transition from Roadway to a Bridge Sidewalk.

Where bicycle use of bridge sidewalks is permitted, the minimum height of a bridge railing along a sidewalk is 1.05 m (42 in). Where extra safety is desired, the preferred height of a bridge railing is 1.35 m (54 in).

Extruded curbs. Do not use extruded asphalt curbs or rolled curbs to separate motor vehicles and bicycles for the following reasons:

- Both motor vehicles and bicycles can hit the curb, lose control, and cross into the path of the other user.
- Because asphalt curbs lack structural strength, they are easily broken if hit by motor vehicles or maintenance equipment, which may result in loose pieces of asphalt being scattered over the riding surface.
- At night, extruded curbs may be hard to see because they are usually the same color as the adjacent pavement. They also cast shadows on the lane, further reducing a bicyclist's visibility of the riding surface.
- Extruded curbs are difficult to maintain, are easily damaged by snow plows and trap and collect debris, sand and leaves.

Reflectors and raised pavement markers. Do not use raised obstructions, such as reflectors or raised pavement markers to delineate a lane that bicyclists may use. These obstacles can deflect bicycle wheels and cause loss of control and create problems for maintenance workers.

4.3.4 Bicycle Lanes at Intersections

When a bicycle lane meets an intersection:

- Do not extend bicycle lane striping across pedestrian crosswalks.
- Do not extend bicycle lane striping through street intersections.
- Where crosswalks are not provided, stop bicycle lane striping prior to the near-side cross-street out of the path of turning vehicles. Resume striping on the far-side of the cross-street.
- Dotted guidelines may be extended through complex intersections or multi-lane roundabouts.
- At uncontrolled intersections where right-turning traffic volumes are low, solid bicycle lane striping may continue to the near-side of the cross-street.
- At uncontrolled intersections where right-turning traffic volumes are high or where a bus stop is located, use a dotted line with 0.6 m (2 ft) dots and 1.8 m (6 ft) spaces for the length of the bus stop. Resume solid striping at the far-side of the cross-street (refer to Fig. 4-9A).
- Where a bus stop is located on the far-side of an intersection, use a dotted line with 0.6 m (2 ft) dots and 1.8 m (6 ft) spaces for the length of the bus stop, usually 24 m (80 ft) (refer to Fig. 4-9A).

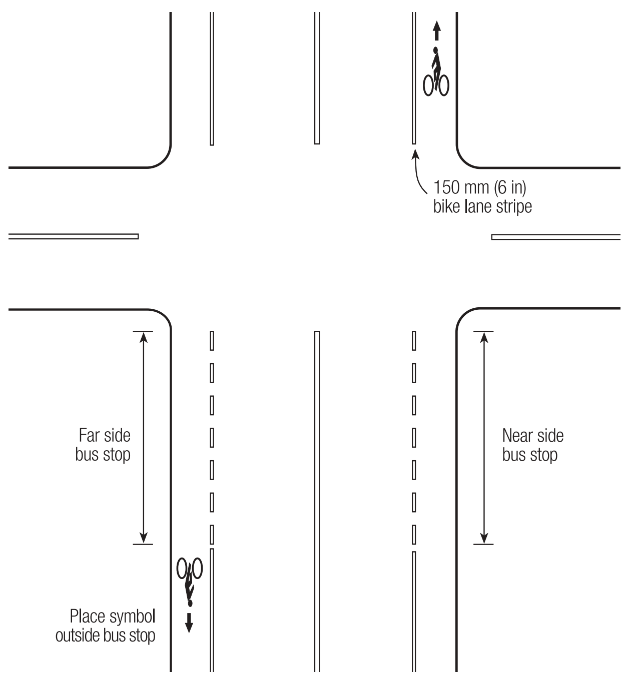


Figure 4-9A.
Typical Pavement Markings for Bicycle Lanes on a Two-Way Street with No Crosswalks.

- Where bicycle lanes exist in advance of a roundabout terminate bike lane striping at the pedestrian crosswalk. See Sections 7.2.3 and 7.2.4 for additional design considerations at roundabouts.
- At signalized intersections, consider placing detector loops in the bike lane to allow triggering of the signal (refer to Section 8.3.3 for a detailed discussion of this topic).

- Where a bike lane is located adjacent to on-street parking, the parking lane should be delineated with either a 4 inch (100 mm) white line or white "tick" marks (refer to Fig. 4-9B)

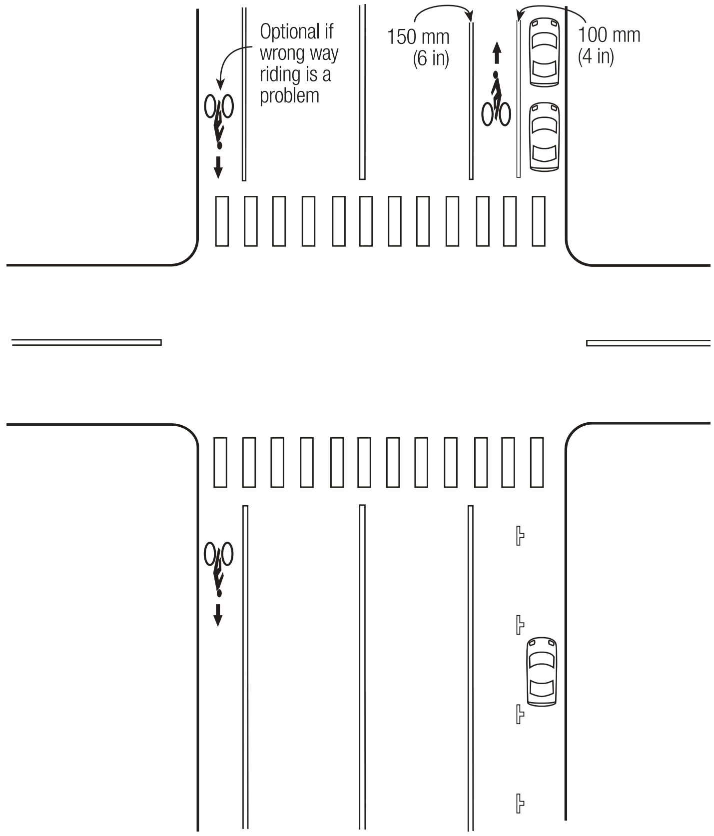


Figure 4-9B.
Typical Pavement Markings for Bicycle Lanes on a Two-Way Street with Crosswalks.

- At T-intersections where crosswalks are not provided, the bicycle lane striping on the side across from the T-intersection should continue through the intersection with no break (refer to Fig. 4-10A).

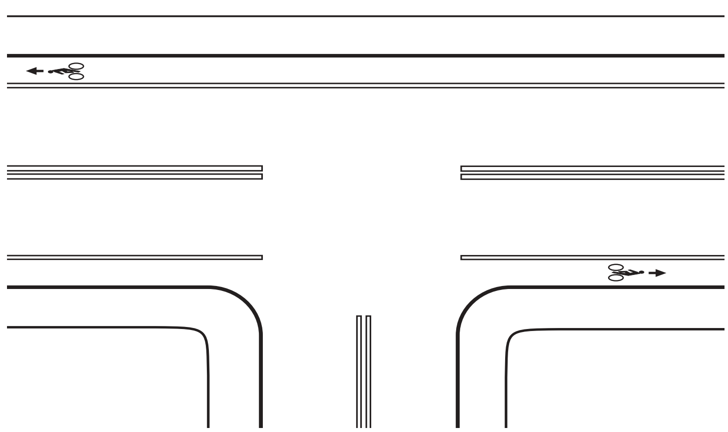


Figure 4-10A.
Typical Pavement Markings for Bicycle Lanes at a T-intersection with No Marked Crosswalks.

- At T-intersections where crosswalks are provided, the bicycle lane striping on the side across from the T-intersection should be discontinued only at the crosswalks (refer to Fig. 4-10B).

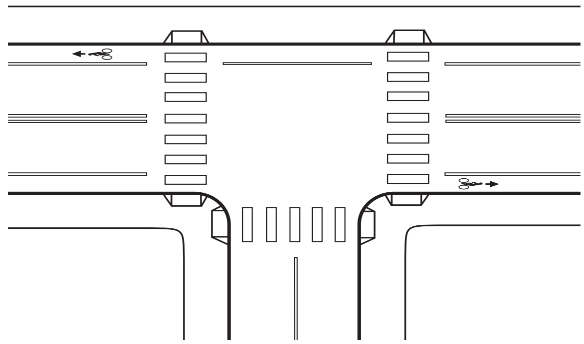


Figure 4-10B.
Typical Pavement Markings for Bicycle Lanes at T-Intersections with Marked Crosswalks.

4.3.5 Bicycle Lanes and Turning Movements

Conflicts between right-turning motorists and bicyclists proceeding straight through an intersection can be lessened by signing and striping:

- Signing and striping configurations which encourage bicyclists and motorists to cross paths in advance of an intersection, in a merging fashion, are preferred over those that force crossing paths in the immediate vicinity of the intersection.
- At intersections controlled by signals or stop signs and where right-turn lanes exist, use a dotted line with 0.6 m (2 ft) dots and 1.8 m (6 ft) spaces for the approach in lieu of solid striping. The length of the broken line is usually 15 to 60 m (50 to 200 ft).

