Chapter 5 – Countermeasures

Shared Roadway

On-Road Bike Facilities

Intersection Treatments

Maintenance

Traffic Calming

Trails/Shared-Use Paths

Markings, Signs, Signals

Education and Enforcement

Support Facilities and Programs

A total of 50 engineering, education, and enforcement countermeasures are discussed in this chapter. The treatments and programs selected for inclusion in this document are those that have been in place for an extended period of time or have been proven effective at the time the material for this product was being compiled. Since that time, new countermeasures have continued to be developed, implemented, and evaluated. Thus, practitioners should not necessarily limit their choices to those included here; this material is a starting point. More information on the latest treatments and programs can be found through many of the Web sites and resources included in this chapter and Chapter 7. The categories of improvements include:

- Shared Roadway
- On-Road Bike Facilities
- Intersection Treatments
- Maintenance
- Traffic Calming
- Trails/Shared-Use Paths
- Markings, Signs, Signals
- Education and Enforcement
- Support Facilities and Programs

The following index can be used to quickly locate the countermeasure of interest.

SHARED ROADWAY

ON-ROAD BIKE FACILITIES

INTERSECTION TREATMENTS

MAINTENANCE

TRAFFIC CALMING

TRAILS/SHARED-USE PATHS

MARKINGS, SIGNS, SIGNALS

EDUCATION AND ENFORCEMENT

SUPPORT FACILITIES AND PROGRAMS

SHARED ROADWAY

Although "shared roadway" is a term used by MUTCD to mean "a roadway that is officially designated and marked as a bicycle route, but which is open to motor vehicle travel and upon which no bicycle lane is designated," the general concepts covered by this category of countermeasures are geared toward providing safe, smooth surfaces, good visibility, and appropriate, safe and easy access for bicyclists on all roadways that bicyclists are allowed to use. The countermeasures described in this category are among perhaps the most important factors in providing a safe and accessible street and path network for bicyclists since the vast majority of travel-ways used by most bicyclists will be roadways shared with motorists. Appropriate use of this group of tools helps to manage traffic and vehicle speeds suitable to the roadway type and area the roadway serves, outcomes that benefit bicyclists and other road users.

The countermeasures discussed under Shared Roadway will remain applicable in most riding circumstances, even for specialized bicyclist facilities such as bike lanes. Lighting, attention to surfaces and other countermeasures are also important with respect to shared-use pathways. Attention to all of these measures will help to ensure that bicyclists have safe places to ride.

Shared Roadway tools are most effectively incorporated at the planning and design stage for streets being constructed or re-constructed, with consideration to all road users. Good design can prevent problems later on and reduce maintenance issues and costs. Some improvements can be made, such as lighting, parking redesign, or maintenance upgrades that improve surface conditions to existing roadways, but are typically more difficult to implement as retrofit measures. Providing safe access to and space on bridges and overpasses and through tunnels and underpasses may be particularly challenging to implement as retrofit measures.

The countermeasures under Shared Roadway are as follows:

- Roadway Surface Improvements
- Bridge and Overpass Access
- Tunnel and Underpass Access
- Lighting Improvements
- Parking Treatments
- Median/Crossing Island
- Driveway Improvements
- Access Management
- Reduce Lane Number
- Reduce Lane Width

PHOTO BY DAN NABORS

Slow speed downtown streets can be safely shared by bicyclists and motorists. (Santa Barbara, CA)

PHOTO BY DAN BURDEN

A raised median helps reduce cut-through traffic and reduce conflicts with turning vehicles.

PHOTO BY DAN BURDEN

Lighting, street trees, on-street parking, bicycle parking, and buildings close to the roadway signal that this is an urban, low-speed, shared-use street. (Santa Cruz, CA)

1. ROADWAY SURFACE IMPROVEMENTS

Bicyclists are particularly vulnerable to sudden changes in the roadway (or path) surface, such as potholes or sudden drop-offs. Slippery surfaces, presence of water or debris, broken pavement, and gaps in pavement parallel to the roadway that can trap bicycle tires can also be hazardous. In addition to causing bicyclist falls, surface irregularities may contribute to a sudden weaving movement that may place the cyclist in the path of a motorist. Poor riding surfaces may also increase bicyclist discomfort and potentially discourage riding. Therefore, providing smooth but non-slippery pavement surfaces is a key to maintaining a good level of service for bicyclists. Good initial design can help reduce future repair and maintenance costs.

Several overarching issues warrant particular attention.

- Initial design and materials selection help to prevent problems such as poor drainage, slippery surfaces, gaps in pavement and others. Once design standards are determined, inspectors and project contractors should ensure that standards are met.
- Having a plan for regular sweeping and identifying and making spot repairs is key to keeping surfaces in good condition.
- Bicyclist considerations should also be incorporated into long-term maintenance and upgrades.
- Good design, hazard identification and maintenance practices should be institutionalized. Identification of bicyclist priorities and a system for regular inclusion of best bicyclist facilities practices within a regular maintenance framework can help to improve conditions for bicyclists without substantially increasing costs.

To provide smooth, level surfaces, the following are some potential hazards that may be minimized by instituting good design and maintenance practices. Drain grates should be maintained level with the surrounding pavement, which may require raising the grates following re-paving, and a bicycle-friendly design should be used so that tires will not be trapped by slots parallel to the roadway (see images). Particularly with new or reconstruction, curb inlets could be installed. Designs should also ensure that utility covers and other potential hazards are placed out of the predominant bicycling pathways, are level with the surrounding pavement, and have non-skid surfaces. Pavement should be kept in good condition, particularly near the edges where bicyclists tend to ride most often.

Additionally, when designing bike facilities, pavement seams should be placed where they minimally conflict with the bicycle right-of-way. Excessively wide gutter pans may unnecessarily reduce bicyclists' space. Paving over the gutter pan is a temporary solution, as seams usually reappear in the pavement within five years. Reflective raised pavement markers also create hazards for bicyclists

Purpose

- Provide smooth, safe surfaces for bicyclists.

Considerations

- Institutionalizing good design, street sweeping, and maintenance practices with respect to bicyclists can help to reduce liability.
- Hazard identification programs can facilitate identification and repair of potential surface hazards.

Estimated Cost

Many of the costs associated with providing and maintaining good bicyclist surfaces should be incorporated into the overall initial project budget or maintenance plan. The costs of hazard identification, short-term sweeping and spot maintenance programs will be minimized if bicyclist concerns are institutionalized within the regular maintenance and repair framework. Special repairs (such as drain grate repair/replacement) will vary considerably by project.

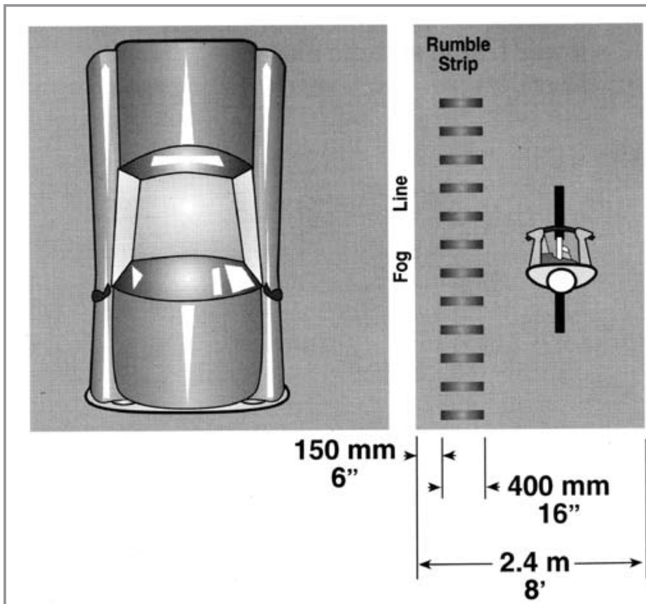
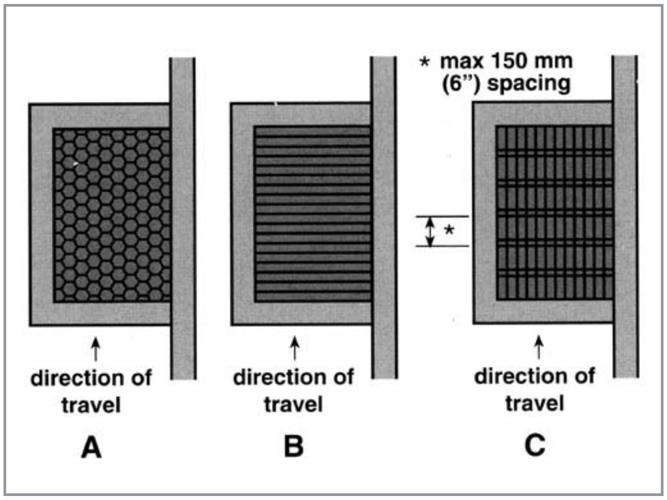
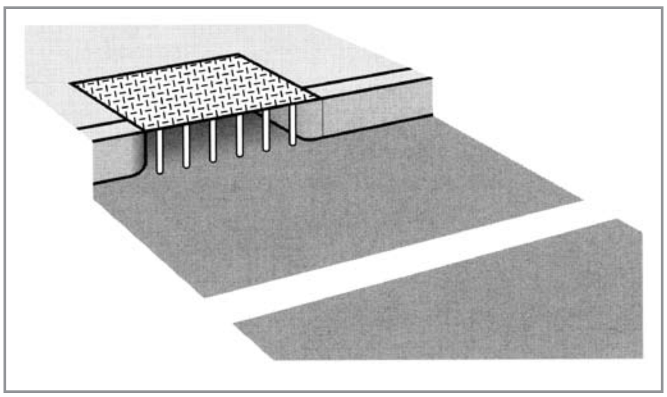


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

A newer rumble strip design is more bicycle-friendly: 400 mm (16 in) grooves are cut into the shoulder, 150 mm (6 in) from the fog line. On a 2.4 m (8 ft) shoulder, this leaves 1.8 m (6 ft) of usable shoulder for bicyclists.



Bicycle safe grates. Note: grates with bars perpendicular to the roadway must not be placed at curb cuts, as bicycle tires could get caught in the slot.



Inlet flush in the curb face. The most effective way to avoid drainage-grate problems is to eliminate them entirely with the use of inlets in the curb face (type CG-3).

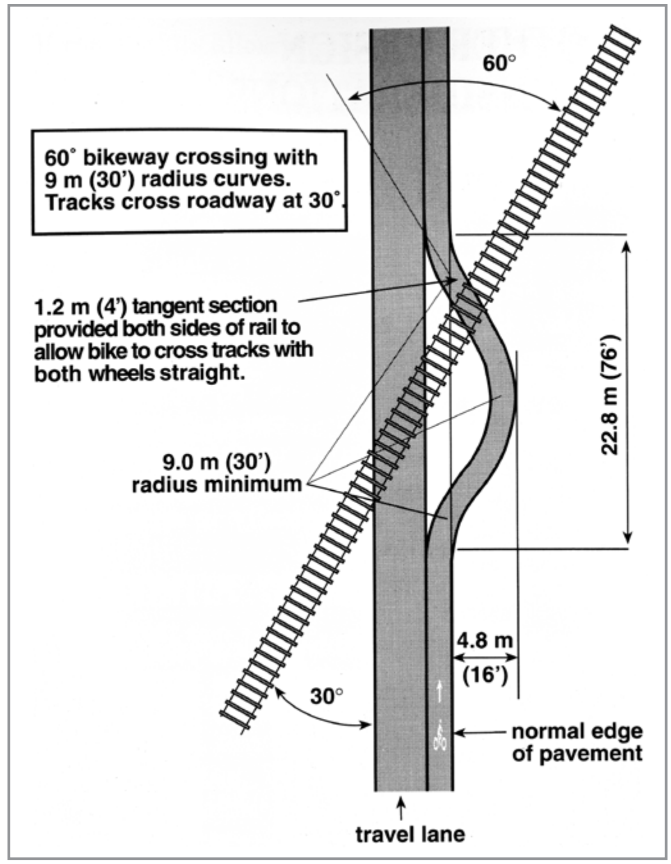
ILLUSTRATIONS FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

and should only be used with appropriate consideration of bicyclists. These can deflect a bicycle wheel, causing the cyclist to lose control.

When rumble strips are used as a motorist alert, for example, along a shoulder, a narrower design placed close to the lane edge line allows more usable bicycle-friendly space. If textured pavers are used, these should not compromise bicyclist safety or comfort.

Finally, care must be taken to provide bicycle-safe railroad crossings. Crossings should ideally be close to 90 degrees. If the crossing is smooth, but non-slippery (concrete paving may work best), and the flange opening is kept as narrow as possible, somewhat more flexibility with the angle may be possible.

The *Oregon Bicycle and Pedestrian Plan* contains more information and illustrations of good surface design practices under the "Other Design Considerations" section (http://www.oregon.gov/ODOT/HWY/BIKEPED/docs/bp_plan_2_ii.pdf).[1]



Bike lane or shoulder crossing railroad tracks.

ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

2. BRIDGE AND OVERPASS ACCESS

Barriers to movement such as rivers, freeways, canyons and railways may present severe impediments to bicyclist travel. According to the Institute of Traffic Engineers' *Innovative Bicycle Treatments*[2], the City of Eugene, OR, determined through a users' survey that bicycle and pedestrian bridges were needed every 1.6 to 2.4 km (1 to 1.5 mi) to cross a geographic barrier through town – in this case the Willamette River. Bridges built to accommodate all modes of travel are typically preferable since they connect with the existing street network. If separated bicyclist/pedestrian facilities are provided, security issues must be addressed. Bridges must be properly designed to provide safe, accessible approaches, with sufficient space for bicyclists to navigate ascents and descents as well as across the overpass, and safe riding surfaces that take into consideration expansion grate design and seam placement that minimize hazards to bicyclists. Bridges should also be well-lit.

If retrofit measures are needed for existing structures, space on the bridge may be provided on the street, on walkways if they are wide enough to safely accommodate pedestrians and bicyclists, or even on a separate deck as

Purposes

- Provide continuity of access for bicyclists.
- Prevent significant detours for bicyclists due to unsurpassable natural or built barriers.

