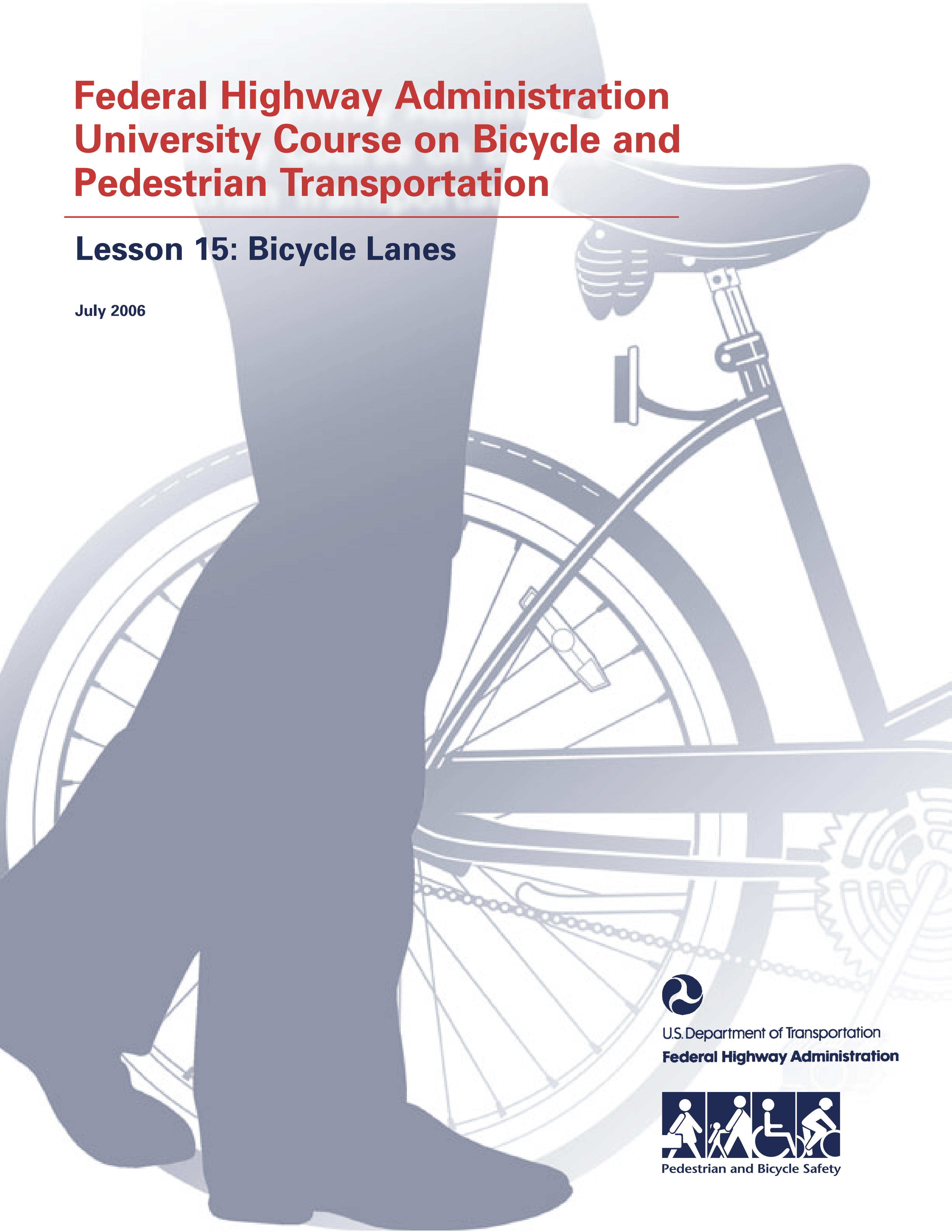

Federal Highway Administration University Course on Bicycle and Pedestrian Transportation

Lesson 15: Bicycle Lanes

July 2006

U.S. Department of Transportation
Federal Highway Administration

Pedestrian and Bicycle Safety

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LESSON 15:

BICYCLE LANES

15.1 Introduction

The 1999 American Association of State Highway and Transportation Officials (AASHTO) publication, *Guide for the Development of Bicycle Facilities* (hereafter referred to as the AASHTO *Guide*), defines a bicycle or bike lane as "a portion of a roadway which has been designated by striping, signing, and pavement markings for the preferential or exclusive use of bicyclists."[1] The public agency and community support for bike lanes as a reasonable accommodation of bicyclists has been growing in many American cities. Although some cities such as Davis, CA, have several decades of experience, many American cities are still developing innovative ways to design bike lanes into complex roadway and traffic environments. A number of best design practices have emerged and are included in the 1999 AASHTO *Guide* or in the *Manual of Uniform Traffic Control Devices* (MUTCD).[2] This lesson includes the design standards from AASHTO as well as additional design guidelines that other cities or States have developed. This lesson also summarizes other innovative bike lane designs and concepts (some are borrowed from Europe—see lesson 23) that are still being tested and evaluated.

The major sections of this lesson are as follows:

- 15.1 Introduction.
- 15.2 Width Standards and Cross-Section Design.
- 15.3 Retrofitting Bicycle Lanes on Existing Streets.
- 15.4 Bicycle Lanes at Intersections and Interchanges.
- 15.5 Bicycle Lane Pavement Markings.
- 15.6 Bicycle Lane Signing.
- 15.7 Other Design Considerations.
- 15.8 Practices to Avoid.
- 15.9 Student Exercise.
- 15.10 References and Additional Resources.

This lesson on bicycle lanes has been derived from several sources, including the 1999 AASHTO *Guide*, the 1995 *Oregon Bicycle and Pedestrian Plan*, and the *Philadelphia Bicycle Facility Design Guidelines*.[1,3,4]

15.2 Width Standards and Cross-Section Design

Bicycle lanes serve the needs of all types of cyclists in urban and suburban areas by providing them with a dedicated travel lane within the street space. The minimum width of a bike lane will vary based on the roadway cross section (see figure 15-1). For roadways with no curb and gutter, the minimum width of a bike lane should be 1.2 meters (m) (4 feet (ft)). If parking is permitted, the bike lane should be placed between the parking area and the travel lane, and have a minimum width of 1.5 m (5 ft). Where parking is permitted but a parking stripe or stalls are not utilized, the shared area should be a minimum of 3.3 m (11 ft) without a curb face and 3.5 m (12 ft) adjacent to a curb.

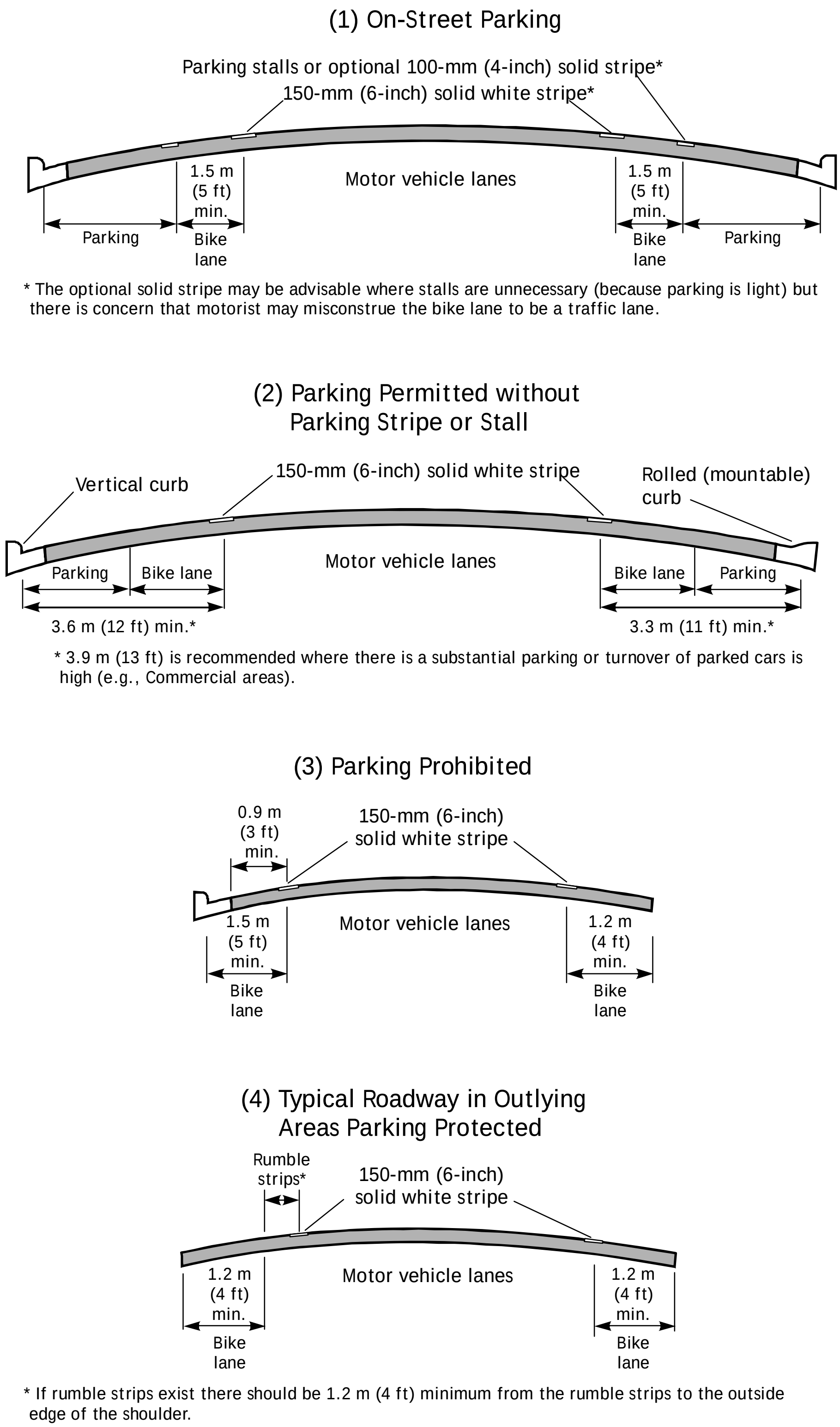

Figure 15-1. Illustrations. Typical bike lane cross sections.