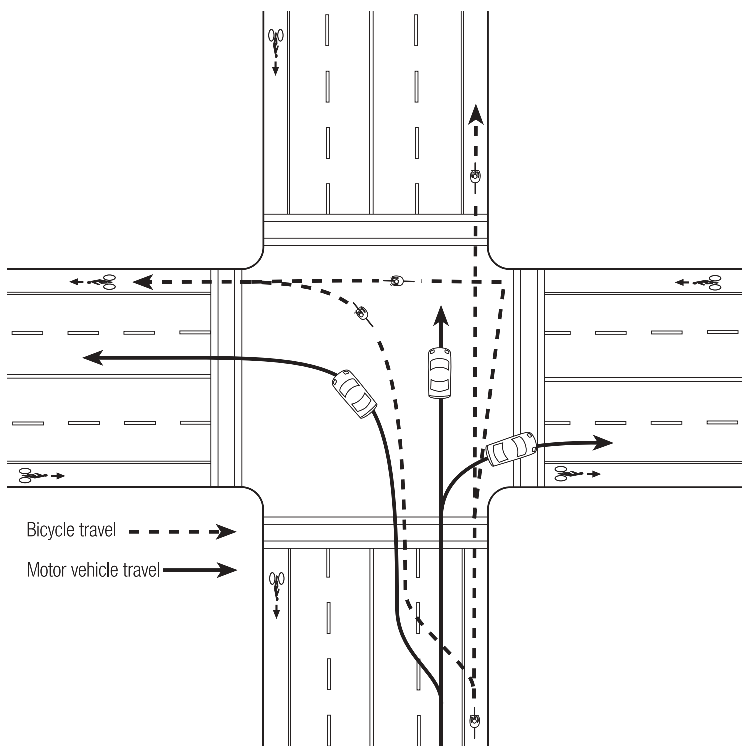


Figure 4-11.
Typical Bicycle and Motor Vehicle Movements at Major Intersections.

- Left-turning bicyclists are permitted their choice of a "vehicular" turn (where the bicyclist merges leftward to the same lane used by left-turning motor vehicles, or a "pedestrian style" left turn (where the bicyclist proceeds straight through the intersection, stops at the far side of the intersection, turns left, then proceeds across the intersection again on the cross street). Refer to Fig. 4-11.
- Where there are numerous left-turning bicyclists, consider providing a left-turn bike lane to the right of the left most travel lane.
- Refer to Figure 4-12 A-B for additional pavement marking treatments where a through bicycle lane and right-turn lanes are provided.
- Bike lanes should never be placed to the right of right turn only lanes, as conflicts with motor vehicle traffic will result.
- Where insufficient width exists, place a separate through bicycle lane to the right of the motor vehicle through lane and include signs and pavement markings as shown in Fig. 4-12C.

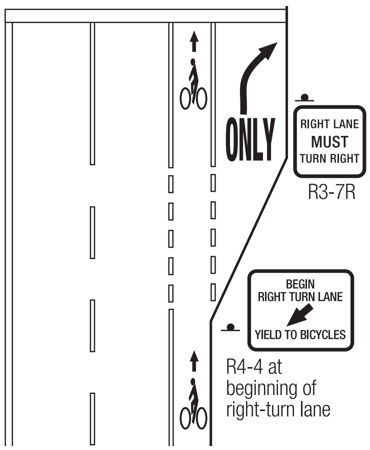


Figure 4-12A
Bicycle Lane with
Developed Right Turn Lane.

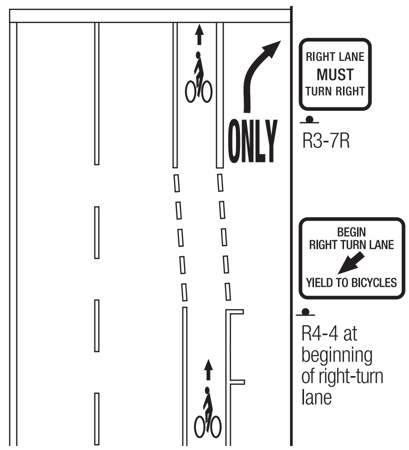


Figure 4-12B
Bicycle Lane and
Dropped Parking Lane.

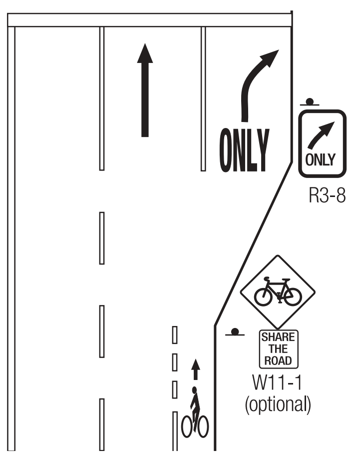


Figure 4-12C
Intersection Widening without Bicycle Lane.

Section 4.3.6 Interchange Areas

Where on-road bicycle facilities are provided, the area around interchanges can present a greater number of potential conflicts with motor vehicle traffic. This is especially true where on and off ramps diverge and merge with the road on which bike lanes are present. In most cases, the horizontal geometry of the ramps is such that motor vehicles exit or enter at relatively high speeds. The shallow angle of ramps also results in wide throats that present long distances in which motor vehicle and bicyclists are in potential conflict. There are design treatments that can increase the visibility of bicyclists by motorists, reduce the area where conflicts are present, and improve sight lines for bicyclists.

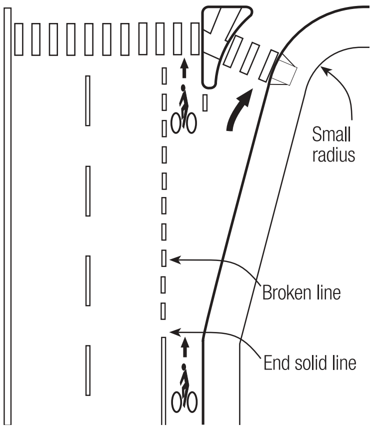


Figure 4-13A.
Dedicated slip lane and small radius curve.

On-Ramps

At on-ramps, there are two design options to accommodate bike lanes. The first is to simply carry the bike lane across the throat of the ramp using dotted line and place additional signs in advance of the ramp (see Figure 4-13B). However, this option does not address all the concerns noted above. The second options is to provide an extension of the bike lane on its own alignment that brings it to a point on the ramp where bicyclists can cross at as close to a right angle as possible. Bicyclists then re-enter the bike lane at a point beyond the on-ramp merge area (see Figure 14-C). The location of the ramp crossing should consider the stopping sight distance requirements for vehicles entering the ramp.

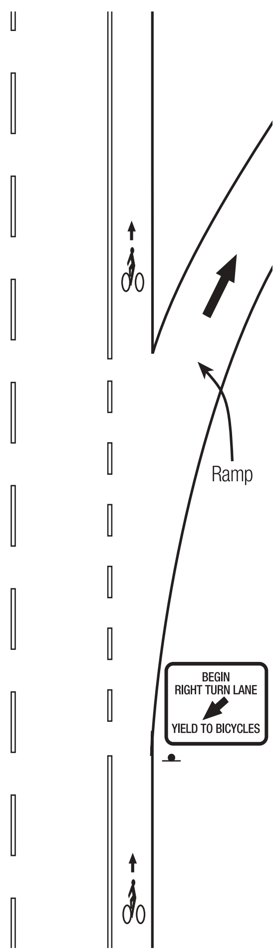


Figure 4-13B
On-ramp with bike lane signs and pavement markings.

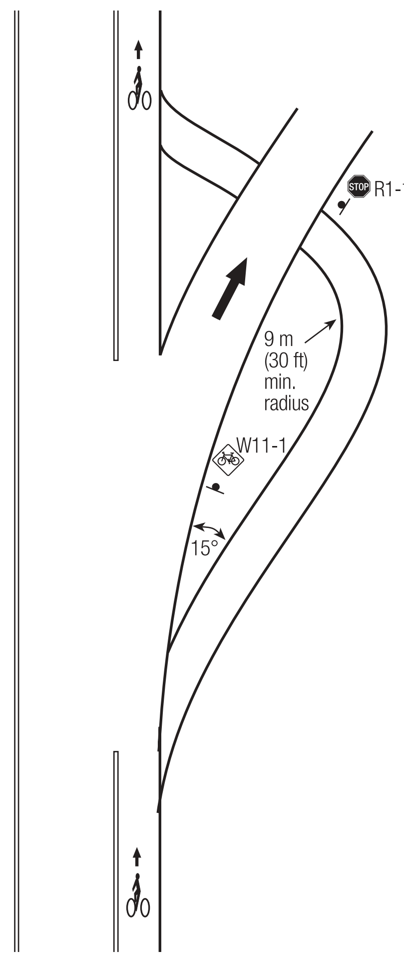


Figure 4-13C
On-ramp with extended bike lane to minimize conflicts.

Off-ramps

Locations where off-ramps intersect a road with bike lanes pose a different set of problems. If the bike lane continues to the right of the travel lane up to the intersection with the off-ramp, bicyclists end up in the gore area between the travel lane and the ramp. This places them in an awkward position on the roadway. A more favorable design is to curve the bike lane within the gore so that it crosses the ramp at a right angle. Once across the ramp, bicyclists are then in their normal position on the right side of the roadway (see Figure 14-D).