Considerations

- Width of travel lanes and existing walkways, length and height of span, and motor vehicle travel speeds and volume should all be considered when determining the best place to provide space for bicyclists.
- Extra buffers may be needed for "shy distance" from railings or from traffic to protect bicyclists from sudden wind.
- Bicyclist access on multi-modal bridges should be provided since these bridges connect with the existing street network. Separate facilities may be desirable to prevent long detours for bicyclists (if additional multi-modal bridges are infeasible) or to connect multi-use paths or separate corridors.

Estimated Cost

Varies widely, depending on whether a new bridge is constructed or a retrofit of existing installation is provided. The type of facilities and changes implemented also affect cost. For retrofit treatments, Portland examples include from $20,000 for restriping to add bike lanes on an existing deck cross section to $10,000,000 for adding a cantilevered shared path to an existing bridge.

PHOTO BY DAN BURDEN

Separated overpasses may be needed to provide safe access across busy freeways or other barriers.

PHOTO BY DAN BURDEN

This cantilevered, shared-use path was added to the Steel bridge in Portland, OR.

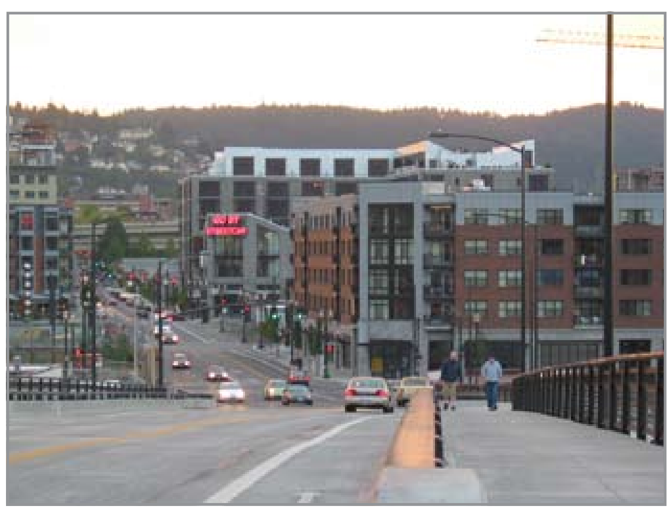


PHOTO FROM ALTA PLANNING + DESIGN

Bike lanes provide space on this bridge.

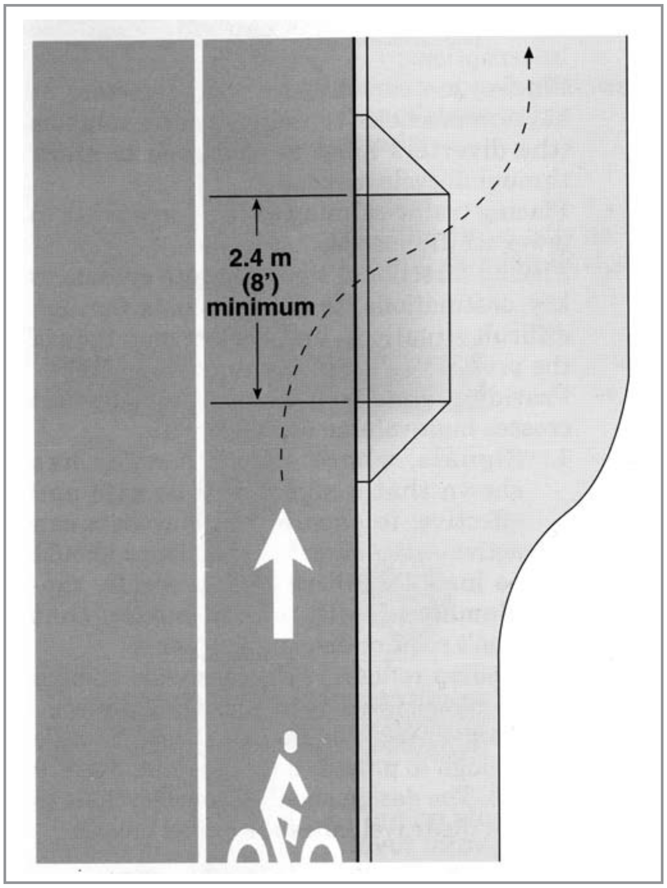


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

Ramp provides bicyclist access to shared-use path from the on-street bike lane.

was done on the Steel Bridge in Portland (see case study #2). If sidewalk access is provided, ramps should provide bicyclists direct access from the street. Sidewalk access may be desirable if traffic volumes and speeds are high, the bridge is long, and there is insufficient roadway space (outside lanes or shoulders are narrow) to safely accommodate bicyclists.

When bicyclist space is provided near bridge railings or near motorized traffic, extra horizontal width or buffer of 0.6 m (2 ft) or more is recommended to protect bicyclists in the event of a crash or wind blast, especially on higher speed bridges or high spans where wind gusts may be strong. Railings should also be provided. The American Association of State Highway and Transportation Officials (AASHTO)[3] recommends a railing height of at least 1.4 m (4.5 ft).

Access from adjoining streets should be as direct as possible to reduce out-of-the-way detours for bicyclists, and designs should endeavor to minimize conflict points at entrances and exits.

PHOTO BY DAN BURDEN

Extra width, concrete barrier, and outside railing protect bicyclists from strong wind gusts. (Seattle, WA)

3. TUNNEL AND UNDERPASS ACCESS

As with bridges and overpasses, safe accommodation should be made for bicyclists to use roadway tunnels and underpasses to prevent impediment to free movement across freeways, railways, and other barriers. Access from adjoining streets should be as direct as possible to reduce out-of-the-way detours for bicyclists, and designs should endeavor to minimize conflict points at entrances and exits. Space should be continued through the facility, with extra consideration for issues such as lighting and personal security. Separate tunnels may also be provided, particularly to connect multi-use or bike paths (also see "Path Intersection Treatments").

PHOTO BY DAN NABORS

State Street underpass with bike lanes, Santa Barbara, CA. Sidewalk is elevated above the roadway.

Most existing roadway tunnels have, however, been built to accommodate motor vehicle traffic, and retrofit measures may be limited if extra space is unavailable to accommodate bicyclists. Planned improvement or tunnel reconstruction projects are an ideal opportunity to improve conditions for bicyclists. In the absence of major reconstruction, some retrofit measures that may improve bicyclist safety or comfort include providing warnings to motorists that bicyclists are present in the tunnel and providing extra lighting, call boxes, and other measures to improve visibility, safety, and personal security. To activate a "bicyclist present in tunnel" flashing warning light, a bicyclist pull-off area and push button are typically provided before the tunnel entrances (see case study #3). If there are no suitable alternate routes, and safe access cannot be provided through a tunnel facility, creative measures may be called for, such as providing transit or shuttle service through the tunnel on a scheduled basis or at certain high-use periods, or other solutions.

New roadway tunnels and underpasses should incorporate planning to accommodate bicyclists. There are at present no specific design standards relating to bicycle accommodation in roadway tunnels. General design standards for bicycle facilities would likely apply, but consideration should be given to providing significant extra width for shy distance from walls or other barriers. Bear in mind that bicyclist speeds will be affected by grade, and extra width may also be needed on steep grades. As previously mentioned, lighting and personal security are issues in tunnels, and designs should maintain good visibility without "hidden" recesses or unlit areas that invite security

Purposes

- Provide continuity of access for bicyclists across barriers.
- Connect shared-use path across a built or natural barrier.

Considerations

- Security issues must be fully addressed.
- Retrofit measures may be restricted since many existing tunnels may have limited space.
- Upgrades and downgrades will affect the speeds of bicyclists and should be considered in the planning or renovation of a tunnel.

Estimated Cost

Flashing warning signs, "Bicyclist in Tunnel," along with widened shoulder for bicyclist pull-off were installed for $5,000 in 1979. Other costs vary widely depending on measures implemented. A variety of cost data can be found at the following Web site: http://www.bicyclinginfo.org/bikecost/.

PHOTO BY DAN BURDEN

Lighting is important for personal safety as well as viewing the riding surface in tunnels and underpasses. (Seattle, WA)

PHOTO BY DAN BURDEN

Bicyclists prefer shorter underpasses where the end is clearly visible.

concerns. Other issues, such as air quality, may be particular to tunnels, but should be addressed from the bicyclist's perspective.

If separated bike and pedestrian tunnels are provided, vertical clearance of 3 m (10 ft) is recommended for bicyclist comfort.[3] Following general AASHTO structure guidelines for shared-use paths, the Iowa Department of Transportation recommends a width of at least the trail width plus clear zones, or a minimum of 3 m (10 ft) if emergency vehicle access must be provided, but the wider the better for lighting and comfort.[4] Security issues must also be addressed in separated facilities. Generally, bicyclists are more comfortable if they can see "the light at the end of the tunnel" when they enter, but appropriate lighting should be provided to ensure good visibility both for security and to view the bicycling surface. Diversion of water away from the tunnel and good drainage and non-slippery surfaces in underpasses are also important design considerations to prevent water from becoming a hazard for bicyclists. The City of Davis bicycle plan also provides some guidance for shared-path underpasses.[5]

4. LIGHTING IMPROVEMENTS

Although bicyclists riding during dark conditions are generally required to have appropriate lighting on their vehicles or persons, requirements vary from state to state and many bicyclists do not comply with the requirements. Good illumination also helps nighttime bicyclists see surface conditions and obstacles or people in the path of travel. Data from five years of North Carolina bicycle-motor vehicle crashes indicate that about one quarter of reported collisions and more than half of bicyclist fatalities occurred during non-daylight conditions, probably far exceeding the proportion of riding that occurs under these conditions.[6] Similarly, estimates referred to by Florida State University[7] indicate that "nearly 60 percent of all adult fatal bicycle accidents in Florida occur during twilight and night hours even though less than 3 percent of bicycle riding takes place during that time period." Bicyclists, particularly commuters, may have to ride during early dawn hours or be caught by twilight, particularly in the winter months.

Purposes

- Illuminate the roadway surface and surroundings.
- Enhance safety of all roadway users.
- Optimize visibility of bicyclists (and pedestrians) during low-light conditions, particularly in locations where high numbers of bicyclists may be expected such as commuter routes, routes to and from universities, intersections and intersections with multi-use trails.
- Improve personal security of bicyclists and pedestrians.

Considerations

- Install lighting on both sides of wide roadways for most effective illumination.
- Provide generally uniform illumination avoiding hot spots, glare, and deep shadows; some intersections may warrant additional illumination.
- Consider rural locations for lighting improvements if nighttime or twilight crashes are a problem.

Estimated Cost

Cost varies depending on fixture type, design, local conditions, and utility agreements.

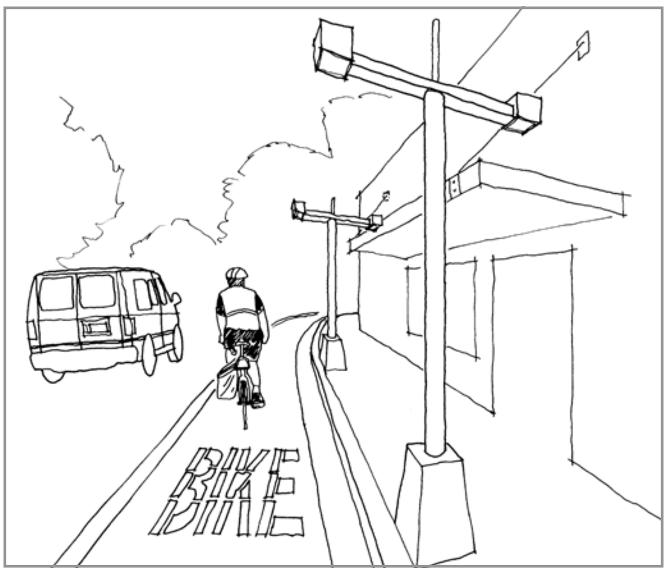


ILLUSTRATION BY A.J. SILVA

Lighting illuminates the roadway surface as well as other roadway users.

Improved roadway lighting may help to reduce crashes that occur under less than optimal light conditions. Intersections may warrant higher lighting levels than roadway segments. Good lighting on roadways, bridges, tunnels and shared-use paths is also important for personal security. Lighting improvements are typically thought of as an urban and suburban treatment, but there may be situations where lighting improvements are appropriate in rural locations. Examples of such locations might include rural roadways that serve as bicycling connectors between outlying or neighboring population areas and urban centers, and intersections or shared-use trail crossings used by significant numbers of cyclists. More research is needed on the safety and mobility benefits of lighting improvements to bicyclists and pedestrians. The American Association of State Highway and Transportation Officials[3] guide recommends using average maintained illumination levels of between 5 and 22 lux, and the Florida DOT recommends 25 as the average initial lux for shared-use paths,

PHOTO BY DAN BURDEN

Lighting is provided for both bicyclists and pedestrians at this location.

PHOTO BY DAN BURDEN

Raised medians provide another option for locating lighting on this shared roadway.

16 for bike facilities on arterial roads, and 11 for all other roadways.[8] The *Wisconsin Bicycle Facility Design Handbook* also provides guidance for path illumination (p. 4–35 to 4–37).[9] Other roadway lighting resources include *American National Standard Practice for Roadway Lighting ANSI IESNA (RP-8-00)* and other publications (available from the Illuminating Engineering Society) and AASHTO's 1984 *An Informational Guide for Roadway Lighting* (update anticipated). A forthcoming NCHRP project will develop guidelines for roadway lighting based on safety benefits and costs.

Lighting is a complex treatment requiring thoughtful analysis. Not only are there safety and security issues for bicyclists, pedestrians and motorists, but potential light pollution, long-term energy costs, and aesthetics also are factors. With good design, lighting can enhance safety of the bicycling (as well as pedestrian) environment and improve the ambience of areas of nighttime activity.