Source: American Association of State Highway and Transportation Officials[1]

The recommended width of a bike lane is 1.5 m (5 ft) from the face of a curb or guardrail to the bike lane stripe. This 1.5-m (5-ft) width should be sufficient in cases where a 0.3–0.6 m (1–2 ft) gutter pan exists, given that a minimum of 0.9 m (3 ft) of ridable surface is provided and the longitudinal joint between the gutter pan and the pavement surface is smooth. If the joint is not smooth, 1.2 m (4 ft) of ridable surface should be provided.

Since bicyclists usually tend to ride a distance of 0.8–1.0 m (32–40 inches) from the curb face, it is very important that the pavement surface in this zone be smooth and free of structures. Drain inlets and utility covers that extend into this area cause bicyclists to swerve, resulting in a reduction of usable lane width. Where these structures exist and the surface cannot be made smooth, the bike lane width should be adjusted accordingly. Regular maintenance is critical for bike lanes (see lesson 16).

Bicycle lanes are always located on both sides of the road on two-way streets. Since bicyclists must periodically merge with motor vehicle traffic, bike lanes should not be separated from other motor vehicle lanes by curbs, parking lanes, or other obstructions. Two-way bike lanes on one side of two-way streets create hazardous conditions for bicyclists and are not recommended. The problems associated with two-way bike lanes are discussed in more detail in section 15.8.

On one-way streets, bicycle lanes should be installed on the right-hand side, unless conflicts can be greatly reduced by installing the lane on the left-hand side. Left-side bicycle lanes on one-way streets may also be considered where there are frequent bus or trolley stops, unusually high numbers of right-turning motor vehicles, or if there is a significant number of left-turning bicyclists.

15.3 Retrofitting Bicycle Lanes on Existing Streets

While bike lanes may be desirable in many urban locations, designers face the reality that space is limited on most urban streets. Unless plans call for a roadway widening project, the extra width for bike lanes is often very difficult to find in retrofit situations. In central business districts, roadway widening for bike lanes is usually not a desired option, since it could cause problems for pedestrians by further reducing sidewalk space. This section discusses possible options to consider when retrofitting bicycle lanes into limited space on existing streets.

Where existing street width does not permit desirable roadway cross-section dimensions to be used, it may be possible to modify elements of the roadway to accommodate bike lanes. In their guidelines, the Oregon Department of Transportation (ODOT) considers these options:[3]

- Reduction of travel lane width.
- Reduction of the number of travel lanes.
- Removal, narrowing, or reconfiguration of parking.
- Other design options.

ODOT uses the guidelines in this section to determine how a roadway can be modified to accommodate bike lanes without significantly affecting the safety or operation of the roadway. The reduced travel lane widths are within AASHTO minimums. ODOT stresses the importance of using good engineering judgment when retrofitting bike lanes on existing streets.

Reduction of Travel Lane Widths

The need for full-width travel lanes decreases with speed (see figure 15-2):

- Up to 40 kilometers per hour (km/h) (25 miles per hour (mi/h)), travel lanes may be reduced to 3.0 or 3.2 m (10.0 or 10.5 ft).
- From 50 to 65 km/h (30 to 40 mi/h), 3.3-m (11-ft) travel lanes and 3.6-m (12-ft) center turn lanes may be acceptable.
- At 70 km/h (45 mi/h) or greater, try to maintain a 3.6-m (12-ft) outside travel lane and 4.2-m (14-ft) center turn lane if there are high truck volumes.

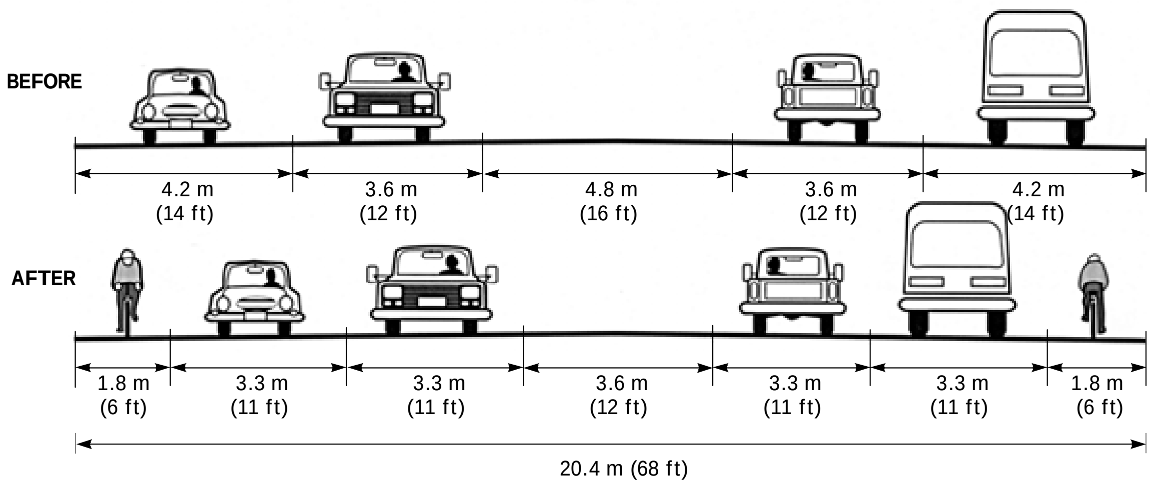

Figure 15-2. Illustration. Retrofitting bike lanes by reducing travel lane widths.
Source: *Oregon Bicycle and Pedestrian Plan*(3)

Reduction of the Number of Travel Lanes

Many one-way street pairs were originally two-way streets. This can result in an excessive number of travel lanes in one direction. A traffic capacity study will determine if traffic can be handled with one less lane (see figure 15-3).

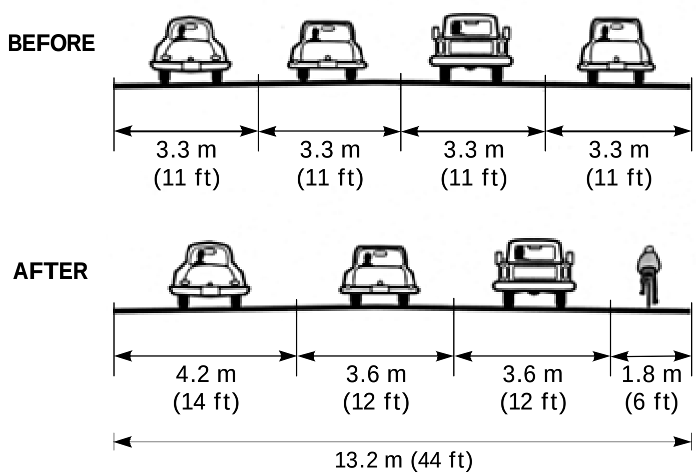

Figure 15-3. Illustration. Reducing the number of travel lanes on a one-way street.
Source: *Oregon Bicycle and Pedestrian Plan*[3]

On two-way streets with four travel lanes and a significant number of left-turn movements, restriping for a center turn lane, two travel lanes, and two bike lanes can often improve traffic flow (see figure 15-4). This type of street reconfiguration is referred to as a road diet and is considered to be effective at calming traffic and providing space for bicyclists while still providing a reasonable vehicle level of service. Burden and Lagerway summarize the street and location criteria that can be used to identify potential candidates for road diets:[5]

- Moderate volumes (8,000–15,000 average daily traffic (ADT)).
- Roads with safety issues.
- Transit corridors.
- Popular or essential bicycle routes/links.
- Commercial reinvestment areas.
- Economic enterprise zones.
- Historic streets.
- Scenic roads.
- Entertainment districts.
- Main streets.

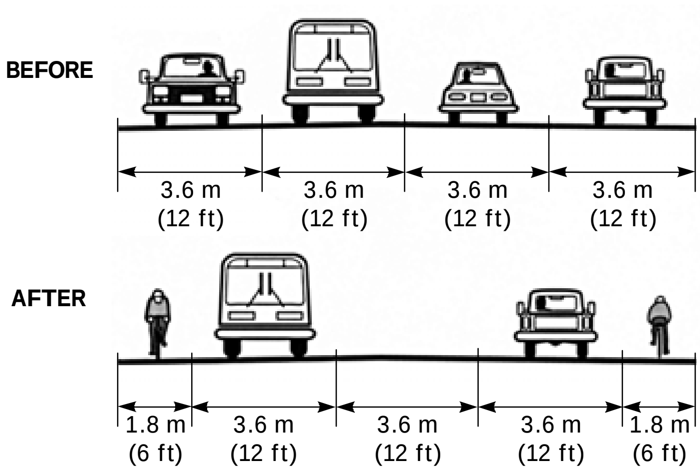

Figure 15-4. Illustration. Road diet: retrofitting bike lanes by reducing the number of travel lanes.
Source: *Oregon Bicycle and Pedestrian Plan*[3]

Removal, Narrowing or Reconfiguration of Parking

A roadway's primary function is to move people and goods rather than to store stationary vehicles. When parking is removed, safety and capacity are generally improved. Removal of parking will require negotiations with the local governing body (such as the city council), affected business owners, and residents. To reduce potential conflicts, careful research is needed before making a proposal, including:

- Counting the number of businesses and residences and the availability of both on-street and off-street parking.
- Selecting which side of the roadway would be less affected by removal (usually the side with fewer residences or businesses, or the side with residences rather than businesses in a mixed-use neighborhood).
- Proposing alternatives such as:
  - Allowing parking for church or school activities on adjacent lots during services or special events.
  - Promoting shared use by businesses.
  - Constructing special parking spaces for residents or businesses with no other options.

Instead of removal of all on-street parking, several other options can be pursued. Parking can be narrowed to 2.1 m (7 ft) (see figure 15-5), particularly in areas with low truck parking volumes.