Special Treatments

To help motorists and bicyclists recognize interchange areas as locations of higher than normal potential conflict; the use of colored bike lanes may be considered. If used, the color should extend for the full width of the bike lane and the 150 mm (6 inch) white line must still be provided. The colored markings should begin in advance of the first on ramp and carried through to the other side of the off ramp. Although the MUTCD does not discuss this treatment specifically, it does provide guidance on the use of different color pavement markings. Colored bike lanes cannot be white, yellow, blue or red. It is recommended that green be used for this application. Because this is considered an experimental pavement marking, a request to experiment must be submitted to FHWA.

High-speed ramps with large radii make crossing and merging maneuvers more difficult for bicyclists. Using a smaller turning radius or a compound curve for ramps and dedicated right-turn slip lanes can lower motor vehicle speeds and improve conditions for both bicyclists and pedestrians. Refer to Figure(s) 4-13A.

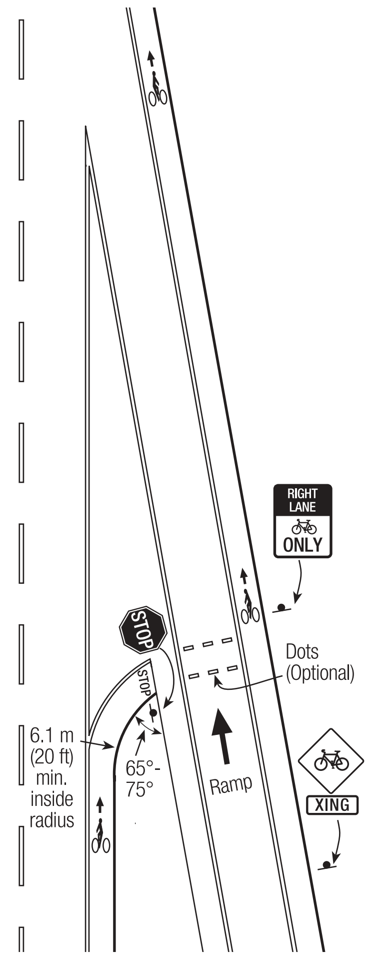


Figure 4-13D
Off-ramp with bike lane signs and pavement markings.

4.3.7 Contra-Flow Bicycle Lanes

Contra-flow bicycle lanes (one-way bicycle lanes that provide a legitimate way for bicyclists to ride against traffic flow) are not usually recommended because riding against the flow of traffic is contrary to traffic law and a leading cause of bicycle crashes with motor vehicles. However, there are special circumstances in which contra-flow lanes may be considered. These include:

- Where the contra-flow bicycle lane is very short (usually not longer than a city block or two).
- Where provision of a contra-flow bicycle lane provides a substantial savings in out-of-direction travel or direct access to high use destinations.
- Where safety along the contra-flow direction is greater than along the longer or more circuitous route.
- Where there are few or no intersecting driveways, alleys or streets on the contra-flow side of the street.
- Where bicyclists can safely and conveniently reenter the traffic stream at both ends of the section.
- Where a substantial number of bicyclists are already using the street.
- Where there is sufficient room to accommodate a bicycle lane. The preferred width of a contra-flow bicycle lane is 3.0 m (6 ft), but no wider.
- On a one-way residential street recently converted from a two-way street, especially where this change was made to calm traffic.

Additional recommendations for contra-flow lanes:

- Only one-way streets should be considered as candidates for contra-flow bicycle lanes.

- Under no circumstances should a contra-flow bicycle lane be installed on a two-way street, even where the travel lanes are separated with a raised median. A contra-flow bicycle lane should be located on the left side of the motor vehicle lane(s).
- A contra-flow bicycle lane should be delineated from the motor vehicle lane(s) by a double yellow line consisting of two parallel 150 mm (6 in) solid yellow stripes, which indicates that the bicyclists are riding on the street legally, in a dedicated travel lane.
- Contra-flow bicycle lanes should be one-way bicycle lanes only. Where two-way bicycle travel is desired along a one way street, an additional bicycle lane should be provided to the right of the motor vehicle lane for bicyclists traveling with the flow of traffic.
- Contra-flow bicycle lanes should be no wider than 1.8 m (6 ft) to discourage motorists from using the contra-flow lane for parking or passing.
- Intersecting alleys, major driveways and streets should have signs indicating to motorists they should expect bicycle traffic on each side of the street.
- Existing signals should be fitted with special signals for bicyclists using bicycle sensitive detectors or push-buttons capable of being easily reached by bicyclists without having to dismount.

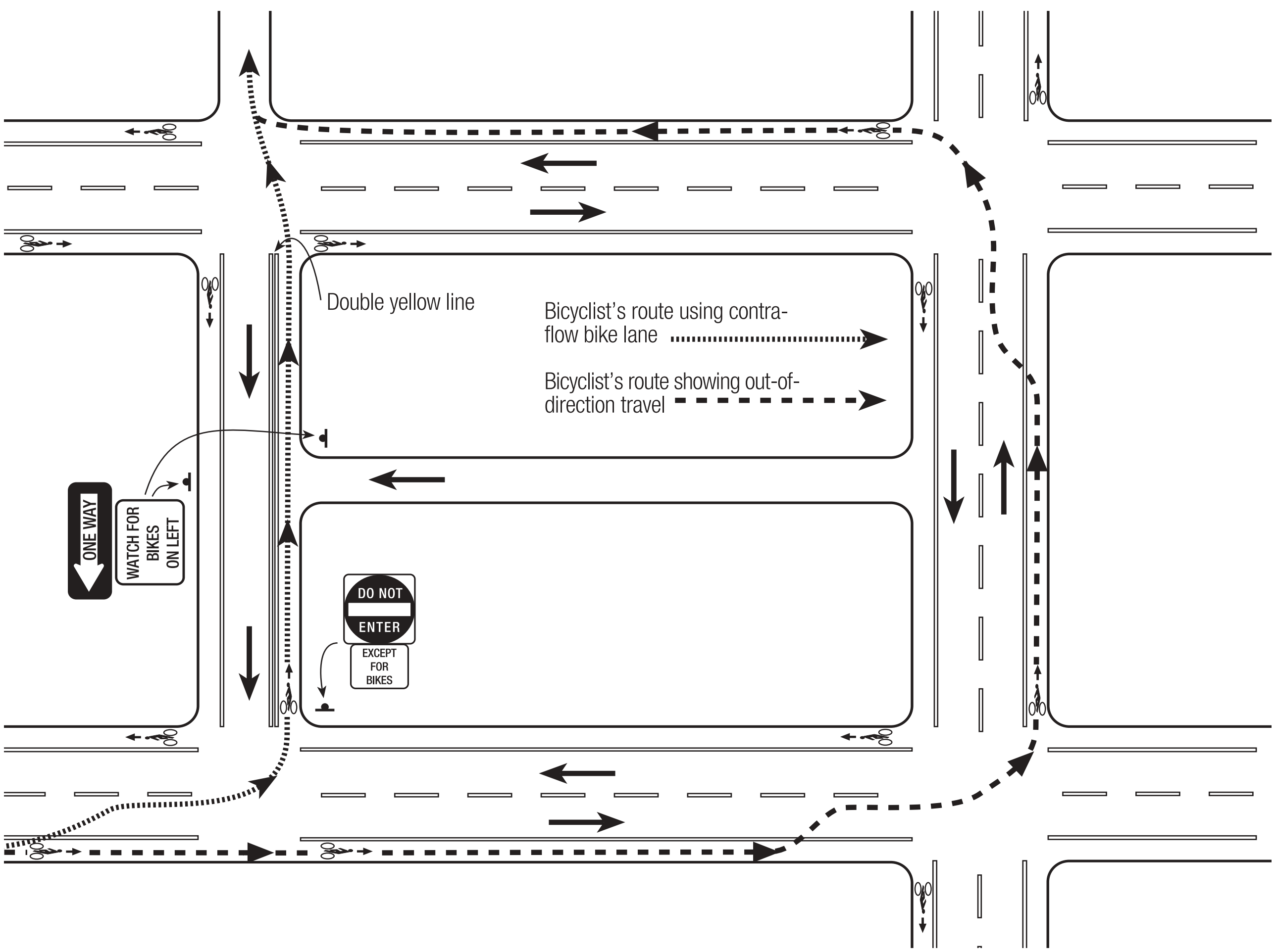


Figure 4-14.
Typical Signs and Pavement Markings for Contra-Flow Bicycle Lanes.

4.3.8 Effect of Grades on Bicycle Lanes

Where grades exceed 1:20 (5 percent), it may be desirable to maintain a 1.8 m (6 ft) bicycle lane or paved shoulder as bicyclists need more space to accommodate wobble and maneuvering. This is especially important on uphill grades where bicyclists are moving slowly, have more difficulty maintaining a straight line of travel and the speed differential is usually greatest between motor vehicles and bicyclists.

Island Pond

On uphill grades, a bicycle climbing lane or wide paved shoulder can provide slowly moving bicyclists with extra width to accommodate wobble and maneuvering.