5. PARKING TREATMENTS

Certain policy, design and configuration practices for on-street parking for motor vehicles can facilitate safer bicycling conditions. Removing parking is one option for reducing conflicts between cyclists and vehicles driving into and out of parking, or with motorists entering or exiting parked cars. Removing or narrowing a parking lane on one or both sides of the roadway is also an option for gaining usable space for bicyclists, for example, to create a bike lane. Also, eliminating or reducing parking will improve sight distance along a corridor and may be particularly useful for segments with numerous busy driveways or conflict areas.

Purposes

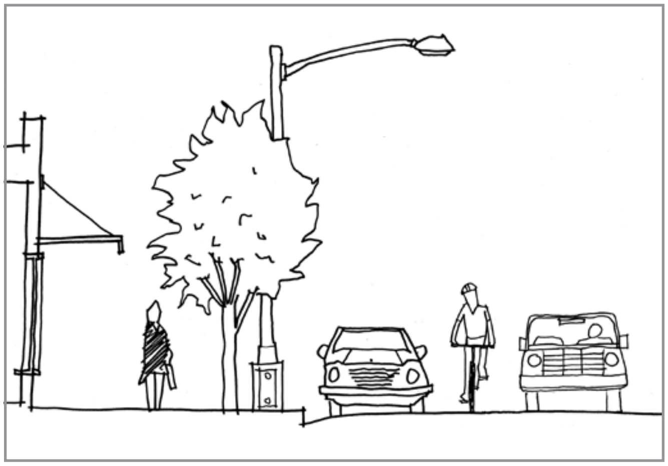
- Reduce conflicts between bicyclists and parking-related incidents (pulling into and out of parking, opening doors).
- Provide more space or facilities for bicyclists on the roadway.
- Improve sight distance along a roadway.

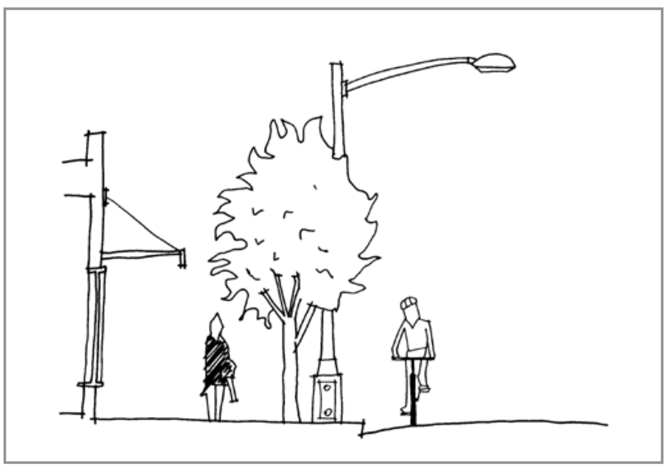
Considerations

- Overall parking demand and space must be evaluated in light of the community's other needs and values. A number of factors should be considered, including the function of the streets to move people and goods safely, the desire to reduce single-vehicle auto use, the need to promote bicycling or transit use, and the need to accommodate business and residential parking demand.
- Space used for on-street parking may provide useable space for bicyclists. Demand for motor vehicle parking could be reduced if sufficient modal shifts occur. Many European cities are reducing motorized vehicle access to urban centers.
- On-street parking, if carefully designed, does not inherently conflict with safe bicycling and may help slow vehicle speeds and improve the safety of the street.
- Creative solutions to meeting parking demand such as timed sharing of public and private facilities may be required.
- Removing parking might result in an increase in vehicle travel speeds if other measures do not compensate.

Estimated Cost

Costs may involve only restriping expense. More extensive work such as adding curb bulb-outs to enclose parking spaces and provide landscape space may increase the cost of parking treatments.





ILLUSTRATIONS BY A.J. SILVA

Before (top) and after (bottom) parking eliminated to gain space for bikes.

Diagonal on-street parking consumes significant roadway width and may also be hazardous to bicyclists since motorists typically must back into traffic. Diagonal parking may be redesigned to a parallel parking configuration, with a typical loss of less than half the spaces. If angled on-street parking is currently provided and maintaining current on-street parking levels is a priority, another option is to reverse the angle direction and require motorists to back in when entering the parking space. Motorists are then facing forward when re-entering the roadway and better able to view both oncoming bicyclists and other motorists (see case study #4).

Policies that may help reduce parking demand or maximize efficient use could be considered if on-street parking is reduced.

Other options are discussed more fully under traffic calming. For example, parking may be configured in a chicane-like pattern by alternating spaces from one side of the street to the other. This treatment forces motorists to shift laterally and slows travel speeds if properly designed. (See Chicanes countermeasure.)

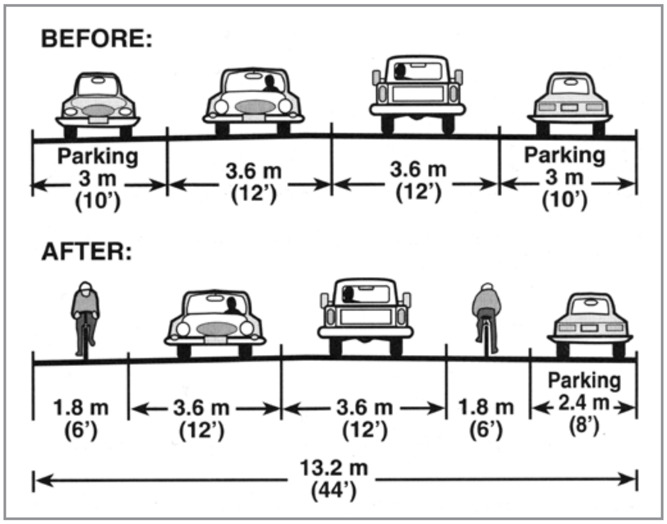


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

Parking removed on one side of a two way street. In some cases, parking may be needed on only one side to accommodate residences and/or businesses. Note: It is not always necessary to retain parking on the same side of the road through an entire corridor.

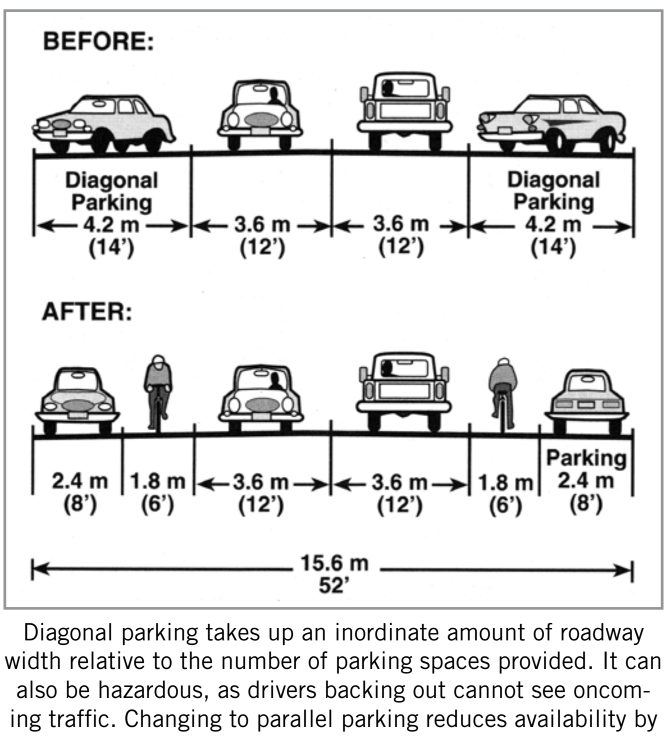


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

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. Special note: on one-way streets, changing to parallel parking on one side only is sufficient; this reduces parking by less than one-fourth.

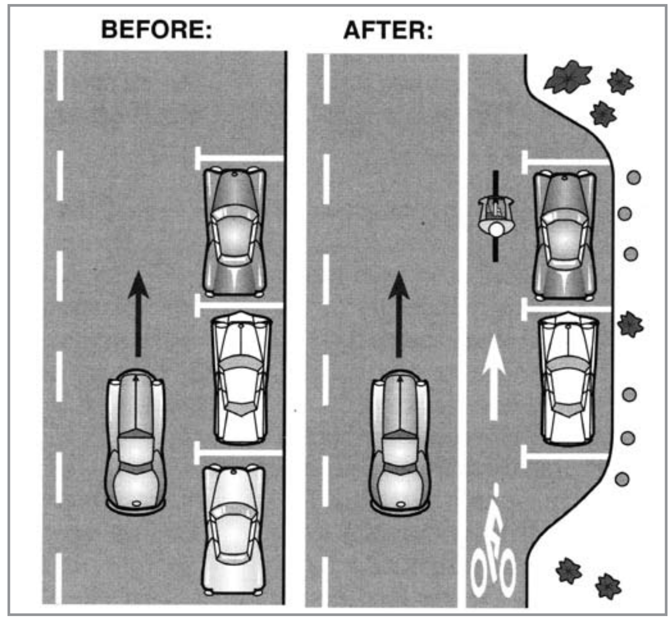


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

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 with 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.

PHOTO BY L. THOMAS

"Door zone" space was left between bike lane and parking space. (Chapel Hill, NC)

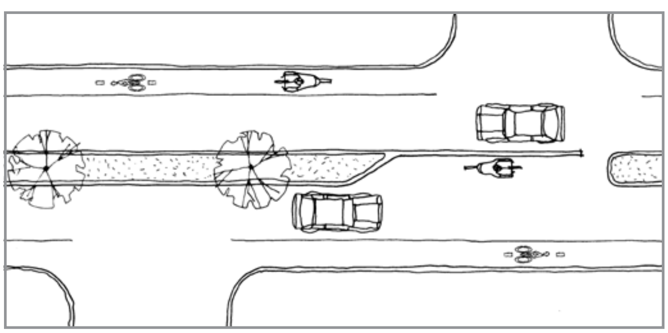
6. MEDIAN/CROSSING ISLAND

Medians are raised barriers in the center portion of the street or roadway that have multiple benefits for bicyclist, motorist and pedestrian safety, particularly when they replace center, two-way left-turn lanes. Two-way left-turn lanes can create problems for bicyclists and pedestrians as well as opposing left-turn vehicles and may be used as acceleration lanes by some motorists. A median (or median island) helps manage traffic, particularly left-turn movements, and reduces the number of conflict areas. Left-turn bays may be incorporated at specific locations. The restricted access to side streets may also help to reduce cut-through traffic and calm local streets. Raised medians are most useful on high-volume roads. Bicyclist (and pedestrian) access to side streets, transit stops, or shared-use paths should be maintained by providing access pockets through the median.

PHOTO BY DAN BURDEN

While this median treatment provides a crossing point and a refuge for pedestrians, space is still available for bicyclists.

ILLUSTRATION BY A.J. SILVA



This design allows bicyclists to make a left turn at a location where motorist left turns are prevented.

Another use of median islands and bicycle crossings is to provide a refuge for bicyclists crossing a busy thoroughfare at unsignalized locations where gaps in traffic in both directions are rare. The median should be at least 2 m (6.6 ft) wide to provide sufficient waiting space for bicyclists.[2] If a full 2 m (6.6 ft) is not available, the bicycle storage area may be angled across the median with bicyclists directed toward oncoming traffic for crossing the second half of the roadway. Railings may be provided for bicyclists to hold so they need not put their feet down to aid in quicker start-ups.

Purposes

- Manage motor vehicle traffic and reduce the number of conflict areas. Provide comfortable left-hand turning pockets with fewer or narrower lanes. May help to slow traffic if roadway is narrowed sufficiently.
- Assist bicyclists in crossing high-volume streets at non-signalized locations by providing a protected refuge for bicyclists crossing or making left turns.
- Provide space for street trees and other landscaping.

Considerations

- Provide bicyclist access to cross streets (or shared use paths) where a median restricts motor vehicle movements.
- Evaluate whether there is sufficient width for appropriately wide sidewalks, bike lanes, and planting strips before proceeding with median construction. Intermittent median islands may be a preferable option for some locations.
- Landscaping in medians should not obstruct visibility between bicyclists (and pedestrians) and approaching motorists.
- Pedestrian median crossings should also be provided at appropriate midblock and intersection locations and designed to provide tactile cues for pedestrians with visual impairments. Examples of good and bad designs for raised median crossings can be found in Chapter 8 of *Designing Sidewalks and Trails for Access: Part II of II, Best Practices Design Guide.*[11]
- Desired turning movements need to be carefully provided so that motorists are not forced to travel on inappropriate routes, such as residential streets, or make unsafe U-turns.
- Bicyclist median access pockets may be difficult to keep clear, depending on width.
- Continuous medians may not be the most appropriate treatment in every situation. In some cases, separating opposing traffic flow and eliminating left-turn friction might increase traffic speeds by decreasing the perceived friction of the roadway.

Estimated Cost

From PEDSAFE: The cost for adding a raised median is approximately $15,000 to $30,000 per 30 m ($15,000 to $30,000 per 100 ft), depending on the design, site conditions, and whether the median can be added as part of a utility improvement or other street construction project.[10]

PHOTO BY DAN BURDEN

Medians and median islands can help narrow roadways and potentially slow motorist speeds.

If travel lanes are sufficiently narrowed, installation of medians may also help to slow traffic speeds. Finally, medians provide space for street trees that may improve the aesthetic environment.

PHOTO BY DAN BURDEN

Pocket in median island maintains access for bicyclists.

7. DRIVEWAY IMPROVEMENTS

Consideration for bicyclists' needs should cover from the trip origin to the destination. A significant proportion of bicycle-motor vehicle crashes occur when either the bicyclist or motorist rides or drives out from a driveway without properly yielding to oncoming traffic. Motorist left turns into driveways and side streets also account for a sizeable portion of crashes involving bicyclists. Thus, the design of connections to the street network has a significant impact on bicyclist safety and access.

Purposes

- Provide good visibility for motorists and bicyclists accessing the roadway.
- Slow motor vehicles entering/exiting the roadway and establish pedestrian right-of-way.
- Reduce the chances of a bicycle-only fall or turning error when bicycles enter or leave the roadway.

Considerations

- Local landscape ordinances and other driveway guidelines may be needed to establish clear zones for driveway rights-of-way, and to maintain sight distance and roadway surfaces.
- Driveway crossings of sidewalk corridors should be wide enough to provide a level pedestrian crossing and a suitable ramp to the street.