Bicycle lanes next to on-street parking can be problematic if enough space is not provided to prevent bicyclists from riding into an opened door. The AASHTO *Guide* recommends a combined width of 3.9 m (13 ft) for combined width of parking and bike lanes (see figure 15-1).

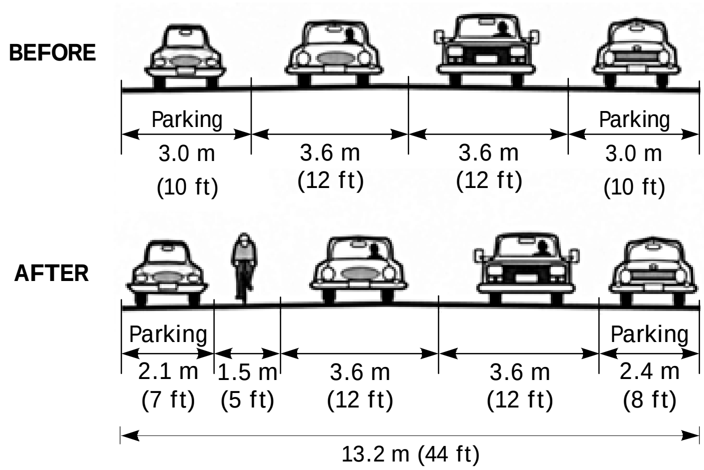

Figure 15-5. Illustration. Narrowing parking on a one-way street.

Source: *Oregon Bicycle and Pedestrian Plan*[3]

In some cases, parking may be needed on only one side to accommodate residences and/or businesses (see figure 15-6). Note that it is not always necessary to retain parking on the same side of the road through an entire corridor.

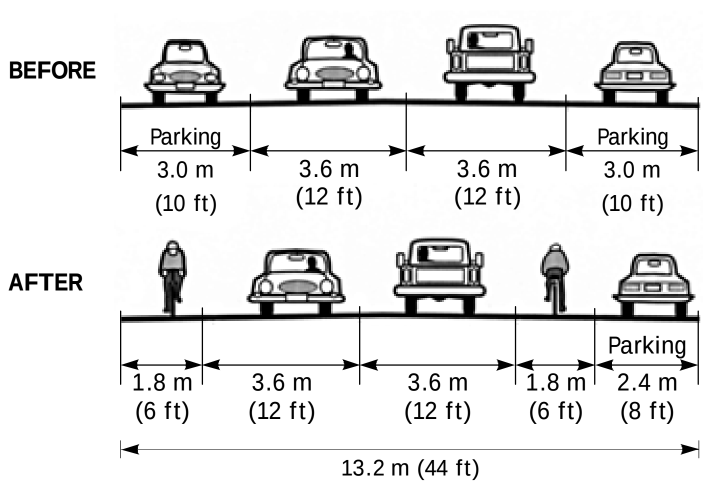

Figure 15-6. Illustration. Parking removed on one side of a two-way street.

Source: *Oregon Bicycle and Pedestrian Plan*[3]

Diagonal parking takes up an inordinate amount of roadway width relative to the number of parking spaces provided. It can also be hazardous, as drivers backing out cannot see oncoming traffic. Changing to parallel parking reduces availability by less than one-half (see figure 15-7). On one-way streets, changing to parallel parking on one side only is sufficient; this reduces parking by less than one-fourth.

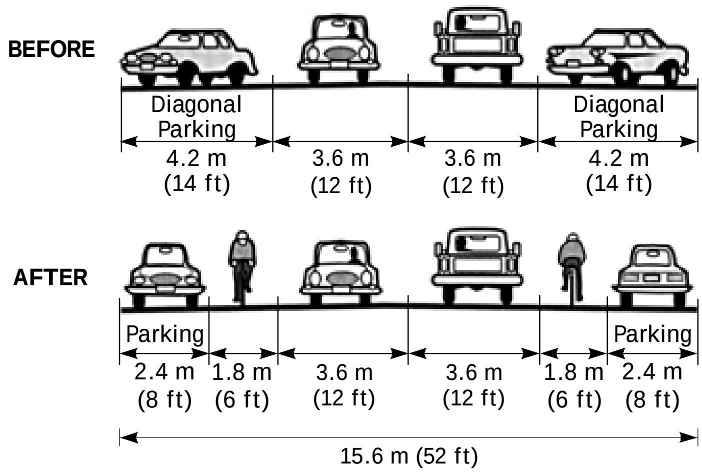

Figure 15-7. Illustration. Changing from diagonal to parallel parking on a two-way street.

Source: *Oregon Bicycle and Pedestrian Plan*(3)

Most business owners cite the fear of losing potential customers as the main reason to retain on-street parking. Many cities have had success with ordinances prohibiting employees from parking on the street. This could help increase the number of available parking spaces for customers, even if the total number of parking spaces is reduced. Note that one parking place occupied by an employee for 8 hours is the equivalent of 16 customers parking for half an hour, or 32 customers parking for 15 minutes.

Where all of the above possibilities of replacing parking with bike lanes have been pursued, and residential or business parking losses cannot be sustained, innovative ideas should be considered to provide parking, such as off-street parking. Other uses of the right-of-way should also be considered, such as using a portion of a planting strip where available (see figure 15-8).

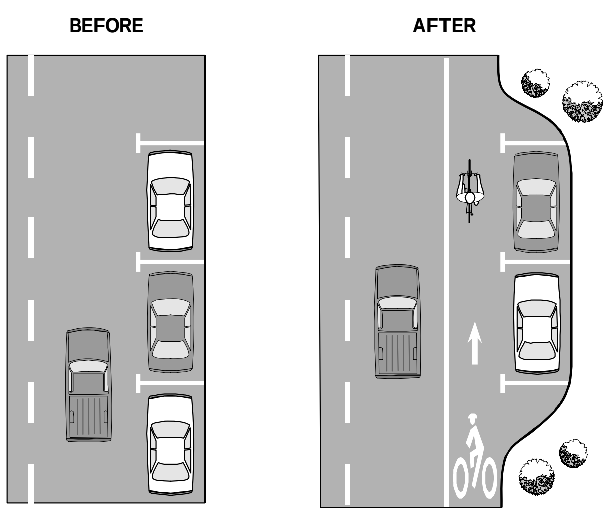

Figure 15-8. Illustration. Providing parking when there are no reasonable alternatives.

Source: *Oregon Bicycle and Pedestrian Plan*(3)

Other Design Options

Not all existing roadway conditions will be as simple to retrofit as those listed previously. In many instances, unique and creative solutions will have to be found. Width restrictions may only permit a wide curb lane (4.2–4.8 m (14–16 ft)) to accommodate bicycles and motor vehicles (see figure 15-9). Bike lanes must resume where the restriction ends. It is important that every effort be made to ensure bike lane continuity. Practices such as directing bicyclists onto sidewalks or other streets for short distances should be avoided, as they may introduce unsafe conditions.

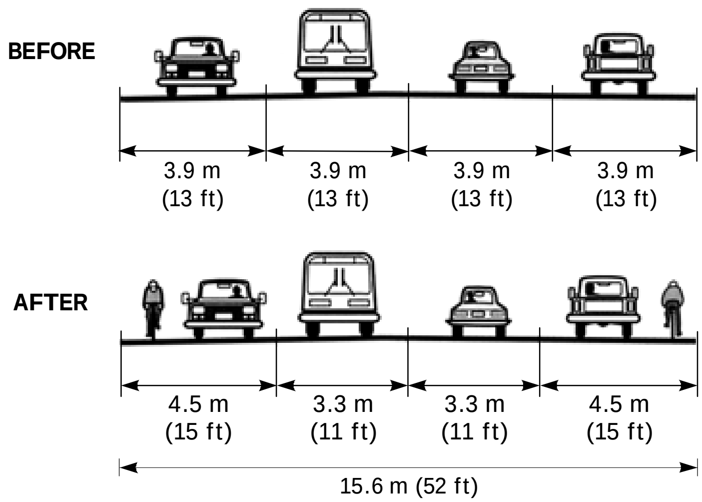

Figure 15-9. Illustration. Restriping for a wide curb lane.

Source: *Oregon Bicycle and Pedestrian Plan*[3]

Other minor improvements at the outer edge of the roadway should be made in conjunction with bike lane restriping, including:

- Existing drainage grates, and manhole and utility covers should be raised flush to the pavement prior to striping a bike lane.
- Minor widening may be required to obtain adequate width.
- Removal or relocation of obstructions away from the edge of the roadway may gain some usable width. Obstructions can include guardrails, utility poles, and sign posts.

Additional Benefits from Retrofitting Bike Lanes

Safety is enhanced as travel lanes are offset from curbs, lanes are better defined, and parking is removed or reduced. Adding bike lanes can often improve sight distance and increase turning radii at intersections and driveways. Restriping travel lanes redistributes motor vehicle traffic, which can help extend the pavement life, as traffic is no longer driving in the same well-worn ruts.

Salem, OR, Case Study

A paper by Chuck Fisher contains information about how the city of Salem, OR, approached the retrofit of bicycle lanes in their city.[6] The first step in the retrofitting process was identifying which streets would make the best connections for bicyclists. In Salem, there is a lack of connectivity between the outer areas' bicycle facilities and the downtown core. Particularly lacking are connecting bicycle lanes within 3 km (2 mi) of downtown, the area most likely served by increased levels of bicycling. Salem city staff recognized that retrofitting these older neighborhoods with bike lanes and removing all on-street parking would probably have created a political firestorm. As a result, the staff developed policies and methodologies that allowed for the mitigation of on-street parking demand.

Policy Language. The relevant policy language is contained within the Goal, Objective, and Policies of the Salem Transportation System Plan's Bicycle System Element:

> **Policy 1.2—Mitigation of On-Street Parking Loss Due to Future Bicycle Facility Projects**. Where new bicycle facilities require the removal of on-street parking spaces on existing roadways, parking facilities shall be provided that mitigate, at a minimum, the existing on-street parking demand lost to the bike project. This policy does not apply to street widening or major reconstruction projects.