4.4 Wide Curb Lanes

Wide curb lanes are suited for use in village or urban areas where insufficient widths for bike lanes exist. They are distinguished from bike lanes by the absence of signs or pavement markings which specifically designate them for bicycle use. The intent of wide curb lanes is to provide extra space to better accommodate bicycles and motor vehicles in the same lane while providing enough space for motorists to overtake and pass bicyclists without changing travel lanes.

4.4.1 Design Considerations

- Wide curb lanes are usually preferred in restrictive settings such as village centers and urban environments where shoulders or bike lanes cannot be provided.
- Where steep grades exist, additional operating width for bicyclists may be required.
- Provide a 100 mm (4 inch) white line or tick marks between wide curb lanes and on-street parking
- Widths greater than 4.2 m (14 ft) that extend continuously along a highway for long distances may encourage the undesirable operation of two motor vehicles side by side in one lane. In such situations, consider striping bicycle lanes or shoulders.

Restriping existing multi-lane facilities may result in enough room to install wide curb lanes where travel lanes and left-turn lanes can be narrowed or the existing number of lanes can be reduced (refer to Section 4.3.9, Reallocating Roadway Space). However, this should only be considered after careful review of traffic characteristics along the corridor and where supported by a documented engineering analysis.

South Burlington

Wide curb lanes are suited for use in village or urban areas where insufficient width for bike lanes exists.

4.4.2 Width

Refer to the Vermont State Standards for minimum widths of wide curb lanes. The widths are dependent on roadway classification, design speed and traffic volume and range from 3.6 m to 4.5 m (12 to 15 ft) Consideration should be given to providing additional width when large numbers of trucks are expected (i.e., 30 or more overtaking heavy vehicles per hour in an outside lane) or limited sight distances exist.

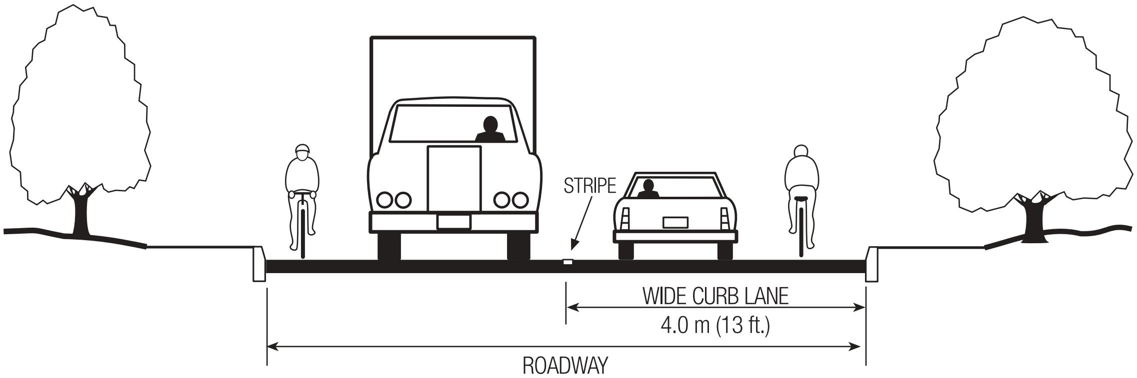


Figure 4-15.
Wide Curb Lane, No Parking.

Notwithstanding the minimum widths in the VT State Standards, the preferred width of a wide curb lane where no on-street parking exists is 3.9 m (13 ft) and 4.2 m (14 ft) wide where on-street parking exists.

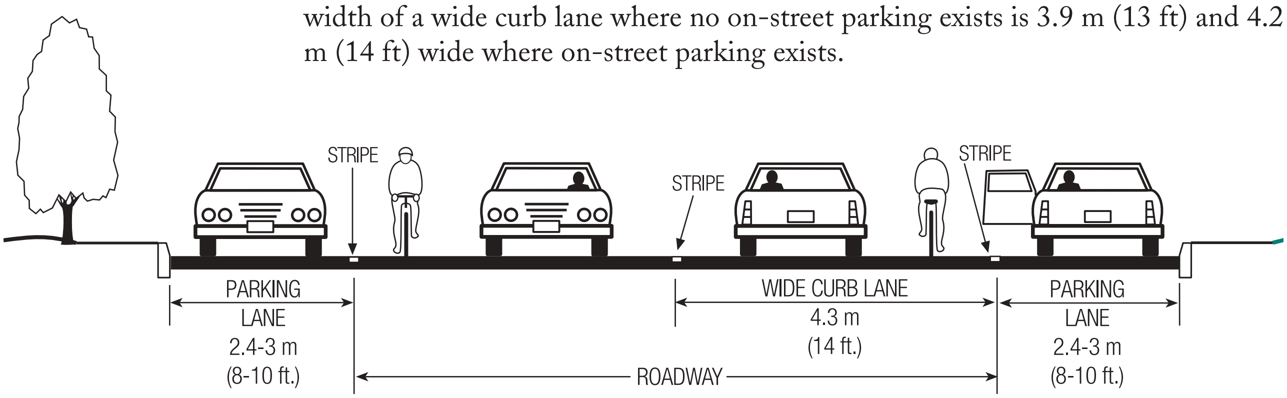


Figure 4-16.
Wide Curb Lane, with Parking.

Table 4-9.
Wide Curb Lanes, Street or Highway, with and without Parking

Minimum[(a)]	Conditions
3.6 m to 4.5 m (12 to 15 ft)	Refer to the Vermont State Standards for minimum widths of wide curb lanes.
Preferred[(a)]	**Conditions**
3.9 m (13 ft)	Preferred width, no on-street parking.
4.2 m (14 ft)	Preferred width, with on-street parking.

[(a)] Add 0.3 m (1 ft) on bridges, or where there are 30 or more overtaking heavy vehicles per hour in a single outside lane or where limited sight distances exist.

4.5 Paved Shoulders

Lowell

Paved shoulders can significantly improve operating conditions for motorists, bicyclists and pedestrians, especially in rural areas.

Width is the most critical factor affecting the ability of a roadway to accommodate both bicycles and motor vehicles. Paved shoulders are a type of facility that can provide additional pavement width adjacent to the outside lane of a roadway, thereby improving operating conditions for drivers of motor vehicles, bicyclists and pedestrians, especially in rural areas. Where paved shoulders are provided, the surface condition is critical to safe bicycling.

In Vermont, the majority of bicyclists typically use local roads and rural highways for long distance travel. Notwithstanding the ability of these roads to serve as shared use facilities (refer to Section 4.6), the development and maintenance of paved shoulders defined by an edge stripe can significantly improve the safety, convenience and comfort of bicyclists and motorists.

Benefits of Shoulders

Paved shoulders have many safety, capacity and maintenance benefits unrelated to bicycling. Most of these benefits also apply to shoulders on rural roads and to marked, on-street bicycle lanes on urban streets.

Safety. Highways with paved shoulders have lower accident rates because paved shoulders:

- Reduce passing conflicts between motor vehicles and bicyclists and pedestrians.
- Provide space for disabled vehicles to stop or drive slowly.
- Provide space to make evasive maneuvers.
- Add a recovery area to regain control of a vehicle, as well as lateral clearance to

roadside objects such as guardrail, signs and poles (highways require a "clear zone," and paved shoulders give the best recoverable surface).
- Provide increased sight distance for through vehicles and for vehicles entering the roadway.
- Make the crossing pedestrian more visible to motorists.
- Contribute to driving ease and reduced driver strain.
- Provide for storm water discharge farther from the travel lanes, reducing hydroplaning, splash and spray to following vehicles, pedestrians and bicyclists.

Capacity. Highways with paved shoulders can carry more traffic because paved shoulders:
- Provide space for bicyclists and pedestrians to travel at their own pace.
- Provide more intersection and safe stopping sight distance.
- Provide space for disabled vehicles, mail delivery and bus stops.
- Allow for easier exiting from travel lanes to side streets and roads (also a safety benefit).
- Provide greater effective turning radius for trucks.
- Provide space for off-tracking of truck's rear wheels in curved sections.

Maintenance. Highways with paved shoulders are easier to maintain because paved shoulders:
- Provide structural support to the pavement.
- Discharge water further from the travel lanes, reducing the undermining of the subbase and subgrade.
- Provide space for maintenance operations and snow storage.
- Provide space for portable maintenance signs.
- Facilitate painting of fog lines.

4.5.1 Design Considerations

- Refer to Vermont State Standards for minimum shoulder widths.
- To be useable by bicyclists, shoulders should be paved with the same surfacing materials as the adjacent roadway travel lane.
- Provide an additional 0.3 m (1 ft) of paved shoulder width where guardrail, bridge railing or other lateral obstructions are present.
- Additional shoulder width should be considered on uphill grades in excess of 1:20 (5 percent) to give slow-moving bicyclists needed maneuvering space, thus decreasing conflicts with faster moving motor vehicle traffic.
- Additional shoulder width should also be considered where downhill grades exceed 1:20 (5 percent) for longer than 1 km (0.6 mi).
- Provide additional width where high volumes of truck traffic are anticipated.
- The use of rumble strips decreases the usability of a shoulder by bicycle traffic (refer to Section 4.7.4, Rumble Strips).
- Delineate paved shoulders from motor vehicle lanes with a 100 mm (4 in) solid white edge line.
- Maintain shoulder widths when adding vehicle passing lanes.
- Provide greater shoulder width where guardrail or other fixed objects are close to the road.