Estimated Cost

No additional costs when incorporated into original plan and construction.

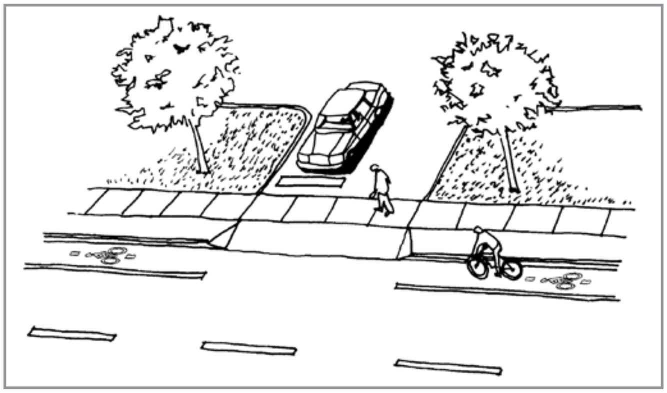


ILLUSTRATION BY A.J. SILVA

Good driveway design provides for safe access to the street network.

Driveway design affects sight distance for both motorists and bicyclists accessing roadways, as well as the speed and perhaps care with which drivers enter or leave the roadway. Right-angle connections are best for visibility of approaching traffic as well as slowing the turning speed for vehicles exiting or entering the roadway. Tighter turn radii at driveways, as well as ramps to sidewalk level, also slow vehicle speeds. *Designing Sidewalks and Trails for Access* provides more information and design alternatives for driveway/sidewalk crossings.[11] Paved driveway aprons of at least 3 m (10 ft) may be desirable for unpaved connections to contain gravel and debris and prevent it from accumulating in the bikeways. Curb cuts should have sufficient flare, however, for bicyclists to complete turns into the driveway or into the nearest lane without 'swinging wide' into the adjacent lane. On streets with sidewalks, the walkway should continue at grade across driveways to provide for through pedestrian movement, slow vehicles, and make it clear to motorists and bicyclists that sidewalk users have the right-of-way.

Stop bars, signs, and other measures may be useful at commercial driveways, but sight distance should not be impaired with too many or improperly-placed signs. Driveway rights-of-way should also be kept cleared of foliage and other objects that obscure visibility.

PHOTO BY DAN BURDEN

Good sight distance helps reduce the potential for conflict between the vehicle emerging from the driveway and a bicyclist in the bike lane.

Every driveway connection is a potential conflict point among motorists, bicyclists and pedestrians. Thus, driveway consolidation or other measures should also be considered for arterials and collector roads. See the Access Management countermeasure for more discussion.

8. ACCESS MANAGEMENT

Every driveway and street connection is a potential conflict point among motorists, bicyclists and pedestrians. Therefore, managing the number, spacing, access, directional flow, and other aspects of driveway and side street connections protects those traveling along the corridor from conflicts with those entering or leaving the corridor. Access management strategies such as providing raised/non-traversable medians and limiting driveway access may be useful in promoting safe bicycle travel, particularly on arterial or major collector streets, since they help reduce the number of potential conflict points.

PHOTO BY DAN BURDEN

Raised medians and driveway consolidation are two access management tools that reduce the number of conflict points.

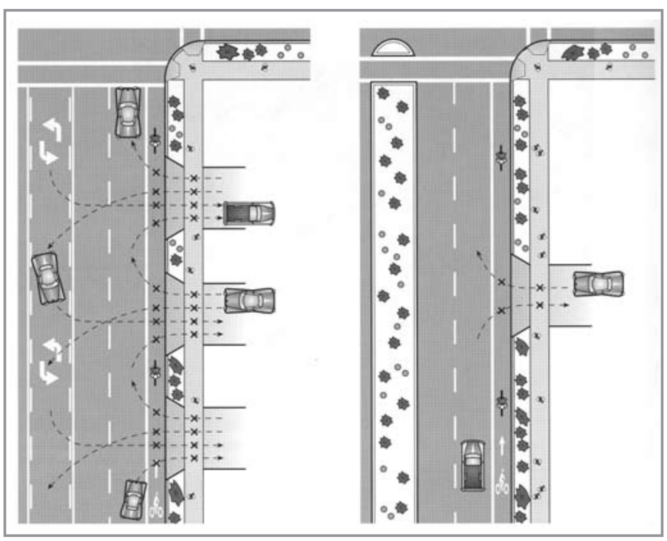


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

Before (left), uncontrolled accesses create eight potential conflict points at every driveway. After (right), a raised median and consolidating driveways reduce conflict points.

Purposes

- Reduce conflicts between those traveling along the corridor and those entering or leaving the corridor.
- Provide access appropriate to the function of the roadway and area it serves.
- Maintain flow of traffic along a corridor.

Considerations

- Consider whether the street's intended function is primarily to move through vehicles (freeways, arterials, collectors) or to provide direct access (neighborhood and local streets).
- Providing for free-flow of traffic by reducing connections may result in increased travel speeds.

Estimated Cost

If included in initial design and construction, access management measures might raise or decrease costs compared to other designs. Cost of retrofit measures would depend on the type and extent. Adding a raised median, for example, is estimated to cost $15,000 to $30,000 per 30 m ($15,000 to $30,000 per 100 ft). Prohibiting left turns with diverters may cost from $15,000 to $45,000 each.

The principles of access management incorporate providing specialized roadways appropriate to their intended use. The trade-off is between providing direct access and promoting through movement. For example, the main purpose of freeways and arterials is to move through traffic, and access should be restricted to necessary interchanges. Local streets should generally serve all destinations and access should not be limited. There are exceptions, however, if management is needed to reduce non-local traffic or create preferential bicycle boulevards (see Traffic Diversion). Access management includes such measures as limiting the number of or establishing minimum spacing between driveways; providing for right-in, right-out only movements; locating signals to favor through movements; restricting turns to certain intersections; and using non-traversable medians to manage left- and U-turn movements. Other measures such as provision of left and right turn lanes at intersections to remove slowing/turning vehicles from the traffic stream could also be included. Hodgson, et al., have provided an in depth discussion of potential impacts (positive and negative) of access management strategies on bicyclists and pedestrians.[12] The Transportation Research Board (TRB) Committee on Access Management identifies 10 principles or strategies of access management altogether, along with the rationale and elements of a comprehensive program (see http://www.accessmanagement.gov/). TRB also published the

Access Management Manual in 2003 that provides a comprehensive description of access management principles, techniques and effects, and rationale and steps toward developing an access management program and policies.[13] Safety and other impacts of access management are documented in *National Cooperative Highway Research Report 420*.[14]

PHOTO BY DAN BURDEN

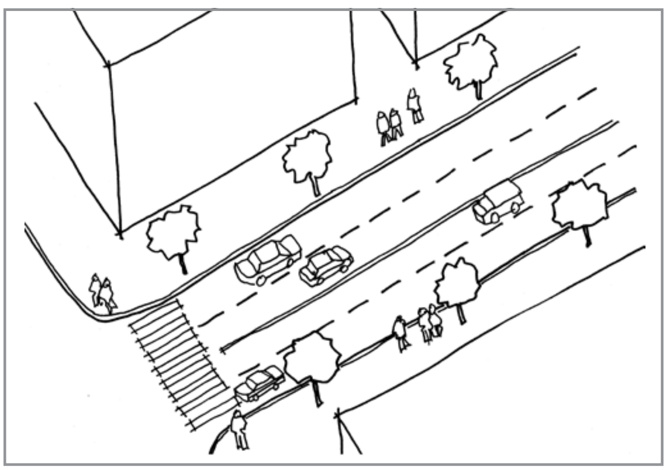
Restricted access can provide for relatively uninterrupted bicycle travel along arterials and collectors.

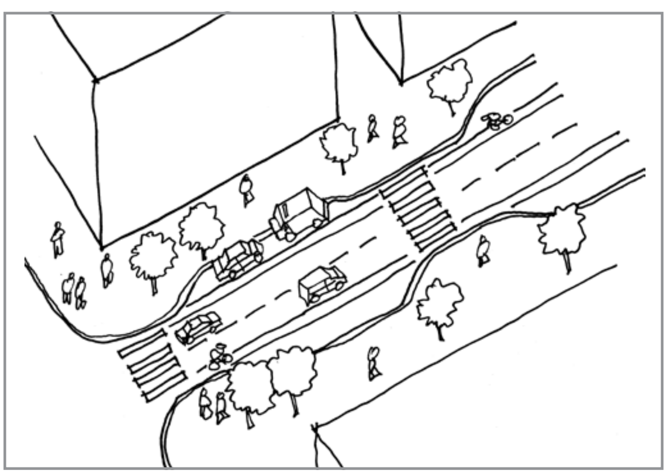
9. REDUCE NUMBER OF LANES

Some roads have more travel lanes than necessary, and the width of the excess lanes could be freed up for other uses. Space may be better used for bicycle lanes, parking, or wider pedestrian buffers or sidewalks (with curb realignment). A traffic analysis should be done to determine whether the number of lanes on a roadway (many of which were built without such an analysis) is appropriate. Reducing the number of travel lanes may also slow travel speeds.

A typical "road diet" may involve converting an undivided four-lane roadway to one travel lane in each direction, with an ongoing center left-turn lane. Road diets have also replaced the second travel lanes with a raised median and turn pockets, and bike lanes in each direction. A raised median allows greater control of turning movements and may enhance bicyclist as well as motorist safety in some circumstances (see Medians/Crossing Islands).

A variety of reconfigurations are possible for lane number reductions depending on the current configuration, user needs, and potential operational and safety outcomes. Other measures could be implemented simultaneously to complete the overall redesign for the street.





ILLUSTRATIONS BY A.J. SILVA

Before (top) and after (bottom) road diet.

Purposes

- Remedy a situation where there is excess capacity.
- Provide space for bicyclists, pedestrians, or parking.
- Reduce apparent width of the road; provide median refuge.
- Improve social interaction and enhance livability of the street.

Considerations

- Traffic studies should determine whether there is excess capacity.
- Studies that include safety effects as well as traffic operations should help to determine preference for an on-going left turn option or whether intermittent left turns will provide the level of service needed.

Estimated Cost

The cost for restriping a kilometer of four-lane street to one lane in each direction plus a two-way, left-turn lane and bike lanes is about $3,100 to $12,400 ($5,000 to $20,000 per mi), depending on the amount of lane lines that need to be repainted. The estimated cost of extending sidewalks or building a raised median is much higher and can cost $62,000 per km ($100,000 per mi) or more. If a reconfiguration is done after repaving or with an overlay, and curbs do not need to be changed, there is little or no cost for space reallocations accomplished through new striping.

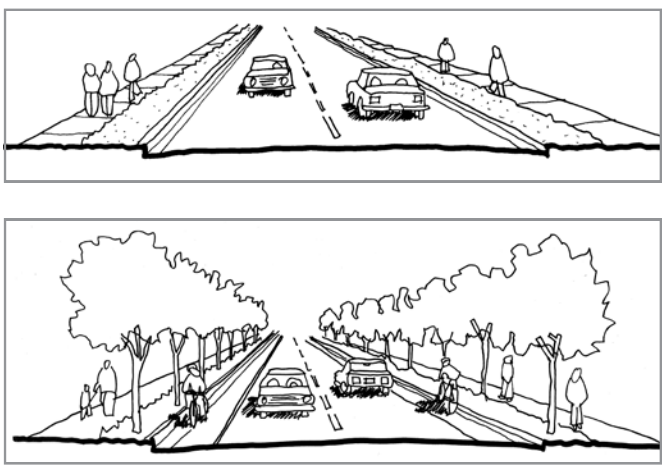
PHOTO BY DAN BURDEN

Lane reduction in Toronto, Canada, from two to one lane in each direction, bike lanes, and center two-way, left-turn lanes.

10. REDUCE LANE WIDTH

Roadway lane narrowing may help to reduce vehicle speeds along a roadway section and enhance movement and safety for bicyclists as well as pedestrians. Lane narrowing is best used where motor vehicle speeds are low to encourage shared lane travel and prevent motorists from attempting to pass bicyclists within the same lane if there is insufficient width. Another use would be to gain space to stripe a bicycle lane or paved shoulder where motor vehicle speeds and volume are higher. Lane width reductions can be achieved in several different ways:

a. Lane widths can be reduced to 3.0 or 3.4 m (10 or 10.5 ft) and excess pavement striped with a bicycle lane or shoulder.
b. Excess lane width can be reallocated to parking.
c. The street and lanes can also be physically narrowed by extending the curb for wider sidewalks and landscaped buffers, or by adding a raised median.



ILLUSTRATIONS BY A.J. SILVA

Before (top) and after (bottom) width of lanes is reduced.

PHOTO BY CITY OF EUGENE, OR

Narrow lanes contribute to slow design speed and shared lane use in downtown Eugene, OR.

Purposes

- Redistribute space to other users, such as to gain space for bike lanes.
- Narrowing travel lanes may lower motor vehicle speeds and encourage safer sharing of the roadway in low speed areas.

Considerations

- Bicyclists must be safely accommodated. Bike lanes, wide curb lanes, or paved shoulders are needed if motor vehicle volumes and speeds are high.
- Road narrowing must consider school bus and emergency service access as well as truck volumes.
- Besides narrowing lanes, tightening curb radii is another way to reduce speeds of turning vehicles.
- Evaluate whether narrowing may encourage traffic to divert to other local streets.

Estimated Cost

Adding striped shoulders or on-street bike lanes can cost as little as $620 per km ($1,000 per mi) if the old paint does not need to be changed. The cost for restriping a kilometer of street to bike lanes or to add on-street parking is $3,100 to $6,200 ($5,000 to $10,000 per mi), depending on the number of old lane lines to be removed. Constructing a raised median or changing the curb alignment (widening a sidewalk or buffer) can cost $62,000 or more per km ($100,000 or more per mi).