The key phrase in the policy is the mitigation of parking demand, not supply. As part of the update of the plan, the staff developed criteria for ranking potential bike projects. Working with this list, the staff determined which projects were to be included for the next construction season. First and foremost, the staff surveys the existing on-street parking demand on the facility. Other data collection includes existing cross sections and on-street parking supply. Analysis activities included sketching cross-section design, locating alternative on-street parking locations, and developing initial project cost estimates.

Public Involvement. At this point, the staff began a public involvement process that included neighborhood meetings, letters to abutting property owners, public workshops to determine alternatives, on-street sign notification, Citizens Advisory Traffic Commission meetings, and final approval by the City Council.

Some of the alternatives presented by the staff at the meeting workshops included restriping the road to accommodate parking on one side instead of two. Neighbors were asked to help determine on which side of the street parking should remain, given that only half of the parking supply would be required to meet the demand. A variation on this would be to alternate the parking from side to side. For instance, if a six-block area required parking on one side, a solution might be to allow parking on one side for three blocks and then changing to the other side for three blocks.

Another alternative would be to build parking bays, especially if only a small amount of parking mitigation would be required. Similar to bus bays or pull-outs, these would add the necessary room to accommodate parking in what had been the planting strip, between the curb and sidewalk.

15.4 Bicycle Lanes at Intersections and Interchanges

At intersections and interchanges, bicyclists proceeding straight through and motorists making turns must cross paths. Lane striping and signing configurations that encourage crossings and merging in advance of the intersection are preferable to those that force a crossing or merging in the immediate vicinity of the intersection. The following paragraphs within this section provide guidance on bike lane design issues at intersections and interchanges.

Intersections with Right-Turn Lanes

The AASHTO *Guide* provides supplemental information about the design of bike lanes at intersections with right-turn lanes.[(1)] Figure 15-10 illustrates typical bike lane design and pavement markings at a variety of intersection approaches. There are several possible approaches for bike lane design where these right-turn lanes are present (see figure 15-11). The most desirable configuration will depend on the local road cross section and turning vehicle traffic patterns.

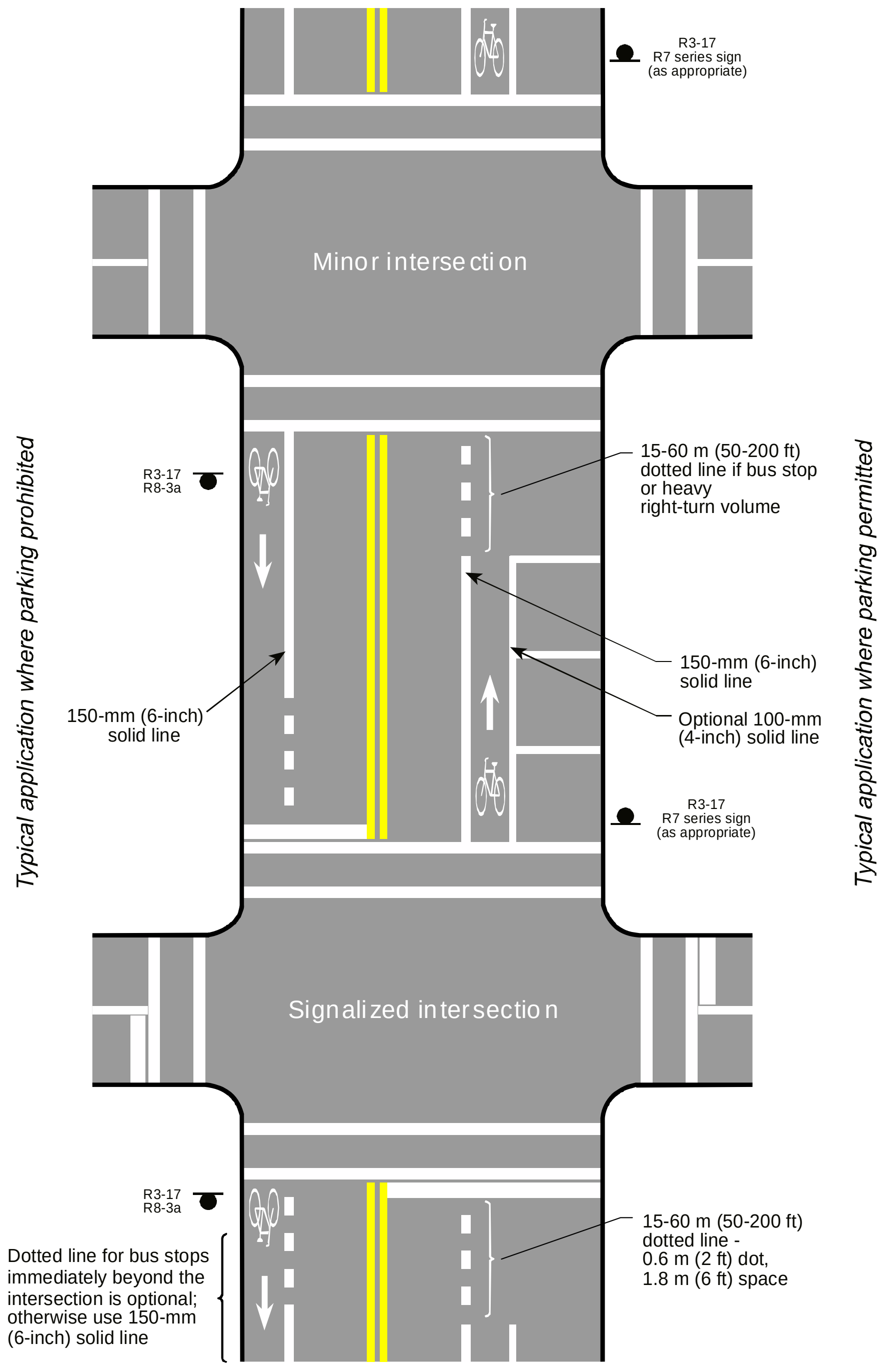

Figure 15-10. Illustration. Typical pavement markings for bike lane on two-way street.

Source: American Association of State Highway and Transportation Officials [1]

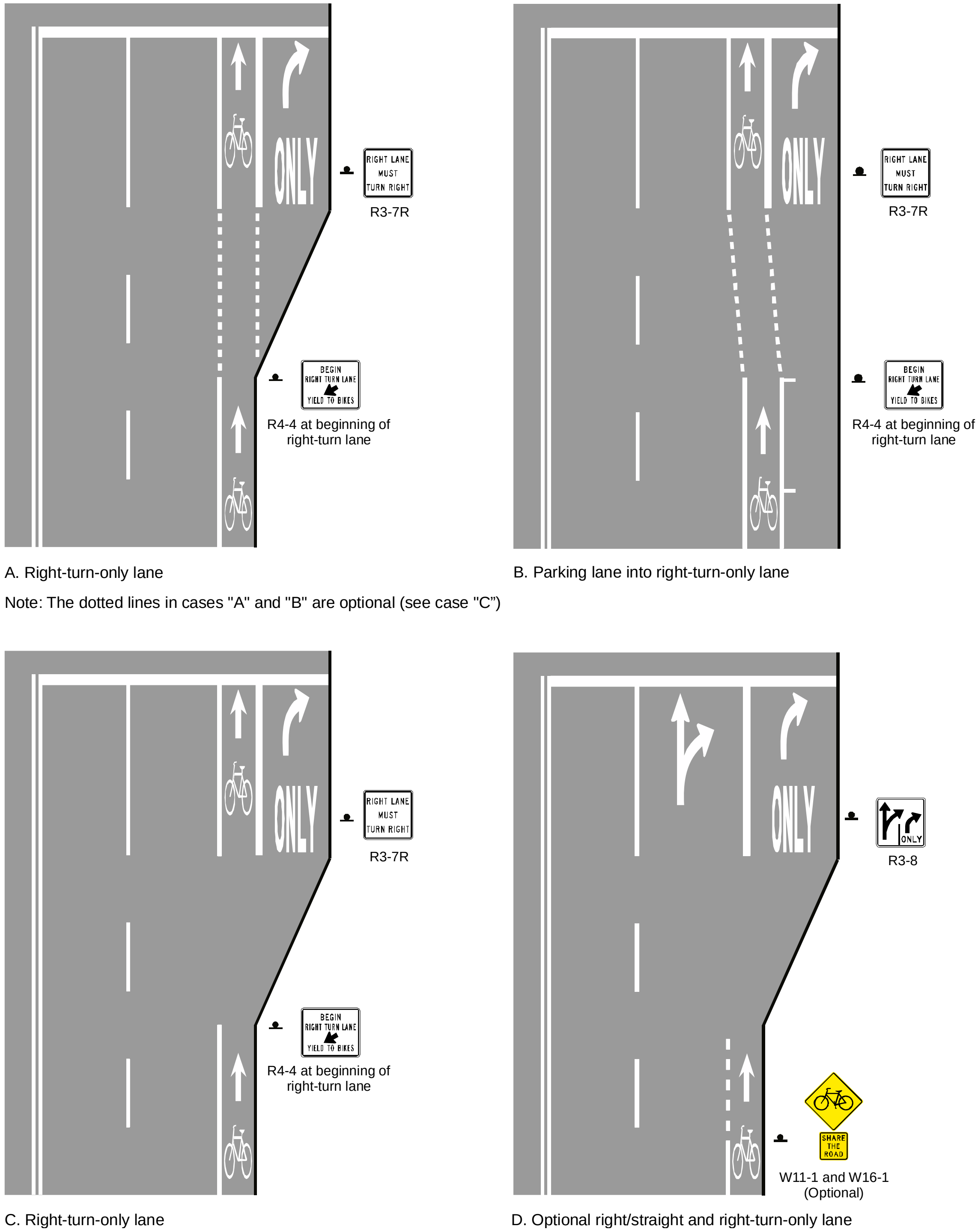

Figure 15-11. Illustrations. Possible configurations for bike lane and right-turn lane.