4.5.2 Width

Refer to the Vermont State Standards for minimum widths of paved shoulders to accommodate bicycles. Notwithstanding the minimum values as stated in the Vermont State Standards, as a general rule a paved shoulder width of at least 0.9 m (3 ft) is preferred to accommodate less experienced bicyclists and to provide additional width beyond the travel lane.

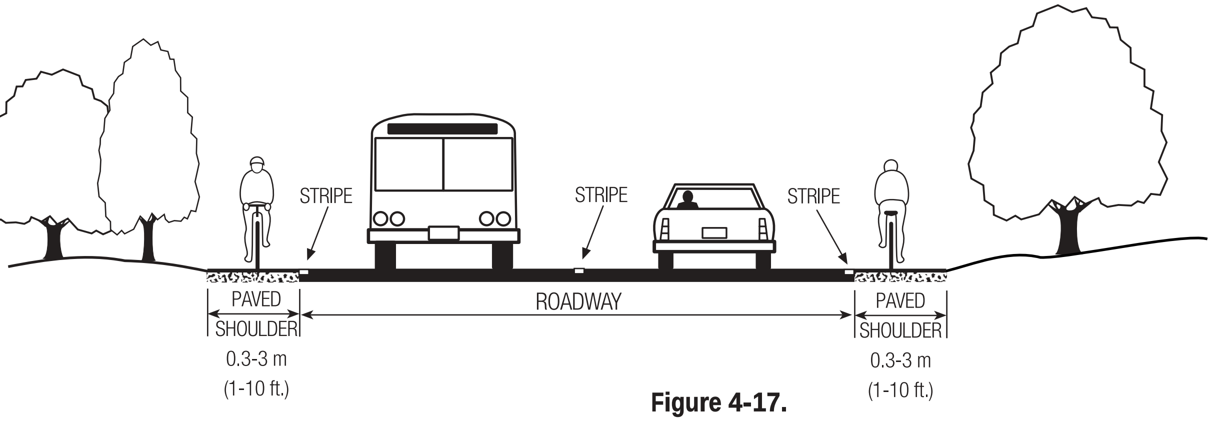


Figure 4-17.
Paved Shoulders.

Table 4-10.
Paved Shoulders.

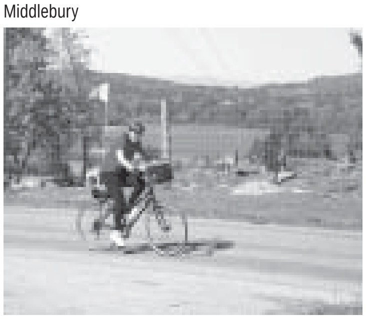
The following widths are preferred, unless the Vermont State Standards call for a greater width given design conditions.

Preferred[(a)]	Conditions
1.1 m (3 ft)	Average conditions (i.e. where traffic or edge conditions do not dictate additional bicycle lane width).
1.2 m (4 ft)	Preferred shoulder width from the edge of an outside travel lane to the face of a guardrail, curb or other roadside barrier and to fully accommodate the operating width of a bicycle (refer to Figure 4-2).
1.5 m (5 ft)	On highways with steep up-grades where bicyclists require additional maneuvering width or where downgrades exceed 1:20 (5 percent) for a distance of 1 km (0.6 mi) or more.
1.5 m (5 ft)	On highways where there are 30 or more heavy vehicles per hour in the outside lane.

[(a)] Usable width measured from the center of the edge line to the unbroken outside edge of the pavement.

4.6 Shared Lanes

Middlebury



Many of Vermont's low volume streets and lightly traveled local roads adequately accommodate bicycles and motor vehicles in shared lane situations without special provisions for either mode.

To a large extent, most of the bicycling that has taken place in Vermont, and can be expected to take place well into the future, occurs with motor vehicles and bicycles sharing a roadway without the benefit of bicycle lanes, wide curb lanes or paved shoulders. In certain situations — such as along low volume, (AADT< 1,000) residential streets; or lightly traveled roads in scenic, rural locations; or along unpaved roads — it may be unnecessary and even undesirable to provide bike lanes, wide curb lanes or paved shoulders to accommodate bicyclists. In the VTrans report, *Bicycle Touring in Vermont & Vermont's Scenic Byways Program* (1995), bicycle tour operators expressed a concern that "improving" roads that attract touring bicyclists might destroy the "nature" of quiet back roads they intentionally seek for their tours.

Where adding an extra foot or two in roadway width is not an option, features such as bicycle-safe drainage grates and bridge expansion joints, improved railroad crossings, smooth pavement, adequate sight distances, and signal timing and detector systems that respond to bicycles can make roadways more conducive to bicycle travel.

4.6.1 Design Considerations

- Bicyclists and motor vehicles share same roadway.
- Common on neighborhood streets and rural roads and highways.
- Many existing neighborhood village and downtown streets and local roads can adequately accommodate bicycles and motor vehicles without special provisions for either mode.
- Where conditions such as limited sight distance exist, driver awareness may be increased by the use of standard warning signs.

Shared roadways are most often used by:

- More experienced bicyclists on rural roads. The best conditions exist where traffic volume is very low (≤ 500 ADT), where a low number of critical events (i.e., when an overtaking motor vehicle meets an oncoming motor vehicle in the presence of a bicyclist also using the roadway) are likely to occur, and where good sight distance is available.
- Less experienced bicyclists including children when traveling on low-volume neighborhood streets where fast moving vehicles or through traffic is not a factor.
- All levels of bicyclists on short segments of highway in village and downtown centers with constrained right-of-way, where pedestrians may be expected in higher numbers, traffic speeds are no higher than 40 km/h (25 mph) and short blocks allow bicyclists to share the road despite high traffic volumes.

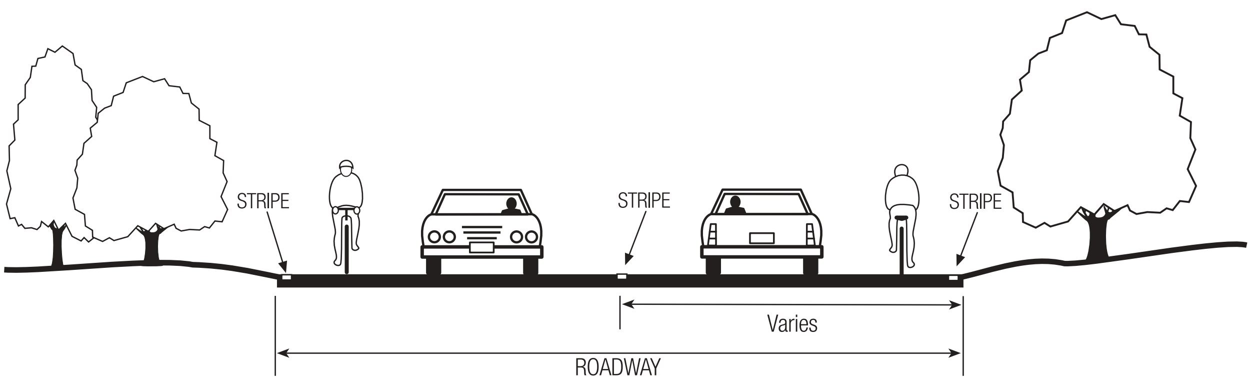


Figure 4-18.
Shared Lanes.

4.6.2 Width

Width is the most critical factor affecting the ability of a roadway to accommodate both bicycles and motor vehicles in shared lane situations. Refer to Vermont State Standards for minimum shared lane widths.

In general, 2.8 m (11 ft) is considered to be the minimum width to accommodate experienced bicyclists and motorists in rural areas in low volume situations. Greater widths may be required to accommodate less experienced bicyclists or all bicyclists where higher traffic volumes, traffic speeds, heavy vehicles, or limited sight distances exist.

In village and downtown centers with on-street parking, at least 6 m (20 ft) of combined width for the travel lane and parallel parking stall is desirable. For angled parking, more width is required depending on the angle but generally 9 m (30 ft) is desirable.

4.6.3 - Unpaved Roads

Pittsford

Many bicyclists prefer the low traffic volumes, exceptional scenery and variations in terrain offered by Vermont's unpaved roads.

Many bicyclists prefer the riding experience offered by the unpaved roads in Vermont. These roads often have very low volumes and offer exceptional scenery and variations in terrain. There are no specific design considerations related to accommodating bicycling on unpaved roads. Because of the low volumes, no additional width is recommended. In the event that there is a particular hazard along an unpaved road (e.g., sharp curve, narrow bridge), bicyclists will benefit from the warning signs that are posted for all traffic on these roads.

Unpaved roads, like all roads, require regular maintenance. The most important consideration for accommodating bicycling on unpaved roads is the surface condition. This is not an issue particular to bicycling, as all users of the road desire a smooth surface free of irregularities. To maintain a smooth road surface on unpaved roads, proper drainage is critical. This is provided by constructing and maintaining adequate ditches and by adequately grading and compacting the road. For additional information about properly maintaining unpaved roads, refer to the Vermont Better Backroads Manual.