ON-ROAD BIKE FACILITIES

Bicycles are vehicles and need to be safely accommodated on our streets and roadways. FHWA has supported routine accommodation of bicyclists (and pedestrians) since 2000. This means that our streets should be designed to accommodate all modes, including motor vehicles, transit, bicycles, and walking. Facilities that are safe, accessible and aesthetically pleasing attract bicyclists. Evidence is increasing that bicyclist safety improves as more bicyclists are part of the traffic stream.[1] The countermeasures related to on-road bicycle facility design include:

- Bike Lanes
- Wide Curb Lanes
- Paved Shoulders
- Combination Lanes
- Contraflow Bike Lanes

PHOTO FROM ALTA PLANNING + DESIGN

Bike lanes provide bicyclist access on roads connecting with bridges and overpasses. (Portland, OR)

PHOTO BY ANDY CLARKE

Wide curb lanes provide room for both bicyclists and motor vehicles.

PHOTO BY DAN BURDEN

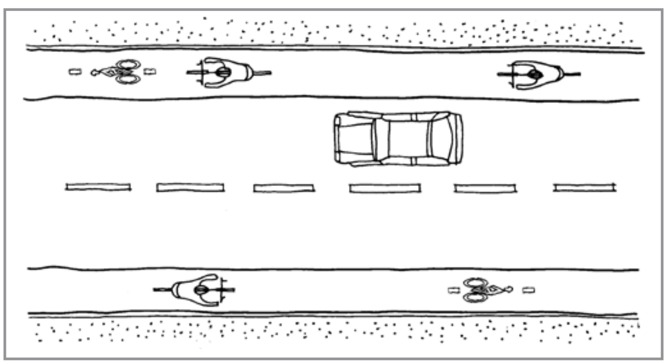
Paved shoulders provide space for bicyclists.

11. BIKE LANES

Bike lanes indicate a preferential or exclusive space for bicycle travel along a street. Bike lanes are typically 1.2 to 1.8 m (4 to 6 ft) in width and are designated by striping and/or signs. Colored pavement (for example, blue or red bike lanes) or a different paving material has also been used in certain situations to distinguish bike lanes from the motor vehicle lanes. Use of colored bike lanes is being considered but is not yet an accepted MUTCD standard.[2] Bike lanes are usually marked along the right side of the roadway and should be designated to the left of parking or right-turn lanes. Sometimes bike lanes are marked on the left side of a one-way street.

Adaptations to bike lanes have been used to solve local problems. An innovative bike lane transit stop treatment in Portland, OR, is used to reduce conflicts between bicyclists and streetcar transit stop users adjacent to a bike lane (see case study #13). (Adaptation for this treatment should be possible for a shared roadway situation.) Some communities also employ combination bike and bus lanes, a single lane nearest the curb that is shared by the two modes. This is generally workable unless there is considerable bike and bus traffic.

ILLUSTRATION BY A.J. SILVA



Bike lanes on a two-lane roadway.

PHOTO BY SHAWN TURNER

In Madison, WI, bike lanes have been placed to the left of bus and right-turn lanes to reduce conflicts for through bicyclists.

Purposes

- Create on-street, separated travel facilities for bicyclists.
- Provide separate operational space for safe motorist overtaking of bicyclists.
- Reduce or prevent the problems associated with bicyclists overtaking motor vehicles in narrow, congested areas.
- Narrow the roadway or roadway motor vehicle traffic lanes to encourage lower motor vehicle speeds.

Considerations

- Where bike lanes are to be considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide adequate bike lane width.
- Provide a smoothly paved surface and keep the bike lane free of debris.
- Provide adequate space between the bike lane and parked cars so that open doors do not create a hazard for bicyclists.
- Avoid termination of bike lanes where bicyclists are left in a vulnerable situation.
- Determine if special signs or markings are necessary for situations such as a high-volume of bike left turns on a busy roadway.

Estimated Cost

The cost of installing a bike lane is approximately $3,100 to $31,000 per kilometer ($5,000 to $50,000 per mile), depending on the condition of the pavement, the need to remove and repaint the lane lines, the need to adjust signalization, and other factors. It is most cost efficient to create bike lanes during street reconstruction, street resurfacing, or at the time of original construction.

Bike lanes have been found to provide more consistent separation between bicyclists and passing motorists than shared travel lanes. The presence of the bike lane stripe has also been shown from research to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both motorists and bicyclists.[3] The extra space created for bicyclists is also a benefit on congested roadways where bicyclists may be able to pass motor vehicles on the right.

12. WIDE CURB LANES

A wide curb lane (WCL) is the lane nearest the curb that is wider than a standard lane and provides extra space so that the lane may be shared by motor vehicles and bicycles. These facilities can also be placed on roads without curbs and are sometimes called wide outside lanes. WCLs may be present on two-lane or multi-lane roads. A desirable width is 4.3 m (14 ft), not including the gutter pan area. Lanes wider than 4.3 m (14 ft) sometimes result in the operation of two motor vehicles side by side. However, the WCL may need to be 4.6 m (15 ft) in width where drainage grates, raised reflectors, or on-street parking reduce the usable lane width. WCLs are sometimes designated when right-of-way constraints preclude the installation of "full width" bike lanes. WCLs are sometimes put in place by re-striping, especially when a section of roadway is resurfaced, by narrowing the other travel lanes.

PHOTO BY DAN BURDEN

Wide curb lane in Ft. Lauderdale, FL.

WCL advocates believe that these wider lanes encourage bicyclists to operate more like motor vehicles and thus lead to more correct positioning at intersections, particularly for left-turning maneuvers. A previous FHWA publication recommends WCLs in many kinds of roadway situations where most bicyclists are experienced riders.[4] Since WCLs are a shared-lane traffic situation, they are not signed or marked like a bike lane would be. As a result, many bicyclists do not know of their existence or utility as a bicycle facility. More detail on the comfort and safety of WCLs can be found in Hunter et al., 1999, and Harkey et al., 1996.[3,5]

Purposes

- Create on-street travel facilities for bicyclists.
- Create a lane wide enough so that motor vehicles and bicycles have adequate room to share the lane during overtaking.

Considerations

- Where WCLs are to be considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide appropriate WCL width, especially where drainage grates or other factors reduce the usable lane width.
- Consider the use of "Share the Lane" signing if used on a heavily traveled roadway.
- Consider the use of a stencil such as the Shared Arrow or the SHARROW (developed in San Francisco) to help with proper bicyclist placement within the WCL and to encourage bicyclists to travel in same direction as motor vehicle traffic.
- Truck traffic should not exceed five percent of the total motor vehicle traffic.

Estimated Cost

Normally, the only cost associated with WCLs is for re-striping the roadway. A ballpark cost for large striping is $5,500 per km ($3,470 per mi). It is most cost efficient to create WCLs during street reconstruction, street resurfacing, or at the time of original construction.

13. PAVED SHOULDERS

Paved shoulders are very similar to bike lanes as a bicycle facility. The pavement edge line for the paved shoulder provides separated space for the bicyclist much like a bike lane. Depending on the situation, the width of the shoulders may vary. If the paved shoulder is less than 1.2 m (4 ft) in width it should not be designated or marked as a bicycle facility. Widths are typically a function of amount of bicycle usage, motor vehicle speeds, percentage of truck and bus traffic, etc., although widths are sometimes purely a function of available right-of-way. More paved shoulder design details are given in the AASHTO Green Book.[5] Prior research has shown that paved shoulders tend to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior and enhanced comfort levels for both motorists and bicyclists.[3]

Colored shoulders have been used in Europe to visually narrow the roadway. This technique has been tried in Tavares, FL, where a section of roadway added painted red shoulders (see case study #14). The intent was to provide increased room and comfort for walkers and bicyclists. The 0.6 km (1 mi) treated section of roadway was a two-lane rural roadway with approximately 1,700 vehicles per

Red shoulders in Tavares, FL.

Bike pocket striped to the left of a right-turn lane aids through bicyclists using a paved shoulder facility.

Purposes

- Create travel facilities for bicyclists.
- Create separated space for bicyclists.
- Reduce or prevent the problems associated with bicyclists overtaking motor vehicles in narrow, congested areas.

Considerations

- Provide adequate width by taking into account factors such as the amount of bicycle usage, motor vehicle speeds, percentage of truck and bus traffic, etc.
- Provide ride-able space for bicyclists if rumble strips are used.
- Examine alternative space for bicyclists if there are intersecting side streets.
- Provide a smoothly paved surface and keep free of debris.

Estimated Cost

Paved shoulder costs can be quite variable. Using data from Iowa DOT average contract prices for calendar year 2000, a minimum design width of 1.2 m (4 ft) of paved shoulder width to accommodate bicycle traffic was estimated at $44,000 per km ($71,000 per mi).[8]

day and had a 56 km/h (35 mi/h) speed limit. Even after the roadway was widened, the use of the red shoulders resulted in motor vehicle speeds similar to the before (narrower roadway) situation.[6]

Broward County, FL, has experimented with another paved shoulder variation. Undesignated lanes 0.9 m (3 ft) have been implemented on a number of roadways which formerly had wide 4.3 m (14 ft) curb lanes in place (i.e., 3.4 m (11 ft) travel lane and 0.9 m (3 ft) undesignated lane). The lanes were left as undesignated because they were too narrow to be referred to as bike lanes. The striping resulted in a delineated, although sub-standard, space for bicyclists to operate on these roadways (see case study #15).[7]

Rumble strips are often used on shoulders to alert sleepy or inattentive motorists, but there is considerable debate about what kinds of designs are safe or appropriate for bicycles. AASHTO recommends that 1.2 m (4 ft) of rideable surface should be present for bicyclists if rumble strips are used on a shoulder.

14. COMBINATION LANES

A combination lane usually refers to a lane nearest the curb which serves various modes of traffic or movements. An example would be a transit-bicycle lane. Generally such multiple uses are operationally acceptable unless there is considerable bus and bike traffic. Signs might identify this lane as a priority BUS AND RIGHT TURNS ONLY EXCEPT BIKES. Another signing alternative is BICYCLES BUSES AND RIGHT TURNS ONLY. The lane would accommodate bus traffic, motor vehicles making right turns, and bicycles where it is not feasible to provide separate facilities.

These combination lanes are not without problems. If there is a shortage of bus and bike traffic, the lane can become another peak hour traffic lane. Provision of combination lanes on arterial streets with on- and off-ramps creates a difficult riding situation for bicyclists.

PHOTO BY ARTHUR ROSS

This combination lane in Madison, WI, has little bus and bike traffic, which can result in use of the lane by other motor vehicles at peak hours.

If bus and bike traffic need to be separated, the bus lane is usually nearest the curb, which reduces conflicts between buses accessing stops and bicycles traveling through, and between bus passengers and bicyclists. Separated lanes should reduce conflicts associated with buses moving in and out of a single bus and bike lane.

Communities with shared bike/bus lanes include Santa Cruz, CA; Philadelphia, PA; Tucson, AZ (case study #16); and Toronto, ON.

Purposes

- Create on-street travel facilities for bicyclists where it is not feasible to provide a completely separate bicycle facility or lane.
- Create separated space from higher-speed traffic lanes for bicyclists.

Considerations

- Provide appropriate lane width.
- Provide appropriate signs.
- Evaluate the amount of right-turning motor vehicles to determine if the use of a combination lane is appropriate.
- Determine if special signs or markings are necessary for situations such as a high volume of motor vehicle right turns.
- Ample bus and bike traffic may create a "leap frog" effect with buses and bikes passing each other frequently.

Estimated Cost

The cost for markings and signs for a bus-bike lane is in the range of about $100 per sign, posted about every 0.2 km (eighth of a mile), and painted pavement symbols spaced throughout.

PHOTO BY SHAWN TURNER, ITE PEDESTRIAN AND BICYCLE COUNCIL

Use of a bike lane next to a bus lane in Madison, WI.

15. CONTRAFLOW BIKE LANES

Bicyclists are expected to follow established rules-of-the-road. A particular example is riding in the same direction as motor vehicle traffic. However, there are certain situations where the placement of a bicycle lane counter to the normal flow of traffic may increase safety or improve access for bicyclists. For example, connectivity may be enhanced, and out-of-the-way detours and wrong-way riding reduced, if a contraflow bike lane is designated on some one-way streets, allowing bicyclists to ride against the main flow of traffic.

It should be made clear that there are safety concerns associated with contraflow riding, as this places bicycles in a position where motorists do not expect to see them. Thus, a careful assessment should be made before installation. However, there is precedent for opposite direction riding that emanates from Europe, where cyclists are often allowed to ride in the opposite direction on one-way streets, usually with slow motor vehicle traffic. The contraflow bike lane is a specialized bicycle facility that can be used in particular situations and is intended to reduce the number of conflicts between bicycles and motor vehicles. The facility also would be intended to save time by preventing cyclists having to travel an extra distance to ride in the same direction as motor vehicles. Contraflow lanes may also alleviate riding on a high speed, high volume route.

Contraflow bike lanes can be found in cities in the United States with large numbers of bicyclists, including Cambridge, MA (see case study #18); Boulder, CO; Madison,

Blue pavement was used to increase conspicuity of this contraflow lane in Cambridge, MA.

Purposes

- Create specialized on-street facilities for bicyclists.
- Enhance bike connectivity.
- Reduce out-of-direction riding on a one-way street network.

Considerations

- Install contraflow lanes on the correct side of the street, i.e. on the left side facing the one-way traffic.
- Where contraflow bike lanes are considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide adequate bike lane width.
- Provide appropriate pavement markings and signing along the route.
- Consider whether colored pavement in the contraflow lane is needed.
- Avoid termination of contraflow bike lanes where bicyclists are left in a vulnerable situation.
- Avoid situations where there are many driveways, alleys, or streets that would intersect with the contraflow lane.
- Determine if there is room for a regular bike lane in the direction of motor vehicle travel on the opposite side of the street.
- Determine if existing traffic signals need to be modified with loop detectors or push buttons to accommodate bicyclists.
- Ensure contraflow bike lanes are legal under local traffic laws.