Source: American Association of State Highway and Transportation Officials[1]

Dual right-turn lanes are particularly difficult for bicyclists. Warrants for dual turn lanes should be used to ensure that such lanes are provided only if absolutely necessary. The design for single right-turn lanes allows bicyclists and motorists to cross paths in a predictable manner, but the addition of a through lane from which cars may also turn adds complexity. Some drivers make a last minute decision to turn right from the center lane without signaling, thus catching bicyclists and pedestrians unaware.

Several approaches to bike lane design with dual right-turn lanes are provided in figure 15-12. Design alternative A encourages cyclists to share the optional through-right-turn lane with motorists. Design alternative B guides cyclists up to the intersection in a dedicated bike lane. Design alternative C allows cyclists to choose a path themselves (this design is the AASHTO recommendation—simply dropping the bike lane prior to the intersection). Engineering judgment should be used to determine which design is most appropriate for the situation.

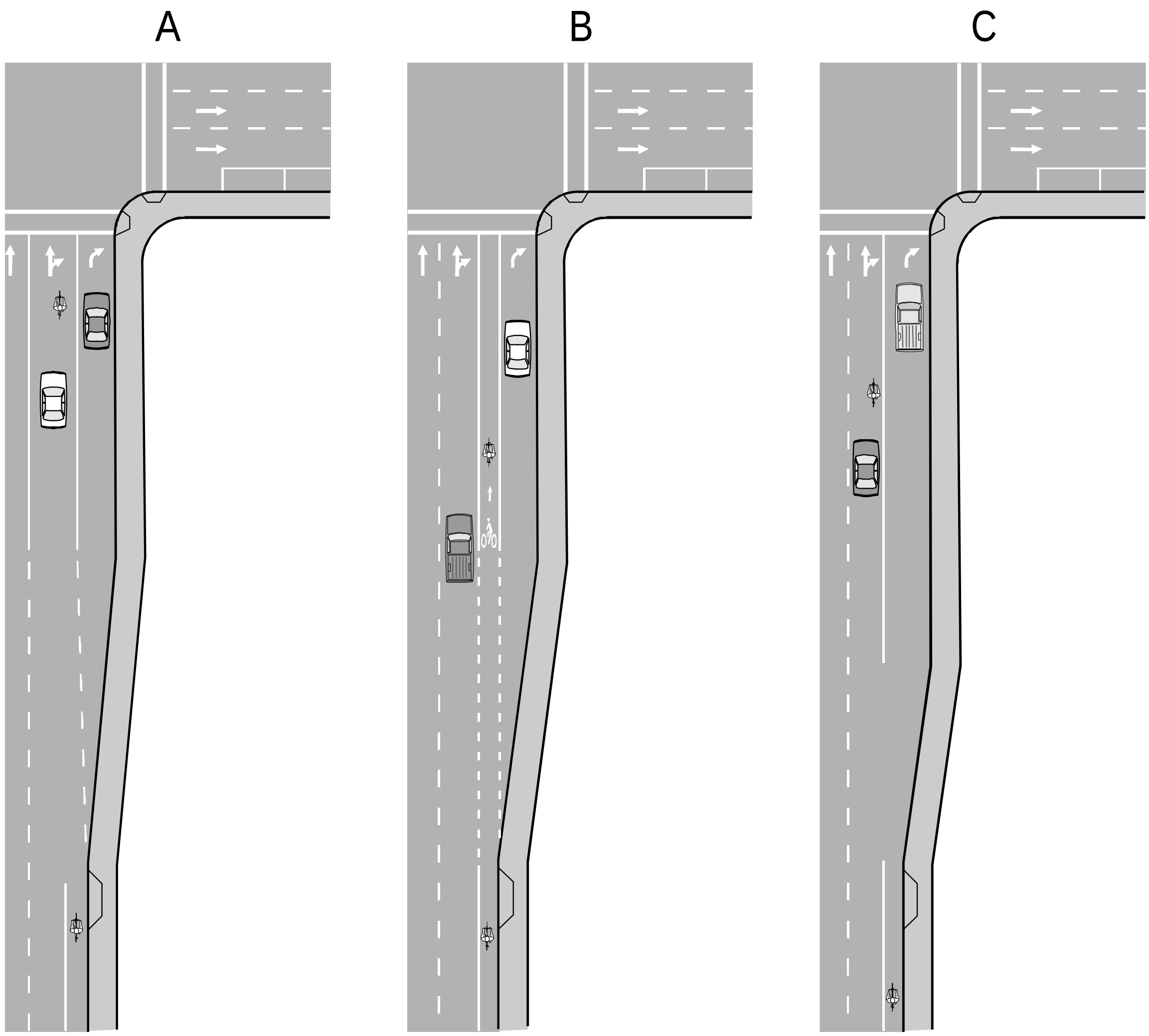

Figure 15-12. Illustrations. Design alternatives for a through bike lane with dual right-turn lanes.

Source: *Oregon Bicycle and Pedestrian Plan*(3)

On bike lane retrofit projects where there is insufficient room to mark a minimum 1.2-m (4-ft) bike lane to the left of the right-turn lane, a right-turn lane may be marked and signed as a shared-use lane to encourage through-cyclists to occupy the left portion of the turn lane (see figure 15-13). This has proven to be most effective on slow-speed streets.

Figure 15-13. Illustration. Right-turn lane shared by bicyclists and motorists.

Source: *Oregon Bicycle and Pedestrian Plan*[3]

Intersections with Bus Stops

If there is a bus stop at the near side of an intersection, a broken white bike lane line between 15 and 60 m (50 and 200 ft) in length should be used, and the solid white line should resume on the far side of the intersection, immediately after the crosswalk (see figure 15-10). If a bus stop is located on the far side of the intersection, the solid white line on the far side of the intersection should be replaced with a broken line for a distance of at least 24 m (80 ft) from the crosswalk.

Traffic Signal Actuation

It is recommended that new on-road bicycle facilities include traffic signals that detect bicycles for all actuated signal systems. The *Traffic Detector Handbook* recommends several bicycle-sensitive loop configurations (loops are wires installed beneath the pavement surface that detect the presence of vehicles) that can effectively detect bicycles.[7] The quadrupole loop is the preferred solution for bike lanes, and the diagonal quadrupole loop is preferred for use in shared lanes (see figure 15-14).

A potential solution for existing intersection signals that do not respond well to bicycles is to install a special pavement marking over the exact spot that a bicycle must stop in order to activate the signal. MUTCD, 2003 edition, recommends a pavement marking that can be used to locate these sensitive areas covering loop detectors for bicyclists (see figure 15-15).[2]

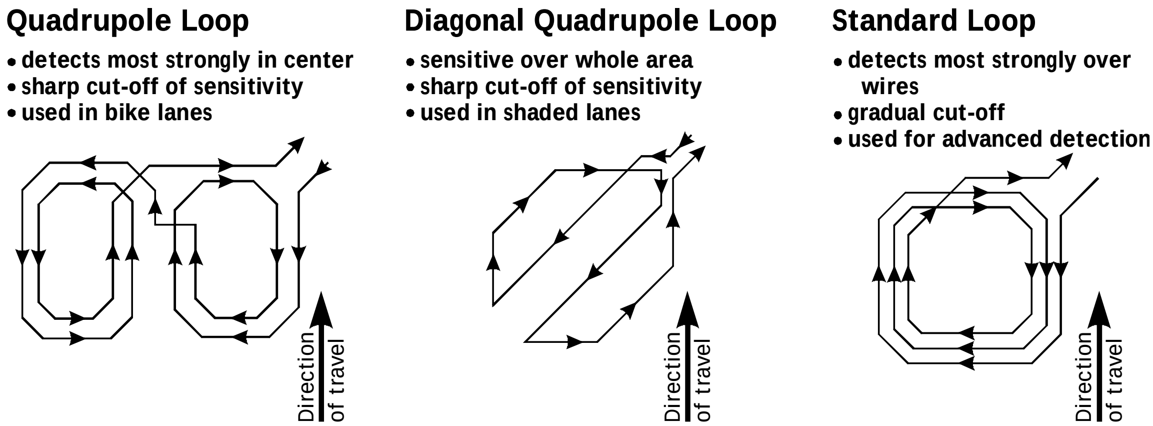

Figure 15-14. Illustrations. Different loop detector configurations for traffic signals.
Source: *Traffic Detector Handbook*(7)

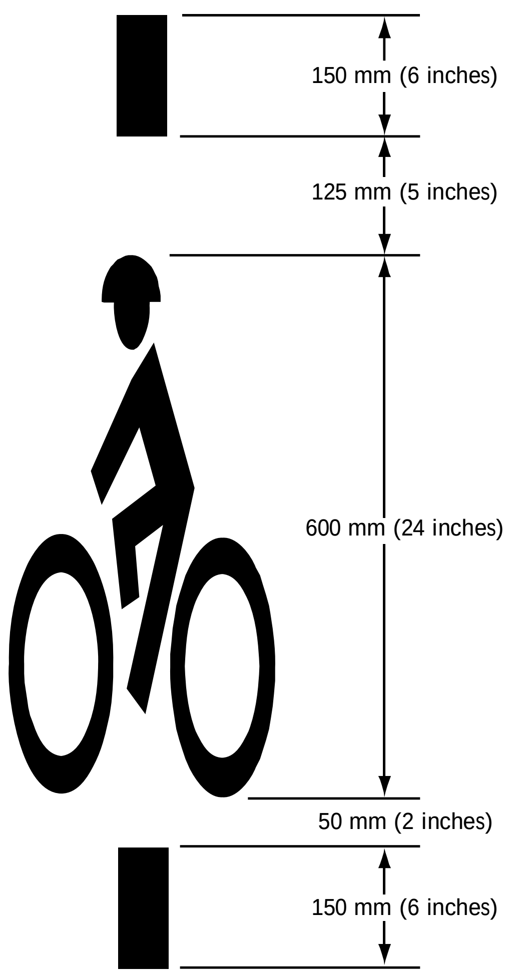

Figure 15-15. Illustration. Example of bicycle detector pavement marking.
Source: MUTCD, 2003 Edition(2)

Expressway Interchanges

Expressway interchanges often present barriers to bicycle travel. Designs that encourage free-flowing motor vehicle traffic movements are the most difficult for pedestrians and bicyclists to negotiate.