4.7 Incremental Improvements

When bike lanes, wide curb lanes or paved shoulders are not feasible, and to improve conditions in shared lane situations, it is often possible to significantly improve the bicycling experience through the implementation of incremental roadway improvements.

From the bicyclist's perspective, as little as 0.6 m (2 ft) of usable riding surface to the right of a roadway edge stripe on major arterial and collector streets and roads can provide an improved operating environment while improving highway capacity.

Next, if it is still not possible to provide any type of bicycle facility using the existing width, evaluate segments for whether:

- Any extra paved space can accommodate incremental improvements.
- The condition of the shoulder can be improved.
- Overly-wide motor vehicle lanes can be narrowed to minimum widths prescribed by the Vermont State Standards.
- The number of motor vehicle lanes can be reduced such as in the case of a roadway that has more than two existing lanes which may be built beyond existing or projected capacity (refer to 4.8, Reallocating Roadway Space).
- Parking can be eliminated.

Implementation of traffic calming (refer to Chapter 7) can also reduce the speed of motor vehicles through physical changes to the vertical or horizontal alignment of the roadway. Speed humps, islands, bulb-outs, and roundabouts are common traffic calming devices.

Other incremental improvements include:

- Bicycle-safe drainage grates (refer to Section 4.9.1).
- Bicycle-friendly railroad crossings(refer to Section 4.9.2).
- Pavement surfaces free of irregularities.
- Bicycle-oriented signs and bicycle-sensitive traffic detection devices (refer to Chapter 8).
- Encouraging through-traffic and large trucks to travel on a few limited corridors.

- Use of limited signing to indicate to motorists that bicyclists are present in significant numbers.
- Slip-resistant durable pavement markings.
- Roadway maintenance including removal of accumulated dirt, broken glass and other debris (refer to Chapter 9).
- Reducing and enforcing posted speed limits.

4.8 Reallocating Roadway Space

Restriping Multi-Lane Roadways

To accommodate bicycle lanes, wide curb lanes or paved shoulders along roadways where widening is impractical, an opportunity may exist to narrow or reduce the number of motor vehicle travel lanes or parking lanes. This may be especially true where roadway capacity exceeds demand. Engineering studies and citizen support should be developed before the number of lanes or parking spaces is reduced. Lane and shoulder widths must meet the minimum dimensions as outlined in the Vermont State Standards.

Where traffic volume, speed or other conditions warrant, **four-lane highways** can be reduced to two-lane designs using raised medians or turning medians. The remaining space can then be used for bicycle lanes or wide curb lanes as space permits. Refer to Figure 4-19A

Where traffic volume, speed or other conditions warrant, **three-lane highways** can be reduced to two-lane designs if the center two way left turn lane is removed or replaced with raised traffic separators. The remaining space can then be used for bicycle lanes or wide curb lanes as space permits. Refer to Figure 4-19B

Westfield, NY

Where traffic volume, speed or other conditions warrant, four-lane highways can be reduced to two-lane designs using raised medians or turning medians.

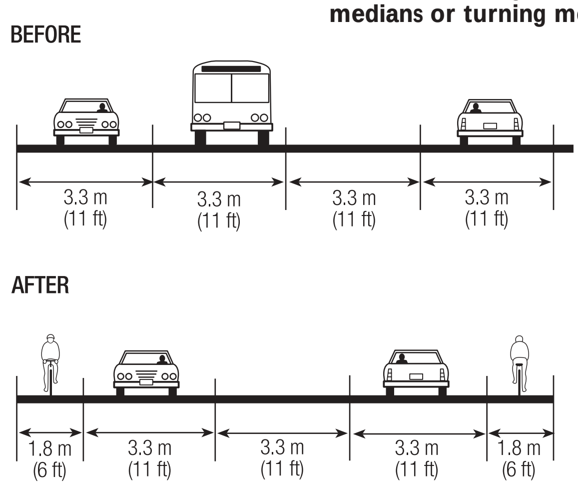


Figure 4-19A.
Going From Two Travel Lanes in Each Direction to One Each Direction with Continuous Two-way Left Turn Lane.

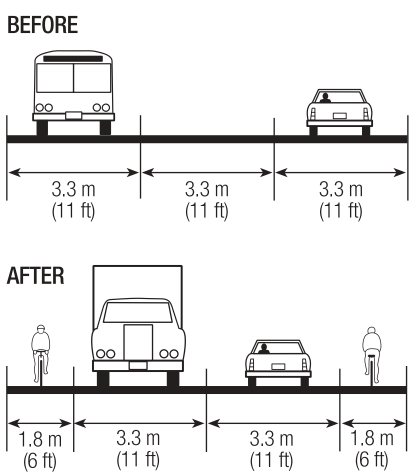


Figure 4-19C
Narrowed Four-Lane Section to Add Bicycle Lanes.

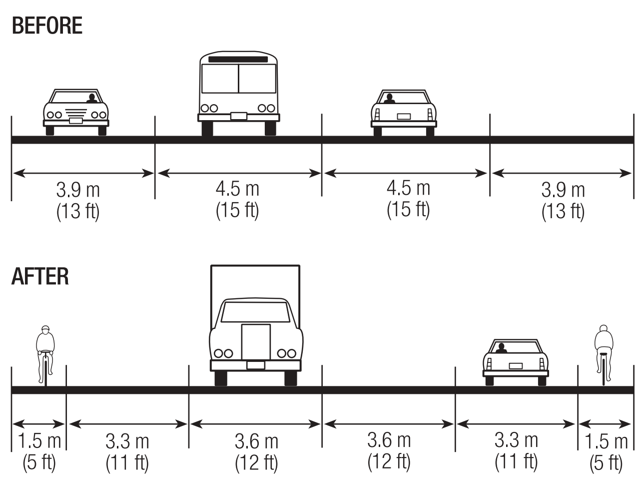


Figure 4-19B.
Going From Two Travel Lanes with Median to No Median.

Reevaluating Existing On-street Parking

A highway's primary function is to move people and goods. Removing or reconfiguring on-street parking may also provide opportunities for gaining additional roadway space for bicycle lanes or wide curb lanes. However, because adjacent business owners or residents may be affected by such a move, careful research is needed before making recommendations that affect parking.

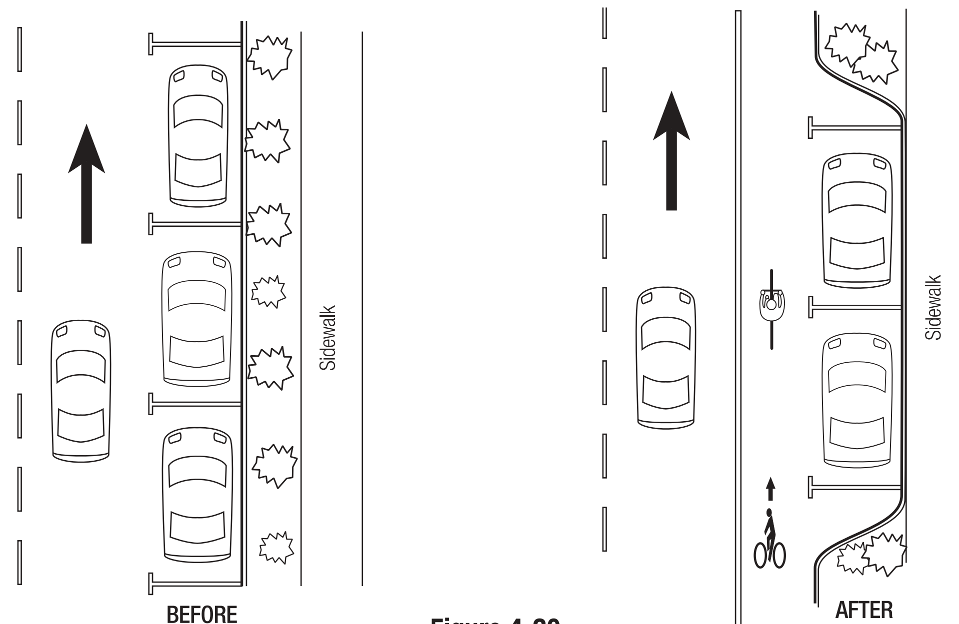


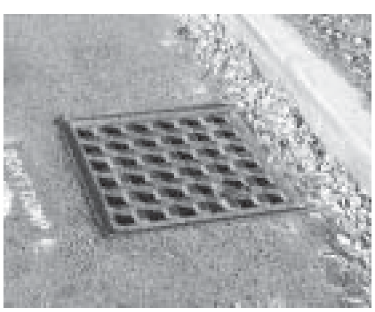
Figure 4-20.
Reevaluating the Need for Parking.

Alternatives to the elimination of parking spaces include: narrowing the parking lanes, removing parking on only one side of a roadway, or changing from diagonal parking to parallel parking. If a green strip of sufficient width exists, a portion of the strip can be converted to on-street parking to make room for bike lanes.

4.9 Other Considerations for On-road Bicycle Facilities

4.9.1 Drainage and Drainage Grates

Drainage grates and utility covers can cause problems for bicyclists. Raised or sunken drainage grates or utility covers can stop or divert a bicyclist's front wheel, causing wheel damage or resulting in a crash. A related problem involves old-style parallel bar drainage grates, which can trap the front wheel of a bicycle causing the bicyclist to be pitched over the handlebars.