Estimated Cost

The cost of installing a normal bike lane is approximately $3,100 to $31,000 per kilometer ($5,000 to $50,000 per mile), depending on the condition of the pavement, the need to remove and repaint the lane lines, the need to adjust signalization, and other factors. Depending on complexity, such costs could also be associated with contraflow bike lanes. However, the most likely additional costs would pertain to thermoplastic bike symbols and arrows or inlay bike symbols and arrows. It is most cost-efficient to create contraflow or normal bike lanes during street reconstruction, street resurfacing, or at the time of original construction.

WI; and Eugene, OR. A Madison contraflow lane exists on a street with high traffic volumes. In this case, the contraflow lane is separated from motor vehicle traffic with a raised median (see case study #17).

PHOTO BY DAN BURDEN

Separated contraflow bike lane in Boulder, CO.

INTERSECTION TREATMENTS

Over half of all bicycle-motor vehicle crashes occur at or near intersections or other junctions. Improvements at these locations have the potential to significantly increase safety. Specialized intersection markings that may help bicyclists and motorists safely navigate through intersections and use of innovative techniques, such as bike boxes, are gaining more prominence in some communities. Other measures are designed to reduce conflict areas at intersections. It is also important to try to slow motor vehicle speeds through intersections to reduce both the number and severity of intersection collisions, and some of the treatments described below pertain to this objective. Other measures to slow speeds may be found in the Traffic Calming section. The countermeasures included in this section are as follows:

- Curb Radii Revisions
- Roundabouts
- Intersection Markings
- Sight Distance Improvements
- Turning Restrictions
- Merge and Weave Area Redesign


PHOTO BY DAN BURDEN

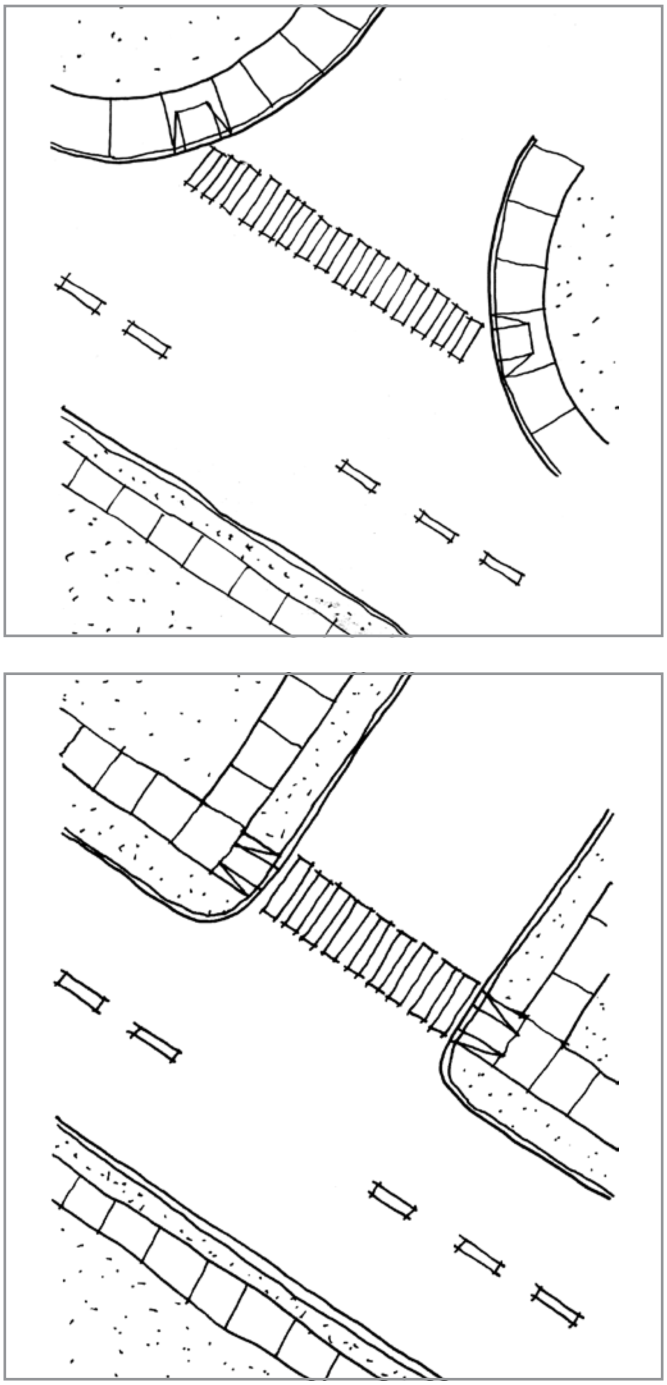
A roundabout intersection design should force slow travel speeds.


PHOTO BY PETER LAGERWEY

Reducing the curb radius by extending the curb and realigning skewed intersections can improve intersection safety.

16. CURB RADII REVISIONS

Motor vehicles turning at a high rate of speed pose problems for bicyclists (as well as pedestrians). This is a common problem when motorists traveling on an arterial street turn onto a residential street. A typical bicycle-motor vehicle crash type, sometimes called a "right hook," occurs when a motor vehicle passes a bicycle going straight ahead and then turns right shortly after making the passing maneuver. Reducing the radii of curbs at these high speed right turns provides a remedy. Creating 90-degree intersection corners or corners with tight curb radii tend to slow motorists.



ILLUSTRATIONS BY A.J. SILVA

Before (top) and after (bottom) curb radius is reduced.

Purposes

- Create a safer intersection design.
- Slow right-turning motor vehicles.
- Lessen likelihood of "right hook" crashes.

Considerations

- Where curb radii revision is to be considered, the road or street should be evaluated to determine if appropriate for this facility.
- Make sure that public maintenance vehicles, school buses, emergency vehicles, and typical trucks and buses can be accommodated.
- Determine if the presence of on-street parking and/or bike lanes help to tighten the radii more than the norm.

Estimated Cost

Costs for reconstructing a curb to a tighter radius can vary from approximately $5,000 to $40,000, depending on site conditions (e.g., the amount of concrete and landscaping that is required, whether drain grates and other utilities have to be moved, and whether there are other issues that need to be addressed).

Some communities routinely reduce curb radii at locations where the routes: (1) are used by schoolchildren or the elderly, (2) are in neighborhood shopping areas with high bicycle and pedestrian volumes, and (3) are at particular intersections known to have a safety problem (see case study #20). A logical step is to evaluate the curb radii along a corridor frequented by bicyclists, along with a

PHOTO BY PETER LAGERWAY

Tighter curb radii at obtuse angle corners forces slower motorist turns. (Seattle, WA) study of the crash types. Care must be used when revising curb radii on routes with truck and bus traffic. If a curb radius is made too small, large trucks and buses may ride over the curb or may veer out into an adjacent traffic lane to make the turn.

When there is parking and/or a bike lane, curb radii can be tighter, because the motor vehicles will have more room to negotiate the turn. Older cities in Europe and in the northeast United States frequently have curb radii of 0.6 to 1.5 m (2 to 5 ft) without suffering any detrimental effects. More typically, however, in new construction the appropriate turning radius is about 4.6 m (15 ft) and about 7.6 m (25 ft) for arterial streets with a substantial number of turning buses and/or trucks. Tighter turning radii are particularly important where streets intersect at a skew. While the corner characterized by an acute angle may require a slightly larger radius to accommodate the turning maneuvers, the corner with an obtuse angle should be kept very tight to prevent high-speed turns.

17. ROUNDABOUTS

A modern roundabout is built with a large, usually circular, raised island located at the intersection of two or more streets and may take the place of a signalized intersection. Traffic maneuvers around the circle in a counterclockwise direction, and then turns right onto the desired street. Entering traffic yields to traffic in the roundabout, and left-turn movements are eliminated. Unlike a signalized intersection, vehicles generally flow and merge through the roundabout from each approaching street without having to stop. If properly designed, roundabouts force slow intersection speeds and reduce the number of conflict areas.[1]

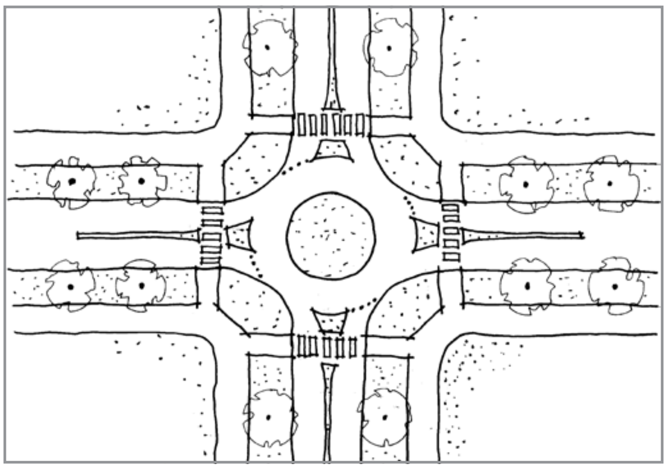


ILLUSTRATION BY A.J. SILVA

Bicyclists may safely share space with motor vehicles in low-speed, single-lane roundabouts.

Roundabouts need to accommodate bicyclists and pedestrians. It is important that motor vehicle traffic yields to pedestrians crossing at the roundabout. Splitter islands at the approaches slow vehicles and allow pedestrians to cross one traffic lane at a time. Single-lane approaches can be designed to keep speeds down to safer levels and allow pedestrians to cross. Multi-lane roundabouts tend to have higher motor vehicle speeds and create more conflicts between bicycles (and pedestrians) and motor vehicles.

Unless the road leading to a roundabout has two lanes, slow motor vehicle traffic speeds, and low traffic volumes, bicyclists may have difficulty navigating the roundabout. Marking bike lanes through the roundabout has not been shown to be safer and may actually be less safe. In high volume, mutli-lane roundabouts, an off-road shared path may be needed for bicyclists. Such a treatment delays and inconveniences bicyclists but may improve safety.

National Cooperative Highway Research Program Project 3–65, "Applying Roundabouts in the United States," is scheduled to be completed in 2006. The objectives of this project are to: (1) develop methods of estimating the safety and operational impacts of U.S. roundabouts, in-

Purposes

- Provide good traffic management where the intersection is large and complex.
- Replace a traffic signal that is experiencing heavy traffic backup and congestion.
- Reduce speeds at intersection.
- Create a gateway into an area.

Considerations

- Bike lanes should generally be discontinued when leading to low-speed roundabouts. Bicycles are expected to merge with the flow of traffic—a low design speed is required.
- Street widths and/or available right-of-way need to be sufficient to accommodate a properly designed roundabout.
- Roundabouts often work best where there is a high percentage of left-turning traffic.
- Deflection on each leg of the intersection must be set to control speeds to 24 to 29 km/h (15 to 18 mi/h).

Estimated Cost

The cost for a landscaped roundabout varies widely and can range from $45,000 to $150,000 for neighborhood intersections and up to $250,000 for arterial street intersections, not including additional right-of-way acquisition. Yet, roundabouts have lower ongoing maintenance costs than traffic signals.

PHOTO BY DAN BURDEN

Mountable curbs provide access for buses, trucks, and emergency vehicles.

cluding a thorough examination of interactions between motor vehicles and pedestrians and bicyclists, and (2) refine the design criteria used for them.[2]

PHOTO BY DAN BURDEN

Bike lanes should be discontinued before roundabouts.

PHOTO BY DAN BURDEN

Splitter islands and narrow curb radii slow speeds approaching the roundabout.

18. INTERSECTION MARKINGS

Some 50 to 70 percent of bicycle-motor vehicle crashes occur at intersections or other junctions such as driveways. Intersection markings are one method of helping bicyclists negotiate these problem areas. The AASHTO *Guide for the Development of Bicycle Facilities* discusses recommended placement of bike lane striping for various kinds of intersections.[3] The guide also covers special situations where there are high numbers of right-turning motor vehicles and where auxiliary right-turn lanes are needed. Bike pockets may be used to direct bicyclists to the best placement in the intersection. Bike pockets placed next to a roadway centerline may also be used to make it easier for bicyclists to negotiate an offset intersection.

PHOTO BY DAN BURDEN

This bike pocket positions bicycles to the left of right-turning motor vehicles.

Sometimes dashed lines are used to indicate the proper path for the bicycle in a complex intersection. Colored pavement may also be used for this purpose, as well as to indicate the weaving area for bicycles and motor vehicles when right-turning motor vehicles cross the path of bicycles in a bike lane. The intent is to increase awareness and safe behaviors by both cyclists and motorists and yielding behaviors by motorists.

Other kinds of markings are available for use at intersections. Bike box is the term that has gained popularity in the United States for a European treatment usually known as the advanced stop bar. The box is a right-angle extension to a bike lane at the head of the intersection (see drawing). The box allows bicyclists to get to the head of the traffic queue on a red traffic signal indication and then proceed first when the traffic signal changes to green. Such a movement is beneficial to bicyclists and eliminates conflicts when, for example, there are many right-turning motor vehicles next to a right-side bike lane. Being in the

Purposes

- Create on-street travel facilities for bicyclists.
- Create separated space for bicyclists.
- Increase awareness and safe behaviors by both cyclists and motorists.

Considerations

- Where intersection markings are to be considered, the road or street should be evaluated to determine what markings are appropriate.
- Provide adequate width if space is created for cyclists.
- Provide appropriate signs.
- Use marking and sign configurations that encourage the weaving of bicycles and motor vehicles where there are adequate gaps in traffic, usually in advance of the intersection proper.