Interchanges with access ramps connected to local streets at a right angle are easiest for bicyclists to negotiate. The intersection of the ramp and the street should follow established urban intersection designs. The main advantages of this approach are:

- The distance that pedestrians and bicyclists must cross at the ramps is minimized.
- Signalized intersections stop traffic.
- Visibility is enhanced.

If these configurations are unavoidable, mitigation measures should be sought. Special designs should be considered that allow pedestrians and bicyclists to cross ramps in locations with good visibility and where speeds are low.

Where it is not possible to accommodate pedestrians and bicyclists with at-grade crossings, grade separation should be considered. Grade-separated facilities are expensive; they add out-of-direction travel and will not be used if the added distance is too great. This can create problems if pedestrians and bicyclists ignore the facility and try to negotiate the interchange at grade with no sidewalks, bike lanes, or crosswalks.

In some instances, a separate path can be provided on only one side of the interchange, which leads to awkward crossing movements. Some bicyclists will be riding on a path facing traffic, creating difficulties when they must cross back to a bike lane or shoulder (clear and easy-to-follow directions must be given to guide bicyclists' movements if those movements are inconsistent with standard bicycle operation).

The following concepts have been presented by ODOT as examples of innovative solutions to bike lane design at freeway/expressway interchanges and intersections.(3) Traffic entering or exiting a roadway at high speeds creates difficulties for slower-moving bicyclists.

It is difficult for bicyclists to traverse the undefined area created by right-lane merge movements, because:

- The acute angle of the approach creates visibility problems.
- Motor vehicles are often accelerating to merge into traffic.
- The speed differential between cyclists and motorists is high.

The design in figure 15-16 guides bicyclists at merging entrance ramps in a manner that provides:

- A short distance across the ramp at close to a right angle.
- Improved sight distances in an area where traffic speeds are slower than farther downstream.
- A crossing in an area where drivers' attention is not entirely focused on merging with traffic.

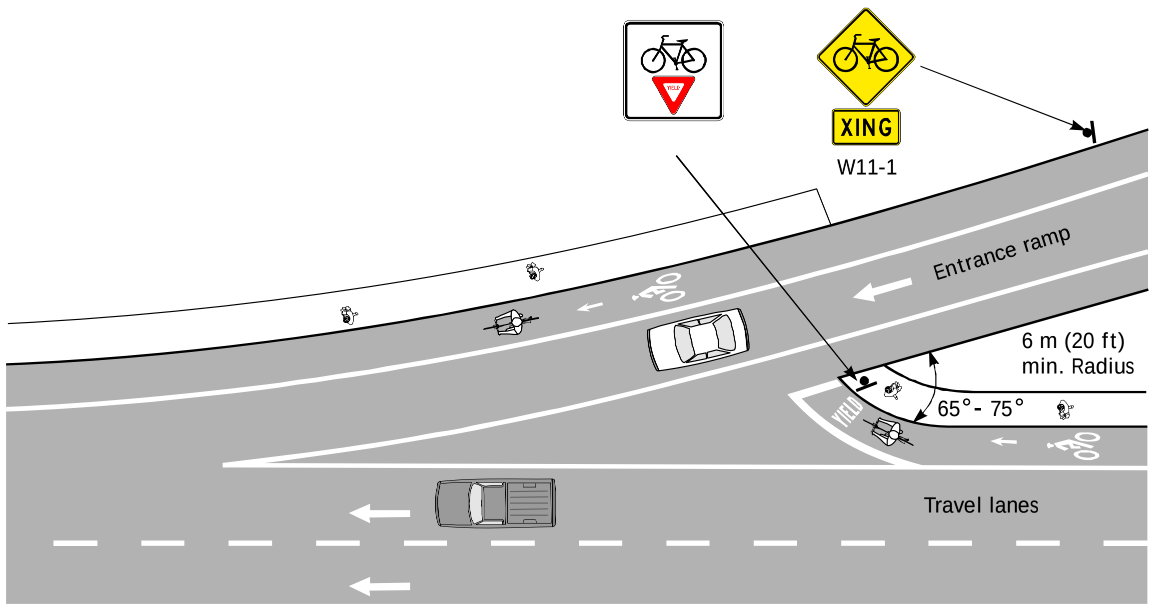

Figure 15-16. Illustration. Bike lane configuration at entrance ramp (urban design—not for limited access freeways).

Source: *Oregon Bicycle and Pedestrian Plan*(3)

Exit ramps present difficulties for bicyclists because:

- Motor vehicles exit at fairly high speeds.
- The acute angle creates visibility problems.
- Exiting drivers often do not use their right-turn signal, thus confusing pedestrians and bicyclists seeking a gap in the traffic.

The exit ramp design in figure 15-17 guides bicyclists in a manner that provides:

- A short distance across the ramp, at close to a right angle.
- Improved sight distances in an area where traffic speeds are slower than farther upstream.
- A crossing in an area where the driver's attention is not distracted by other motor vehicles.

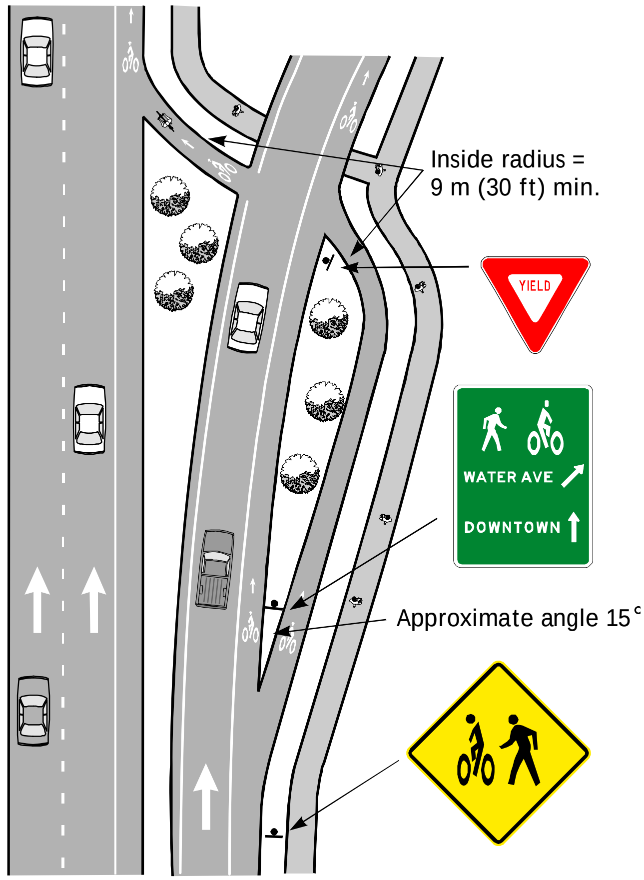

Figure 15-17. Illustration. Bike lane configuration at exit ramp (urban design—not for limited access freeways).

Source: *Oregon Bicycle and Pedestrian Plan*[3]

15.5 Bicycle Lane Pavement Markings

Section 9C of MUTCD addresses numerous aspects of pavement markings for bicycle facilities.[2] Pavement markings typically consist of:

- Solid or broken-edge line lane markings that delineate the vehicle travel lane and the bike lane (see figure 15-10 for examples).
- Lane symbols that indicate the preferential nature of the bike lane and its direction (see figure 15-18 for examples).
- Traffic signal detector symbol to indicate preferred bicyclist stopping location at actuated signals (see figure 15-15 for example).
- Pavement markings to warn of road hazards or obstructions.

Care should be taken to use pavement striping that is durable, yet skid-resistant. Reflectors and raised markings in bike lanes can deflect a bicycle wheel, causing a bicyclist to lose control. If reflective pavement markers are needed for motorists, they should be installed on the motorist's side of the stripe and have a beveled front edge.