Parallel bar drain grates should be replaced with modern bicycle-safe and hydraulically efficient models such as the "vane" or "honeycomb" grates.

Uneven Grates and Utility Covers

Grates and covers that are not level with the roadway surface should be brought to the proper grade by raising or lowering the device. Newly paved surfaces should be feathered within a maximum of 15 mm (0.5 in) of the cover height to make grates and covers nearly flush with the finished surface of the roadway. Refer to VTrans Standard Drawings D-9M, D-9, D-10M, D-10,D-11M and D-11.

Bicycle Safe Drain Grates

Parallel bar drain grates should be replaced with modern bicycle-safe and hydraulically efficient models such as the "vane" or "honeycomb" grates. Where replacement cannot be accomplished immediately, square parallel bar drain grates should be realigned so that the bars are perpendicular to the direction of normal bicycle travel.

Numerous bicycle-safe drainage grate designs have been developed that eliminate the dangers of the parallel bar grate, while at the same time maintaining hydraulic efficiency. Refer to VTrans Standard Drawings.

When it is possible to do more than simply replace a grate, curb inlets or offset grates can move the inlet out of the way entirely, thus improving the operating width of the roadway for both bicycles and motor vehicles. Care should be taken to minimize cross slopes, which, if excessive, can throw bicyclists toward the curb. Care should also be taken to provide a wide enough throat on the recessed curb so that it catches water and the effectiveness of snow plowing and/or removal is not compromised. This is a particularly important on steeper grades.

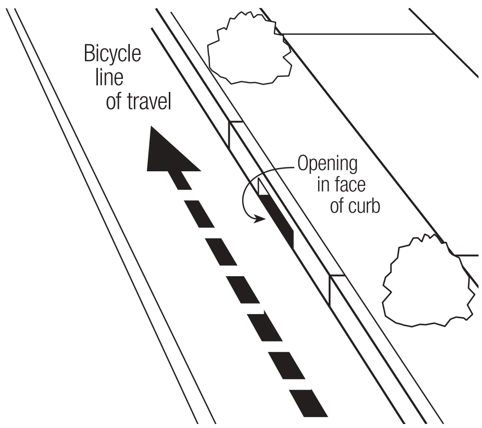


Figure 4-21.
Recessed Drainage Grate.

Parallel bar grates may also be retrofitted with steel straps welded perpendicularly to bicycle travel at 15 cm (6 in) on center to keep bicycle wheels from falling between the parallel bars of the grate. This approach, however, is temporary as motor vehicle traffic can loosen the straps causing an even greater hazard to bicyclists.

4.9.2 Railroad Crossings

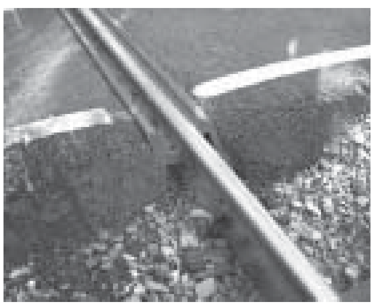
Gaps between railroad tracks and the roadway pavement (called the “flangeway”) can divert the front wheel of a bicycle causing the bicyclist to lose control of the bicycle and crash. The problem is most serious when the tracks are at an acute or obtuse angle (less than 45 degrees or more than 135 degrees) to the roadway and the tracks. The more acute or obtuse the angle, the more hazardous a crossing is for bicyclists. Wet weather can exacerbate the problem, making tracks more slippery than in dry weather.

In addition to problems presented by diagonal tracks, uneven surfaces can also cause bicyclists to fall. Rail crossings take a constant and significant beating from both motor vehicle and train traffic. As a result, crossings may be very rough and uneven. Timbers may break up or shift, and asphalt may crumble, mound into large bumps, or develop pot holes and crack.

All public railroad crossing designs should be approved by the VTrans Rail Division and the railroad operator.

To improve a railroad crossing for bicyclists, provide a paved approach and departure for them to cross the rails as near a right angle as possible without veering into traffic. This often involves providing a widened approach and departure area at crossing locations as shown in Figures 4-22 and 4-23. When physical improvements are not feasible, appropriate warning signs should be installed in advance of the crossing (refer to Chapter 8, Signs, Pavement Markings and Signals). VTrans has developed a specific warning sign for hazardous railroad crossings as shown in Figure 4-25.

Figure 4-25
Sign warning bicyclists of railroad tracks



Rubberized flangeway fillers can smooth railroad track crossings for bicyclists.

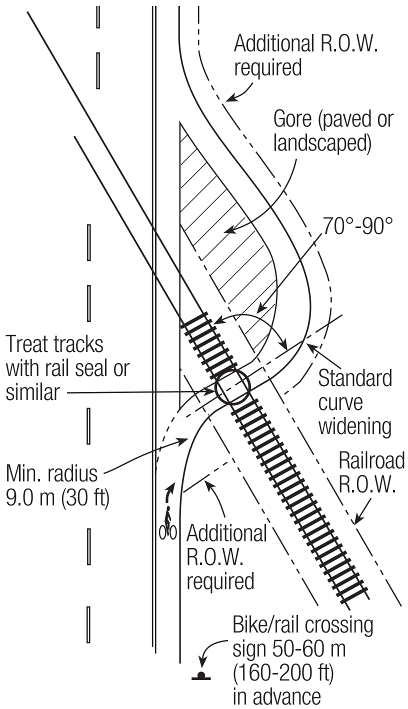


Figure 4-22.
Ridable Railroad Crossing for Acute Angle.

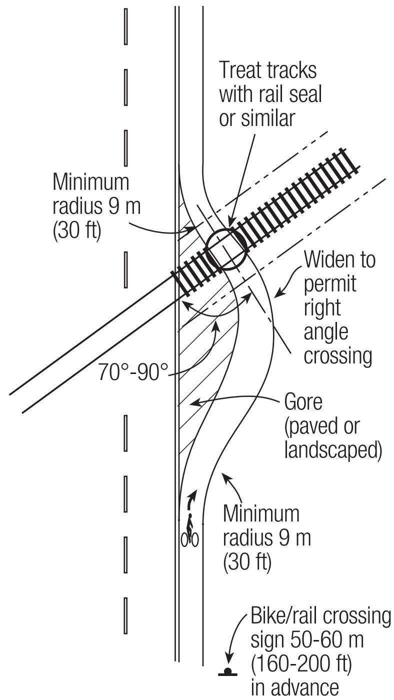


Figure 4-23.
Ridable Railroad Crossing for Obtuse Angle.

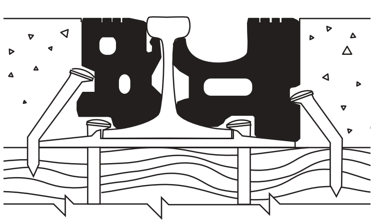


Figure 4-24.
Railroad Flange Filler.

To provide a smooth crossing for bicyclists, commercially available rubberized flangeway fillers can be installed adjacent to the inside edge of the track; however, this technique is suitable for low speed rail lines such as might be found in an industrial rail yard or rail car loading zone. Since a train's wheel must compress the flangeway filler, it is essential that the train be moving very slowly, otherwise a derailment could occur.

The best solution is to replace timber and untreated crossings with a concrete crossing. Concrete crossings could decrease long-term maintenance costs while greatly improving bicyclists safety. Refer to VTrans Standard Drawings for details of concrete crossings.

If a crossing is particularly hazardous (less than 45 degrees or greater than 135 degrees) and no physical improvement is possible in the near term, install appropriate warning signs if warranted (refer to Figure 4-25).

4.9.3 Bridges and Undercrossings

Because bicycle use for transportation is largely dependent upon convenience and access, any barrier that requires bicyclists to travel long distances out of direction is a serious disincentive. Common barriers include natural features such as rivers, streams and ravines, as well as man-made features such as highways and railroads. In such cases, bridges or underpasses may be the only way to overcome the barrier and ensure continuity of the transportation network for bicyclists.

Where on-road accommodation for bicycles has been provided, the approach width of the bicycle facility should be carried across a bridge or through a tunnel. It is recommended that an additional clear space of 0.6 m (2 ft) be provided along the entire length of the bridge or underpass. Where frequent use by inexperienced riders or children is expected it may be appropriate to include a wide sidewalk in the design or provide a supplemental facility physically separated from the roadway facility.

Surface Conditions

As with all surfaces on which a bicycle will be operated, the surface of a bridge deck should be smooth. There are features common to bridges that can be a hazard to bicyclists. These features include expansion joints, longitudinal gaps, longitudinally grooved pavement, and metal grating (commonly found on draw bridges).

The most critical area for bicyclists is the right-most portion of the bridge in both directions. Where feasible, potentially hazardous surfaces should be discontinued in the area near the right edge of the traveled way for a width of at least 1.2 m (4 ft). Where traffic volumes and speed are high, the width of the smooth surface should be increased.

Other possible treatments include, covering expansion joints with a beveled-edge non-skid steel plate attached to one side, covering longitudinal gaps with a non-skid surface or filling them with a weatherproof sealant.

Metal grate bridge decking can cause a bicyclist to lose control, particularly if the deck is wet or the bicyclist is inexperienced. Filling the voids with lightweight concrete is one solution that can successfully ameliorate the problem. The width of the treatment should be as described above for other hazardous surfaces.