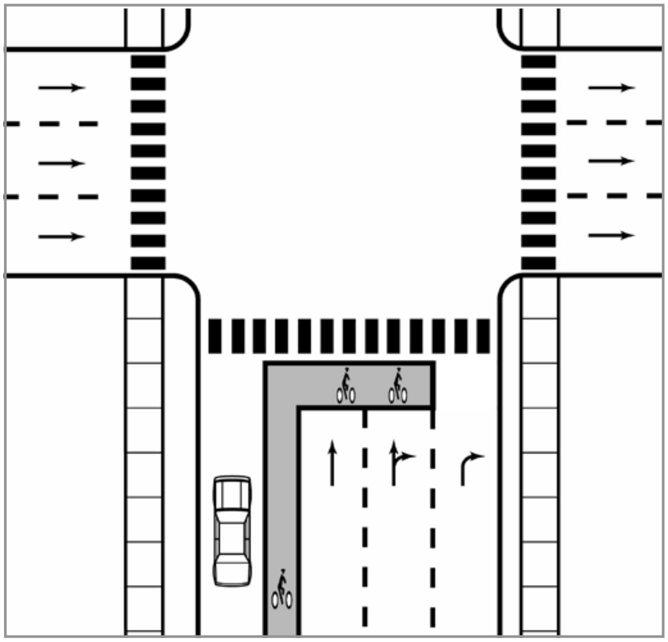
Estimated Cost

Costs will be variable, depending on the type of marking used. For a combination bike lane-right turn lane, costs include paint (regular, not thermoplastic) removal, new thermoplastic paint, one sign placed in ground and another sign up next to signal head for approximately $1,500 parts and labor. If traffic loops have to be moved, the cost would be an extra $1,000 per lane.

PHOTO BY DAN BURDEN

Dashed lines may assist both bicyclists and drivers in complex intersections.

box, and thus at the front of the traffic queue, also tends to make bicyclists more visible to motorists. Recessed stop lines operate similarly. These treatments should only be considered where there are a considerable number of daily bicycle commuters. Multi-lane streets with high traffic volume should be carefully evaluated to be sure the treatment would be safe. (See case study #26.)



This innovative bike box was used in a one-way street with a left side bike lane in Eugene, OR.

Another example is a combination bicycle lane-right-turn lane at an intersection. There are many intersections where using a minimum-width bike lane is not possible due to limited right-of-way. The use of a shared, narrow right-turn lane in combination with a bike lane in a limited right-of-way situation is a novel approach. This treatment could be applied in initial intersection design, when retrofitting a bike lane to an existing right-of-way, and when adding an auxiliary right-turn lane. This innovative application is used in Eugene, OR, to allow straight-through bicyclists to share a narrow right-turn lane with motorists. At the intersection proper, the total right-turn lane width is 3.6 m (12 ft), which includes a bike lane (pocket) of 1.5 m (5 ft) and a 2.1 m (7 ft) space to the right of the bike pocket. Depending on the size of the motor vehicle, the bicycle could be positioned in front of, beside or behind the motor vehicle in this combination lane. (See case study #21.)

The city of Portland, OR, has used special markings to direct bicycles around a street car transit stop in the vicinity of a bike lane (see case study #13) and to provide bicycle access through an offset intersection (see case study #23).

PHOTO BY CITY OF PORTLAND, OR, OFFICE OF TRANSPORTATION

A bicycle-only center-turn lane in Portland, OR, helps bicyclists navigate an offset intersection.

19. SIGHT DISTANCE IMPROVEMENTS

Adequate sight distance is vital for safe bicycling. Bicyclists need to see the movements of motor vehicles, and vice versa. Intersections are often areas where a number of sight distance problems occur. For example, on-street parking of motor vehicles can restrict the view. Trees, shrubbery, and other flora can also impede the line of sight. Improper placement of signs can decrease sight distance. Skewed intersections, where cross streets are greater or less than 90 degrees, can make it difficult to see other vehicles, as well as increase the exposure of bicyclists (or pedestrians) crossing the street. Problems similar to the above also often occur where driveways intersect with streets.

PHOTO BY PETER LAGERWEY

Realigning skewed or obtuse-angle intersections improves sight angles for intersecting roadways.

Sight distance problems can also occur away from intersections due to vertical curves. Use of the SHARE THE ROAD sign (see case study #41) would be appropriate on roads or streets with significant bicycle traffic.

PHOTO BY CHARLES HAMLETT

Transit stop placement can impact sight distance at junctions.

Purposes

- Improve the ability to see other modes of traffic.
- Increase awareness and safe behaviors by both cyclists and motorists.
- Increase reaction time.
- Decrease stopping distance.

Considerations

- Determine whether on-street parking is necessary.
- Determine the most appropriate kind of parking if necessary.
- Provide appropriate signs at street intersections and problem driveways.
- Provide the appropriate kinds of trees, shrubbery, and flora.
- Place street furniture so sight distance is not reduced.
- Determine if skewed intersections should be realigned.

Estimated Cost

Costs will vary depending on the treatment. Re-striping may be all that is necessary to eliminate unnecessary parking. The cost of sign removal or relocation is dependent on the size of the signing. The same would also be true for removal of trees, shrubbery, and other flora.

20. TURNING RESTRICTIONS

A frequent crash type involves a collision between a bicycle and a turning motor vehicle. One scenario involves a bicyclist going straight ahead and an oncoming motorist turning left at an intersection or into a driveway. If the motorist is intent on finding a gap between oncoming motor vehicles, he or she may fail to recognize an approaching bicyclist. Another scenario involves motor vehicles turning right on red. This is a particular problem for bicycles riding against traffic.

ILLUSTRATION BY A.J. SILVA

A permissible Right Turn On Red (RTOR) was introduced in the 1970s as a fuel-saving measure and has sometimes had detrimental effects on bicycling. While the law requires motorists to come to a full stop and yield to cross-street traffic, including bicyclists (and pedestrians), before turning right on red, many motorists do not fully comply with the regulations, especially at intersections with wide turning radii. In addition, motorists are so intent in looking for traffic approaching on their left that they may not be alert to bicyclists (or pedestrians) approaching on their right. Motorists also often pull into the crosswalk area to wait for a gap in traffic, which may put them directly in the path of bicyclists (or pedestrians) crossing in the crosswalk.

In locations where there is bicycle traffic, use of signs prohibiting certain turning movements may be warranted. One example is the standard sign preventing motor vehicles from turning left, usually placed over the roadway or at a left-hand corner of the intersection. The sign may be installed adjacent to a signal face viewed by motorists in the left lane. Prohibiting RTOR should be considered as well (also with high pedestrian volumes). This can be done with a simple sign posting at the right-hand corner of the intersection. The sign may also be installed adjacent to a signal face viewed by motorists in the right lane.

There are some options that are more effective than a standard sign. For example, one option is a larger 762

Purposes

- Increase bicycle (and pedestrian) safety and decrease crashes with turning motor vehicles.
- Increase safety in crosswalks.

Considerations

- Signs should be used where necessary and not overused. Overuse of signs breeds non-compliance and disrespect.
- Traffic signs used on public property must comply with the *Manual on Uniform Traffic Control Devices* (MUTCD).
- Signs should be placed in clearly visible locations.
- Signs should be checked to assure adequate nighttime reflectivity.

Estimated Cost

Sign costs are variable but typically range from $30 to $150. Installation may cost another $200. Electronic signs are appreciably more expensive.

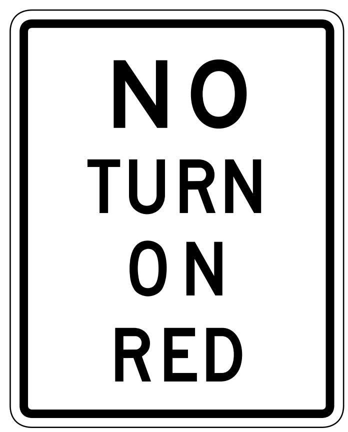


ILLUSTRATION BY A.J. SILVA

mm by 914 mm (30 in by 36 in) NO TURN ON RED sign, which is more conspicuous. For areas where left and right turns are acceptable during certain times, time-of-day restrictions may be appropriate using variable-message signs.

A partial restriction may prohibit left turns except for bicycles and transit. Such signs could be used in conjunction with bicycle boulevards or other low-volume, low-speed streets to not only reduce conflicts at the intersection, but help create a preferential bicycling cross-street. Turns may also be restricted with diverters and partial diverters.

21. MERGE AND WEAVE AREA REDESIGN

Merge areas that affect bicyclists are typically associated with intersections. Generally the pavement markings are for lane separation, for indicating an assigned path or correct position for the bicyclist, and for information about upcoming turning and crossing maneuvers. The *Manual of Uniform Traffic Control Devices* (MUTCD) is the national standard for all pavement markings (as well as signs and signals).[4]

Pavement markings, such as bike pockets adjacent to left- or right-turn motor vehicle traffic lanes, can be used to make bicycling safer. Double left- and right-turn lanes are particularly difficult for bicyclists. Long merge areas or high speed merges for motorist left turns are also problems for bicyclists needing to make left turns. Local geometric design tailoring may be needed on streets with these characteristics that also have a considerable number of bicyclists in the traffic stream.

In addition to intersection problems, bicyclists often ride on arterials or urban parkways which may contain some freeway-style designs such as merge lanes and exit ramps. If there is bicycle traffic on these roadways then it is likely that a bike lane or paved shoulder will be available. The 1995 *Oregon Bicycle and Pedestrian Plan* has a good description of the problems that can occur and potential solutions, and the description below is adapted from the plan.[5]

For the merge lane or entrance lane situation, several problems exist:

- The angle of approach creates visibility problems.
- Motor vehicles are accelerating to merge with traffic on the main road.
- Motor vehicles are typically traveling much faster than bicycles.

Purposes

- Provide for safer merging of bicycles with motor vehicle traffic.
- Improve sight distance and awareness for bicycles and motor vehicles involved in potential conflicts at entry and exit ramps.

Considerations

- Where entry and exit ramp revisions are to be considered, the road or street should be evaluated to determine if appropriate for this facility.
- Determine if other sight distance improvements need to be made.
- Try to avoid double left- and double right-turn situations for bicyclists.

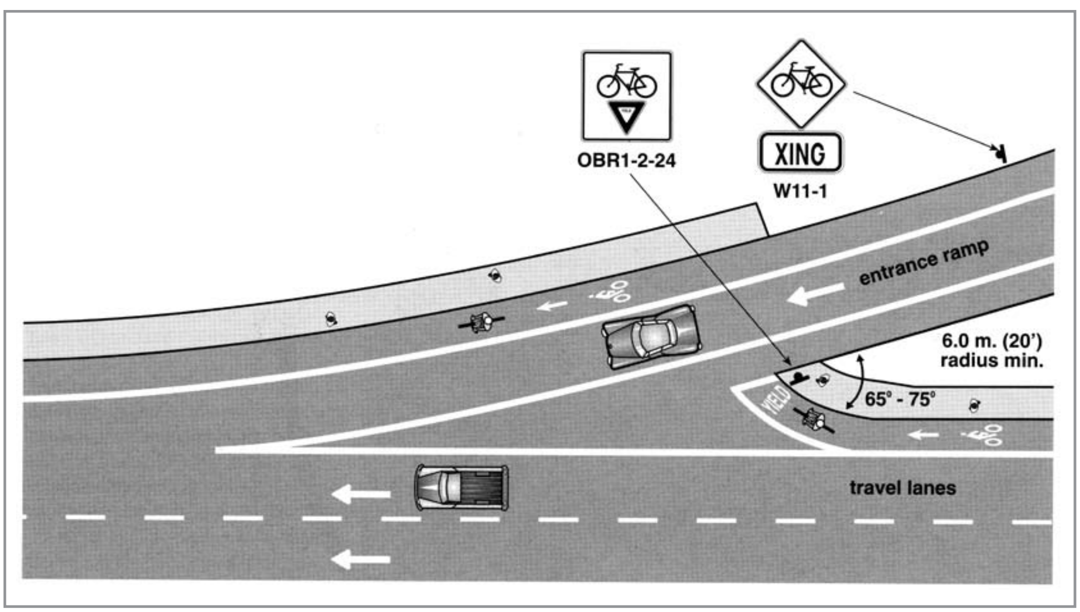
Estimated Cost

Construction costs for reconstructing a tighter turning radius are approximately $2,000 to $20,000 per corner, depending on site conditions (e.g., drainage and utilities may need to be relocated). Costs for reconstructing entrance and exit lanes on arterials or urban parkways are also dependent on site conditions.

The Oregon DOT offers the design shown below as one alternative to the entrance lane problem.[5]

This design creates a short distance across the ramp for the bicyclist at nearly a right angle for improved sight distance, as well as providing a crossing in a location before drivers' attention is focused on the upcoming merge with motor vehicles.

ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT



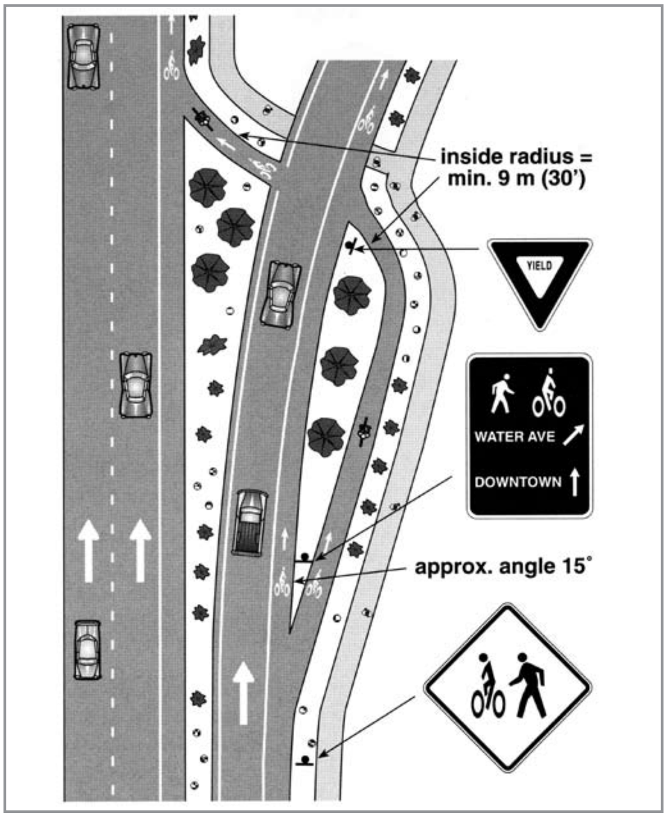
Design solution for bicycles and motor vehicles at an entrance ramp.