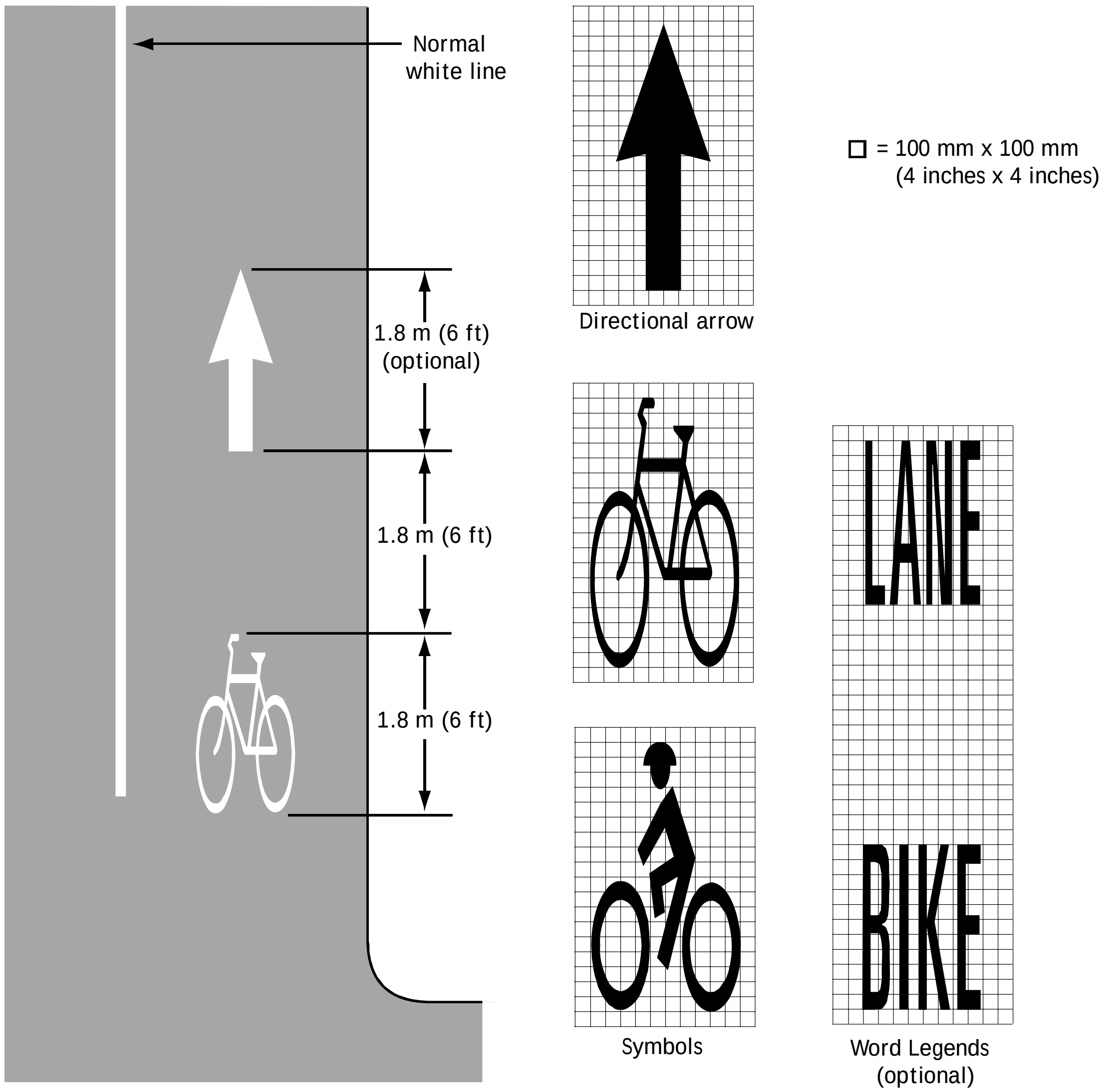

Figure 15-18. Illustrations. Examples of optional word and symbol pavement markings for bike lanes.

Source: MUTCD, 2003 Edition[2]

15.6 Bicycle Lane Signing

MUTCD section 9B addresses standard bike lane signing. Figure 15-19 shows regulatory signs for bicycle facilities (including bike lanes). MUTCD also provides recommendations for warning signs and bicycle route guide signs. Key MUTCD signing principles for bicycle facilities are:

- Bicycle signs shall follow standard MUTCD conventions for shape, legend, and color.
- All signs shall be retroreflectorized.
- Where signs serve bicyclists and other road users, the size, vertical mounting height, and lateral placement shall be as specified for vehicle traffic applications.

- Except for size, the design of signs specifically for bicycle facilities should be identical to that specified in MUTCD for vehicular travel.

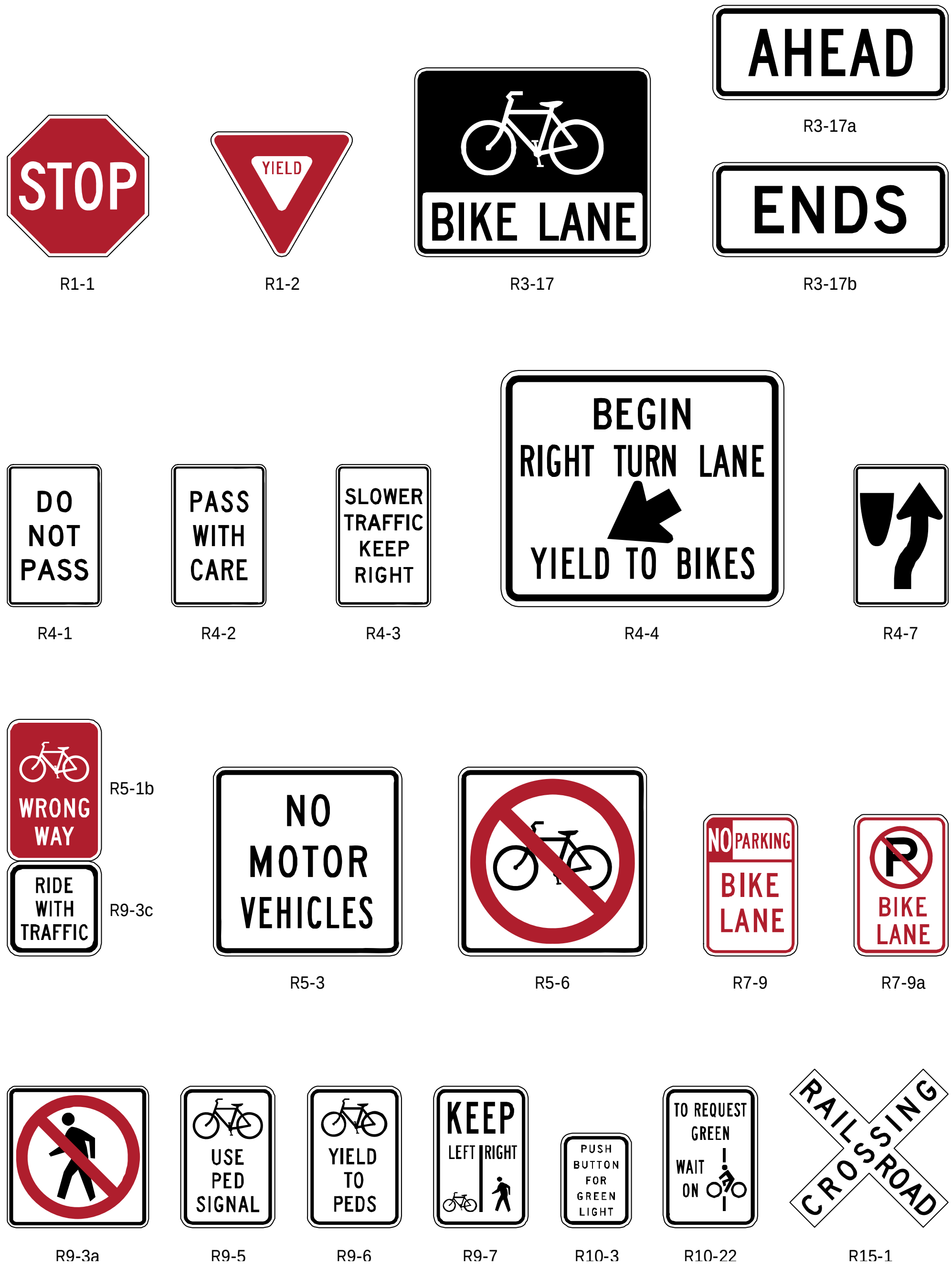

Figure 15-19. Illustrations. Regulatory signs for bicycle facilities.

Source: MUTCD, 2003 Edition[2]

15.7 Other Design Considerations

Colored Bike Lanes

Colored bike lanes have been tested in two U.S. cities (Portland, OR, and Cambridge, MA) as a way to guide bicyclists through complex intersections as well as to make motorists aware that they are crossing a bike lane. The concept of colored bike lanes has been applied and is standard practice in several European countries such as The Netherlands, Germany, Denmark, Sweden, Switzerland, Belgium, and France (see lesson 23). A study of blue bike lanes in Portland, OR (see figure 15-20 for example), reached the following conclusions:[8]

- Significantly more motorists yielded to bicyclists and slowed or stopped before entering the blue pavement area;
- More bicyclists followed the colored bike lane path.
- Fewer bicyclists turned their heads to scan for traffic or used hand signals, perhaps signifying an increased comfort level or lower level of caution.

Colored bike lanes have issues of maintenance—the paint wears quickly with vehicle traffic. As of 2004, the use of colored bike lanes has not been endorsed by any national design manuals or standards (such as the AASHTO *Guide* or MUTCD).

Figure 15-20. Photo. Example of blue bike lane in Portland, OR.

Source: *Evaluation of the Blue Bike-Lane Treatment Used in Bicycle/Motor Vehicle Conflict Areas in Portland, Oregon,* http://www.trans.ci.portland.or.us/bicycles/broadwayblue.htm[8]

Contraflow Bike Lanes

Contraflow bicycle lanes on a one-way street are not usually recommended. They may encourage cyclists to ride against traffic, which is contrary to the rules of the road and a leading cause of bicycle/motor vehicle crashes. There are, however, special circumstances when this design may be advantageous:

- A contraflow bike lane provides a substantial savings in out-of-direction travel.
- The contraflow bike lane provides direct access to high-use destinations.
- Improved safety because of reduced conflicts on the longer route.
- There are few intersecting driveways, alleys, or streets on the side of the contraflow lane.
- Bicyclists can safely and conveniently reenter the traffic stream at either end of the section.
- A substantial number of cyclists are already using the street.
- There is sufficient street width to accommodate a bike lane.

A contraflow bike lane may also be appropriate on a one-way residential street recently converted from a two-way street (especially where this change was made to calm traffic).

For a contraflow bike lane to function well, special features should be incorporated into the design:

- The contraflow bike lane must be placed on the proper side of the street (to motorists' left) and must be separated from oncoming traffic by a double yellow line. This indicates that the bicyclists are riding on the street legally, in a dedicated travel lane.

- Any intersecting alleys, major driveways, and streets must have signs indicating to motorists that they should expect two-way bicycle traffic.

- Existing traffic signals should be fitted with special signals for bicyclists (see figure 15-21); this can be achieved with either loop detectors or pushbuttons (these should be easily reached by bicyclists without having to dismount).

Under no circumstances should a contraflow bike lane be installed on a two-way street, even where the travel lanes are separated by a raised median.

(This picture shows a bicyclist not wearing a helmet.
FHWA strongly recommends that all bicyclists wear helmets.)

Figure 15-21. Photo. Contraflow bike lane with bicycle-specific signal in Madison, WI.

Diagonal Parking

Diagonal parking causes conflicts with bicycle travel: Drivers backing out have poor vision of oncoming cyclists; parked vehicles obscure other vehicles backing out. These factors require cyclists to ride close to the center of a travel lane, which is intimidating to inexperienced riders.