At a minimum, where potentially hazardous conditions exist on bridges, suitable warning signs for bicyclists should be installed on the bridge approaches. It is recommended to use the Bicycle Warning sign (W11-1) with a supplemental plaque advising the type of hazard (refer to Figure 4-26 for an example).

Figure 4-26.
Rumble Strip Warning Sign.

Covered Bridges

Reduced light levels inside a covered bridge can make it difficult for motorists to see bicyclists and for bicyclists to see gaps between wooden floor boards that could trap the front bicycle wheel causing a crash. Where an even surface cannot be provided or maintained, warning signs may be provided to alert bicyclists of an uneven deck. Where feasible, a separate parallel walkway or bridge can improve conditions for motorists, bicyclists and pedestrians.

Bridges and undercrossings built exclusively for bicyclists and pedestrians are discussed in Chapter 5, Shared Use Paths.

4.9.4 Rumble Strips

Rumble strips are used to alert motorists when they begin to traverse from travel lanes onto the shoulder, however, rumble strips can have a serious negative effect on bicycle traffic. Rumble strips placed on highway shoulders decrease the ability of bicyclists to use the shoulder. Rumble strips are a serious safety concern for bicyclists.

Rumble strips take up available paved shoulder width and may force bicyclists to use the travel lane. Bicyclists attempting to initiate a turn, avoid obstructions on the shoulder or traveling downhill at a high rate of speed can lose control of the bicycle and crash if forced to cross a rumble strip. Current VTrans policy is to use rumble strips only on limited access highways only (where bicyclists cannot legally ride).

In the event that more widespread use of rumble strips in Vermont occurs, the following design should be used to minimize their negative impact on bicyclists:

- Provide a minimum clear path of 0.3 m (1 foot) from the rumble strip to the traveled way.
- Provide 1.2 m (4 feet) clearance from the rumble strip to the outside edge of the paved shoulder, or 1.5 m (5 feet) clearance to an adjacent guardrail, curb or other obstacle.
- Provide a gap pattern that provides periodic portions of smooth pavement allowing bicyclists to enter or leave the travel lane when necessary. Smooth gaps 3.7 m (12 feet) in length should be continuously placed along rumbled sections at intervals of 12.2 m (40 feet) to 18.3 m (60 feet).

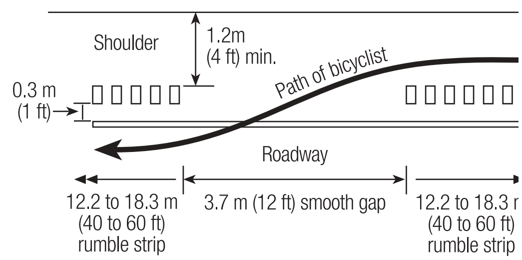


Figure 4-27.
Rumble Strips.
Provide smooth gaps if rumble strips must be used.

- Do not install rumble strips where existing conditions do not allow the minimum desirable clearance (1.2m [4 ft]) or alternative solutions such as decreasing the width of the rumble strip are not possible.
- Where rumble strips are proposed on roads used by bicyclists, increased maintenance of the shoulder should be undertaken to assure a clear path of travel for bicyclists.

4.9.5 Guard Rails

Guard rail design and placement can affect the safety of bicyclists. Designers should consider the impact of guardrail on shoulder width available for use by bicyclists.

Due to the low height of guard rails, bicyclists may topple over the rail and be injured by guard rail posts and mounting hardware.

Where guard rails are placed along a highway or shoulder, they should be set back a minimum distance of at least 0.8 m (2 ft) from the edge of the roadway or shoulder pavement to maintain a clear shy space for bicyclists (and pedestrians). If this cannot be achieved, the effective usable shoulder width is reduced.

The VTrans 2000 “Study of Guardrail Selection Criteria for Vermont Highways” acknowledges the potential impact of guard rail on bicyclists. Where shoulder width is minimal (less than 3 feet) and traffic volumes are greater than 2000 ADT, the study suggests that guardrail systems with narrower profiles (such as 3-cable or box beam) be used to minimize encroachment on available shoulder width. An additional benefit of these alternative guard rail systems is that they are more aesthetic than standard steel W-beam guardrail.

4.9.6 Work Zones and Temporary Traffic Control

Where bicyclists are traveling on a road and a temporary traffic control zone is provided in accordance with the latest version of Part 6 of the MUTCD, they should be expected to traverse the work zone as part of the normal traffic flow. Contractors should consider the needs of bicyclists in establishing and maintaining work zones such that conditions particularly hazardous to bicyclists (e.g. rough surfaces, excessive drop offs, and longitudinal cracks) are avoided. For a more detailed discussion, refer to Section 8.3.4.

4.10 Additional Measures to Improve On-road Bicycling

There are a number of additional measures that can be taken to improve the on-road bicycling experience. These include:

- Bicycle parking devices (refer to Chapter 9, Landscaping and Amenities).
- Accommodating bicycles on public transportation.
- Keeping existing roadways in good condition (refer to Chapter 10, Maintenance).
- Adding shoulders when repaving.
- Using materials that result in smooth surfaces on unpaved roads.
- Using appropriate signs in high bicycle-traffic areas (refer to Chapter 8, Signs, Pavement Markings and Signals).
- Erecting and maintaining signs that identify the names of intersecting roads at every intersection.
- Using appropriate interstate, U.S. route, state route or local route marker signs in advance of roundabouts to alert all road users where to “exit.”

4.10.1 Bicycle Route Maps

Maps designed for bicyclists exist in many forms. In order of increasing complexity, they can:

- Outline short, recreational loop rides.
- Describe the bike route system of a locality (refer to Chapter 2, Planning for Pedestrians and Bicyclists).
- Offer information to bicycle commuters on the most direct routes to various employment centers.
- Define a particular long-distance touring route and provide information about services and attractions along the route.
- Indicate the suitability for shared use of streets and roads by bicycles and motor vehicles throughout a given urban or rural highway system.

The cost of producing, printing and distributing bicycle maps can be much less than the cost of installing and maintaining signs along a route. Defining the function of the map and identifying the primary user group for whom the map is intended will help to determine the type of map which should be produced. Additional discussion of Bicycle Route Maps can be found in Chapter 2, Planning for Pedestrians and Bicyclists..

4.11 Additional Resources

Consult the following resources for the broadest coverage of issues relating to the planning and design of on-road bicycle facilities:

- *A Policy on Geometric Design of Highways and Streets, Fourth Edition,* 2001 (The Green Book). American Association of State Highway and Transportation Officials (AASHTO), P.O. Box 96716, Washington, DC, 20090-6716, Phone: (888) 227-4860.
- *Bicycle Touring in Vermont and Vermont's Scenic Byways Program,* (1995). VTrans Project and Development Division, Local Transportation Facilities Section, National Life Building, Drawer 33, Montpelier, VT 05633-5001.
- *Flexibility in Highway Design,* 1997. FHWA. HEP 30, 400 Seventh Street SW, Washington, DC 20590.
- *Florida Bicycle Facilities Planning and Design Handbook,* Revised 1999. Florida Department of Transportation, Pedestrian and Bicycle Program, State Safety Office, Mail Stop 82, 605 Suwannee Street, Tallahassee, FL 32399-0450, Phone: (850) 487-1200.
- *Guide for the Development of Bicycle Facilities,* 1999., American Association of State Highway and Transportation Officials (AASHTO), P.O. Box 96716, Washington, DC, 20090-6716, Phone: (888) 227-4860.
- *Highway Capacity Manual, Special Report 209,*2000. Transportation Research Board, Box 289, Washington, DC 20055, Phone: (202) 334-3214. Next Edition: FHWA Research Program project has identified changes to HCM related to bicycle and pedestrian design.
- *Implementing Bicycle Improvements at the Local Level,* (1998), FHWA, HSR 20, 6300 Georgetown Pike, McLean, VA.
- *Manual on Uniform Traffic Control Devices,* 2000. Federal Highway Administration (FHWA), available from ITE, ATSSA and AASHTHO.
- *Oregon Bicycle and Pedestrian Plan,* 1995. Oregon Department of Transportation, Bicycle and Pedestrian Program, Room 210, Transportation Building, Salem, OR 97310, Phone: (503) 986-3555.
- *Pedestrian and Bicycle Crash Types of the Early 1990s* (1996). Published by Federal Highway Administration (FHWA). Available from National Technical Information Service, Springfield, VA 22161, Phone: (703) 487-4650.
- *Selecting Roadway Design Treatments to Accommodate Bicyclists,* 1993. FHWA, R&T Report Center, 9701 Philadelphia Ct, Unit Q; Lanham, MD 20706. (301) 577-1421 (fax only).
- *Study of Guardrail Selection Criteria for Vermont Highways*, (2000). VTrans Project Development Division, National Life Building, Drawer 33, Montpelier, VT 05633-5001.
- *Vermont Better Backroads Manual*, November (1995). Goerge D. Aiken and Northern Vermont Resource Conservation and Development Councils. Available from Vermont Local Roads Program, St. Michaels College and George D. Aiken RCD.
- *Vermont State Standards*. VTrans Project Development Division, National Life Building, Drawer 33, Montpelier, VT 05633-5001.