Where possible on one-way streets, diagonal parking should be limited to the left side, even if the street has no bike lane (on one-way streets with bike lanes, the bike lane should be placed adjacent to parallel parking, preferably on the right).

Bike lanes are not usually placed next to diagonal parking. However, should diagonal parking be required on a street planned for bike lanes, the following recommendations can help decrease potential conflicts:

- The parking bays must be long enough to accommodate most vehicles.
- A 200-mm (8-inch) stripe should separate the parking area from the bike lane (see figure 15-22).
- Enforcement may be needed to cite or remove vehicles encroaching on the bike lane.

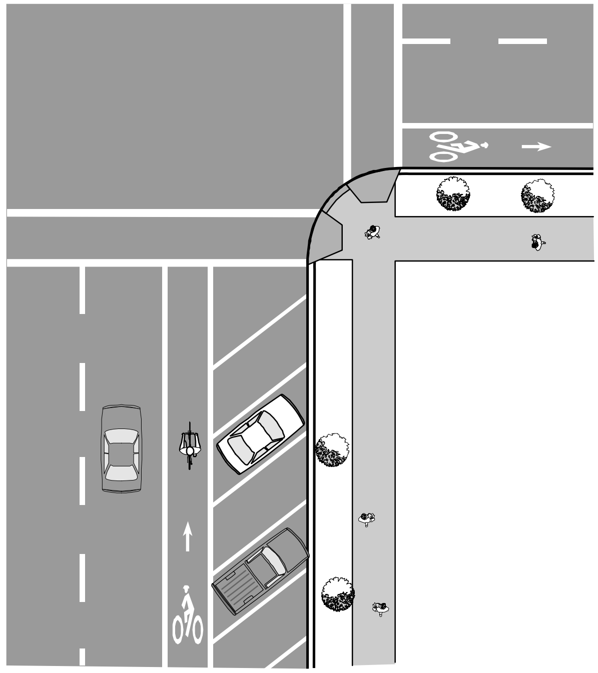

Figure 15-22. Illustration. Use of wide stripe to separate bike lane from diagonal parking.
Source: *Oregon Bicycle and Pedestrian Plan*(3)

Some cities have found the use of back-in diagonal parking to be more effective along streets with bike lanes. With back-in diagonal parking, parking motorists are required to stop in the travel lane and back their car across the bike lane into the parking spot. When leaving the back-in diagonal parking, the motorists are in a much better position to see bicycles approaching the bike lane. This design alternative has not been widely used yet, and more experience will determine its effects on the safety and operation of bike lanes near parking.

15.8 Practices to Avoid

Two-Way Bike Lanes

Two-way bike lanes create a dangerous condition for bicyclists (see figure 15-23). They encourage illegal riding against traffic, causing several problems:

- At intersections and driveways, wrong-way riders approach from a direction where they are not visible to motorists.
- Bicyclists closest to the motor vehicle lane have opposing motor vehicle traffic on one side and opposing bicycle traffic on the other.
- Bicyclists are put into awkward positions when transitioning back to standard bikeways.

If constraints allow widening on only one side of the road, the centerline stripe may be shifted to allow for adequate travel lanes and bike lanes.

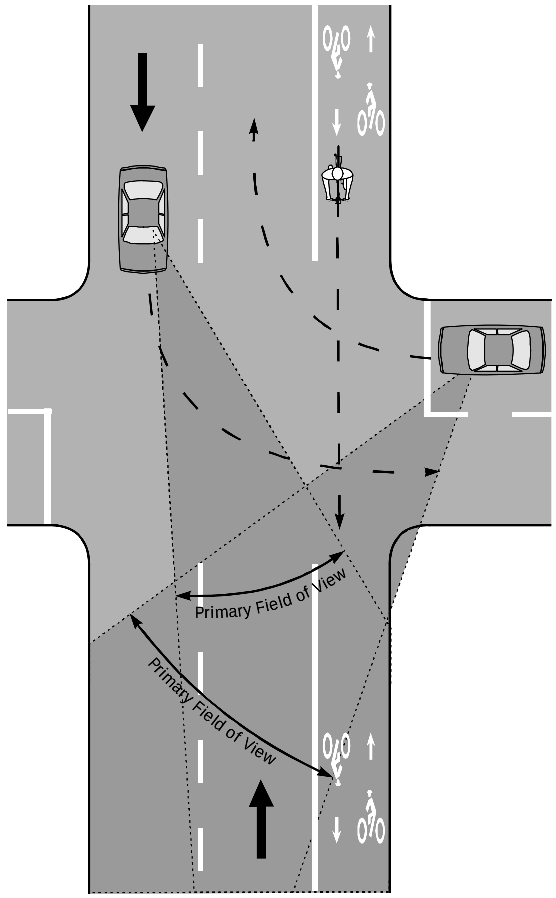

Figure 15-23. Illustration. A wrong-way bicyclist in a two-way bike lane is not in a driver's field of vision.
Source: *Oregon Bicycle and Pedestrian Plan*(3)

Continuous Right-Turn Lanes

A continuous right-turn lane configuration is difficult for bicyclists. Riding on the right puts them in conflict with right-turning cars, but riding on the left puts them in conflict with cars merging into and out of the right-turn lane. The best solution is to eliminate the continuous right-turn lane, consolidate accesses, and create well-defined intersections (Figure 15-24).

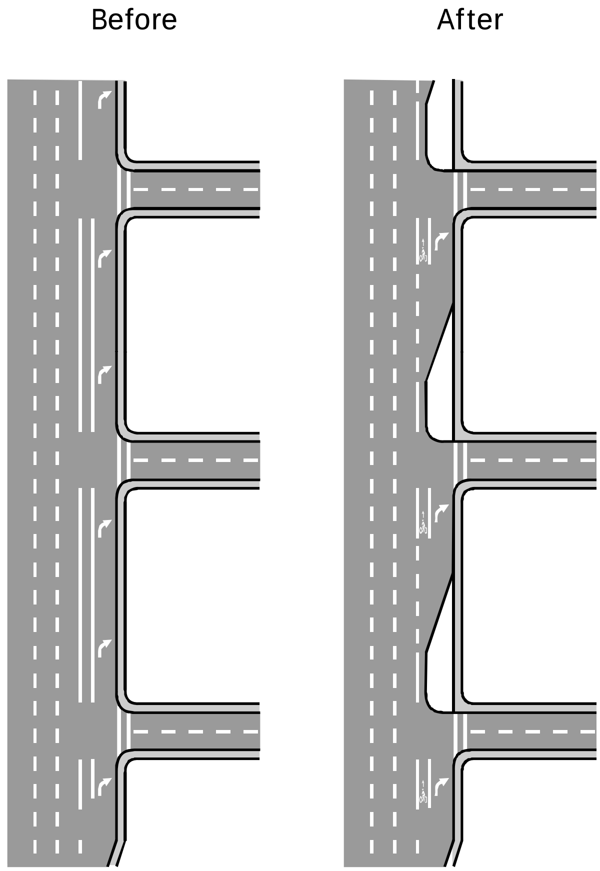

Figure 15-24. Illustration. Reconfiguration of a continuous right-turn lane to be bicycle-friendly.
Source: *Oregon Bicycle and Pedestrian Plan*[3]

15.9 Student Exercise

Exercise A

Redesign a local intersection to include bike lanes. Choose an intersection with a moderate level of complexity, and assume that curb lines can be moved at will in order to achieve your design. Prepare a report and graphics that show existing conditions and your recommended modifications. Signalization changes (if necessary) should also be explained, as well as any advance striping and signing needed on the intersection approaches.

Exercise B

Choose a local urban street that would be a good candidate for a bike lane retrofit project. Redesign a two-block section of the roadway to include bike lanes (sketch drawings will be sufficient). Present at least two options for retrofitting the street, and include solutions that would require further traffic studies. Indicate proposed dimensions for travel lanes, parking lanes, and bike lanes. If removal of parking is one of your solutions, describe the public involvement process you would go through to achieve agreement from adjacent property owners and businesses.

15.10 References and Additional Resources

The references for this lesson are:

1. *Guide for the Development of Bicycle Facilities*, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC, 1999.

2. *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, Washington, DC, 2003, available online at http://mutcd.fhwa.dot.gov, accessed April 22, 2004.

3. *Oregon Bicycle and Pedestrian Plan*, Oregon Department of Transportation, Salem, OR, 1995.

4. *Philadelphia Bicycle Facility Design Guidelines*, Philadelphia Department of Streets, Philadelphia, PA,1998.

5. Burden, D., and P. Lagerwey, *Road Diets: Fixing the Big Roads*, Walkable Communities, Inc., March 1999, available online at http://www.contextsensitivesolutions.org/content/reading/road-diets-3/resources/road-diets-fixing/.

6. Fisher, C., “Retrofitting Bicycle Lanes While Mitigating On-Street Parking Demand,” *Pro Bike/Pro Walk 1996 Conference Proceedings*, Portland, ME, September 1996.

7. Kell, J.H., I.J. Fullerton, and M.K. Mills, *Traffic Detector Handbook*, Publication No. FHWA-IP-90-002, Federal Highway Administration, July 1990, available online at http://www.fhwa.dot.gov/tfhrc/safety/pubs/Ip90002/intro.htm, accessed April 28, 2004.

8. Hunter, W.W., D.L. Harkey, J.R. Stewart, and M.L. Birk, *Evaluation of the Blue Bike Lane Treatment Used in Bicycle/Motor Vehicle Conflict Areas in Portland, Oregon*, Publication No. FHWA-RD-00-150, August 2000, available online at http://www.walkinginfo.org/pdf/r&d/bluelane.PDF, accessed April 28, 2004.

Additional resources for this lesson include:

- *Bike Lane Design Guide*, Pedestrian and Bicycle Information Center (PBIC), October 2002, available online at http://www.bicyclinginfo.org/de/bikelaneguide.htm, accessed April 28, 2004.

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