Similar problems exist for the exit lane situation:

- Motor vehicles are often exiting at high speeds.
- The exit angle creates visibility problems.
- Exiting drivers may not use their turn signal to indicate their desired movement.

The Oregon DOT offers the design shown below as one alternative to the exit lane problem.

ILLUSTRATIONS FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT



Design solution for bicycles and motor vehicles at an exit ramp.

MAINTENANCE

The availability of bicycle facilities is one of the components that can lead to increased riding in a community—if you build it, bicyclists will come. However, if you build it, it will also need to be maintained. Thus, maintenance needs require planning and budgeting. Sample maintenance activities include keeping roadways and bike lanes clean and free of debris, identifying and correcting roadway surface hazards, keeping signs and pavement markings in good condition, maintaining adequate sight distance, and keeping separate shared-use paths in good condition.

Maintenance is an area where planning and attention can provide significant benefits for bicyclists at relatively modest additional cost. Identification of maintenance needs for roadways and bicycle facilities and institutionalization of good maintenance practices are key elements in providing safe facilities for bicyclists. The countermeasures in this category have been divided into the following categories:

- Repetitive/Short-Term Maintenance
- Major Maintenance
- Hazard Identification Programs

The types of activities that will be carried out under each heading will be similar among communities in many cases, but should be identified, categorized, prioritized in terms of urgency and frequency, and budgeted for by each community since local conditions will dictate exact needs. For example, local flora, climate, weather, soil types, and other conditions may dictate frequent landscape maintenance and debris sweeping in some areas but be less frequently needed elsewhere. Winter snow removal may be important in northern communities but irrelevant in warmer climates.

The importance of good planning and initial design also cannot be overstated with respect to long-term maintenance needs. It is easier to obtain outside funding for facilities construction than for on-going maintenance, so plan and build correctly at the outset to reduce future maintenance problems and expense.

PHOTO BY BRIANNA LEON

Well-maintained roadway surface and bike lane free of debris and surface irregularities. (Phoenix, AZ)

22. REPETITIVE/SHORT-TERM MAINTENANCE

Repetitive and short-term maintenance includes activities such as sweeping, landscape maintenance, pavement markings maintenance, drain systems clearance and pothole repair that must be performed at some routine frequency, generally at least once per year, but some much more often. Such activities are crucial to maintaining safe riding surfaces, adequate sight distances and clearance, and clear and visible markings. Activities such as landscape maintenance, sweeping, graffiti removal, emergency telephone repair and general trash pick up also affect the aesthetic environment and promote bicycling through maintaining a more secure and pleasing environment. Regular inspections of structures and general surface conditions should also be performed to detect major maintenance needs.

Maintenance activities related to the safe operation of a facility should always receive top priority. The American Association of State Highway and Transportation Officials *Maintenance Manual*[1] identifies seven maintenance activities that should be carried out on a routine basis:

Signs and Traffic Markings
Signs warning both the motorist and bicyclist should be inspected regularly and kept in good condition; and striping should be kept prominent.

Sight Distance and Clearance
Sight distances on parallel roadways and trails should not be impaired leading up to crossings and curves. Trees, shrubs and tall grass should be regularly inspected and either removed or trimmed if they can interfere. Adequate clearances on both sides and overhead should be checked regularly. Tree branches should be trimmed to allow enough room for seasonal growth without encroaching onto the street or trail.

Purposes

- Maintain surfaces and other riding conditions in a safe and inviting condition for bicyclists.
- Identify, plan, and budget for routine maintenance activities that are critical to 1) maintaining the safety of a facility; 2) protecting the investment in a facility; and 3) protecting aesthetics and the environment.

Considerations

- Good maintenance practices preserve the investment in facilities and keep them in safe, useable condition.
- If facilities are well-maintained for bicyclists, they are apt to be in suitable condition for all shared uses.
- Annual maintenance needs and costs should be considered at the time facilities are constructed since it is more difficult to secure outside funding specifically for maintenance.
- Institutionalizing good maintenance practices may increase bicycling and reduce government liability.
- Develop an annual budget for repetitive maintenance that reflects current and new facilities to prevent unexpected increases.

PHOTO BY LIBBY THOMAS

Sight distance has been impaired due to poor landscape design and insufficient landscape maintenance.

Surface Repair
Streets and trails should be patched or graded on a regular basis. It is important that finished patches be flush with the existing surface. Skid resistance of the repaired area should be the same as the adjoining surface. Ruts should be removed by whatever measures are appropriate to give a satisfactory result and avoid recurrence.

Drainage
Seasonal washout, silt or gravel washes across a street, or trail, and sinking should be watched for, and appropriate measures should be taken to prevent them. Installing culverts or building small bridges could be considered a maintenance function to achieve an immediate result and avoid the expense of contracting. Drainage grates should

PHOTO BY LIBBY THOMAS

Sunken pavement patch and shoulder drop-off to below-grade drainage grate contribute to bicyclist discomfort and possible hazards for bicyclists.

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

Sweeping and Cleaning
The tires of a bicycle can be easily damaged by broken glass and other sharp objects. Bicycle wheels slip easily on leaves or ice. Sand or loose gravel on an asphalt surface can cause a serious fall. When mechanically sweeping roadways, there should also be concern that material is not thrown onto a bike lane, shoulder or trail.

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

Illumination
Lighting improvements should be made at busy arterials. Once installed, the lights should be maintained to not only ensure reliable operation, but that they are kept clean and replaced as required to keep the desired luminescence.

A thorough assessment of all bicycle facilities should be performed to generate a list of repetitive and short-term required maintenance activities. Preferably such processes would occur at the design phase so maintenance activities will be budgeted and planned for in advance. Some maintenance activities may be incorporated under regular roadway and public facilities maintenance, although care should be taken to consider the special needs of bicyclists and provide appropriate standards. For example, when repairing utility cuts, the City of Seattle requires an initial paving, then after allowing time for settling, the area is repaved to ensure that the cut area is made level with the surrounding pavement (see case study #1). Sweeping may also need to occur more frequently for bicyclists than would be necessary for motorists. Institutionalizing regular bicycle facility and shared roadway maintenance practices through scheduling, budgeting and inter-departmental cooperative agreements will ensure that the needs of bicyclists do not "slip through the cracks."

Estimating Cost

Historic costs provide the best roadmap for determining future costs. When estimating costs, there are four things to consider:

- Frequency: Reports of hazards on bicycle facilities are going to come in at about the same rate each year with some increase as new bicycle facilities come on line and the number of bicyclists increases. They are also likely to increase in the spring and summer when more bicycling occurs. Getting a handle on the total number is the first step in developing a budget.
- Types of hazards: Reported hazards should be put into basic categories such as potholes, longitudinal cracks in the pavement, debris that needs sweeping, etc.
- Cost per incident: Once reported hazards have been put into categories, an average cost per incident can be determined. For example, it is relatively easy to come up with an average cost for fixing a pothole.
- Budget: The final step is to develop a budget based on the frequency and cost per incident.

Existing maintenance budgets can often be used to cover the costs of fixing hazards. Once a budget has been determined, it may be possible to simply increase existing budgets proportionally. Some communities create separate budgets for addressing bicycle-related hazards.

23. MAJOR MAINTENANCE

Activities such as repaving a trail surface, replacing bridges and fixing major drainage problems that have a frequency of two or more years will fall into the category of major maintenance. While major maintenance occurs infrequently, it should be budgeted for on an annual basis to avoid large, unexpected budgetary demands.

Once major maintenance categories have been identified, set maintenance priorities by identifying which activities are critical to the safe operation of the facility and which ones are critical to other objectives such as protecting the investment in the infrastructure, protecting the environment and protecting aesthetics. While some priorities may vary to reflect local community expectations, safe operation of the facility should never be compromised. The AASHTO *Maintenance Manual* recommends that maintenance should seek to maintain conformance with the design guidelines used to build the facility.[1] Where proper guidelines were not used, maintenance should include improvements to the facilities' safety and operation.

PHOTO BY LIBBY THOMAS

Bridge replacement offers an opportunity to add space for bikes. (Durham County, NC)

The final major maintenance budget and plan should include a checklist of all maintenance items, the frequency of and cost for each activity, the annual cost of each activity and an indication of who will perform the activity. Priorities related to safe operation of the facility should be clearly identified and a tracking procedure clearly outlined.

Purposes

- Identify major maintenance activities that are critical to maintaining the safety of a facility; protect the investment in a facility; and protect the aesthetics and the environment.
- Develop an annual budget for major maintenance to avoid the periodic need for a major infusion of cash.

Considerations

- Securing maintenance dollars is difficult. Therefore, focus on designing and constructing facilities correctly at the outset to minimize future maintenance costs. In particular, make sure all drainage issues are fully addressed at the time of construction since water is the culprit for many major maintenance problems.
- Make sure that major maintenance is reflected in an annual budget that can be carried over from year to year. By definition, the amount spent on major maintenance will vary from year to year (i.e. a new bridge on a trail is not going to occur every year). Avoid "emergencies" if possible.

Estimating Cost

When developing a major maintenance plan for a new facility, the first step is to check current costs for maintaining an existing facility. The key is to obtain the costs for maintaining a facility that is most similar to the facility you plan to construct.

The next step in developing a maintenance budget and plan is to create a list of all possible maintenance activities. A good way to begin is to list major items included in the facilities' design. Most major items will have a measurable life expectancy. For example, asphalt pavement on a trail may have a 15-year life expectancy. Taking the total miles of asphalt trail and dividing it by 15 will give a good estimate of how much pavement needs to be replaced on an annual basis. Bridges are better handled on a case-by-case basis. Make a list of all bridges on trails, estimate their probable life, and then devise a multi-year plan for major maintenance or replacement. Listing all major maintenance items, while a lot of work, is a one-time activity that will allow you to develop a realistic budget.

24. HAZARD IDENTIFICATION PROGRAM

Roadways and off-road facilities can be made safer and more appealing to bicyclists by developing methods to identify hazards and repair needs and institutionalizing practices to address them. Different and combined approaches have been taken by communities but include developing bicyclist hazard reporting programs, hiring personnel to conduct regular inspections of bikeways, and providing for routine accommodation or scheduling and performance of regular activities such as sweeping, inspection and spot repairs, inspection and landscape maintenance, etc. Public hazard reporting programs typically involve developing a hazard identification reporting form such as a postcard and publicizing the program and procedures to report problems through bicycle shops, bike maps, bike clubs, and other venues. A staff coordinator (may be part-time) will be needed to administer the program, ensure that the problem is referred to the correct department and follow-through on resolution, including contacting the reporting person to advise them of the repair or other outcome.

PHOTO BY LIBBY THOMAS

Below-grade drain grates create hazards for bicyclists.

PHOTO BY LIBBY THOMAS

Short term solution of pavement marking highlights the hazard until unsafe drain grates can be replaced or repaired.

Purposes

- Provide a regular method of identifying hazards for bicyclists.
- Provide procedures for ensuring that maintenance hazards are addressed on a timely basis.

Considerations

- Responding to reported hazards in a timely way is critical to protecting public safety and reducing liability exposure.
- Prioritizing hazards requires a basic understanding of what problems are likely to cause crashes. For example, loose gravel on a curve is likely to cause a crash. Overgrowth that impairs sight distance at a busy intersection should be addressed immediately.
- The level of effort put into responding to bicycle-related hazards should be equal to or slightly greater than the effort put into responding to motor vehicle-related hazards. In other words, be able to demonstrate parity when developing a well-rounded program.

Estimated Cost

Providing paid staff to perform hazard identification program activities for 26 weeks cost one around $10,000. Setting up a volunteer bicyclist hazard reporting program with a coordinator, training and materials printing cost around the same, including a pilot test and evaluation of the program (see case study #28).

See Repetitive/Short-Term Maintenance and Major Maintenance countermeasures descriptions for procedures to establish costs of actual maintenance and repair activities.

Along with identifying problems, it is imperative that effective policies and procedures are in place to resolve them. Much routine maintenance might be accommodated through regular roadway maintenance (and the costs absorbed by, or at least shared within, the regular roadway maintenance budget). It is important that identification methods and maintenance procedures specify issues that are particular or more stringent for bicyclists, and that might otherwise not be detected or repaired to the necessary standard. Examples of issues that require particular attention are drain grates; cracked, uneven, or unswept surfaces—particularly of outside curb lanes, paved shoulders, or bike lanes; poor drainage; and slippery surfaces such as pavement markings, railroad crossings, utility covers, damaged pavement and others.

TRAFFIC CALMING

Traffic calming is a way to lower traffic speeds or volume using physical measures. Traffic calming creates physical and visual cues that induce drivers to travel at lower speeds and is intended to be self-enforcing. The design of the roadway results in the desired effect, without relying on compliance with traffic control devices such as signals and signs, and without enforcement. While added elements such as landscaping and lighting do not force a change in driver behavior, they might supplement the visual and perceptual cues that encourage people to drive more slowly. Slower motorist speeds help reduce the severity and number of crashes and help bicyclists feel more comfortable cycling in traffic.

Traffic diversion uses physical measures to restrict or divert traffic, typically to reduce cut-though motor vehicles, while not blocking local access. Traffic diversion measures may be used if other traffic calming measures do not sufficiently slow vehicles or reduce cut-through traffic. Often the tools of traffic calming and diversion are complementary and are used together. Ideally, streets would be designed and built for the desired travel speed and volume. Unfortunately, many existing local and neighborhood streets that should have slow design speeds and carry only local traffic were not designed to reflect this priority.

Traffic calming is such a powerful and compelling tool because it is very effective if properly applied. Some of the effects of traffic calming, such as fewer and less severe crashes, are clearly measurable. Other outcomes, such as enhanced community livability, are less tangible, but are also important.

Bicyclists deserve special consideration when planning, designing, and implementing traffic calming and diversion measures. Roadway narrowing or vertical or horizontal deflections of traffic to slow vehicles may have adverse impacts on bicyclists unless carefully done. Thoughtfully designed and used traffic calming measures, on the other hand, are valuable tools to enhance bicyclist safety and access. When traffic diversion is used, bicyclist and pedestrian access must be maintained. Typically, traffic calming and diversion measures are most appropriate on local streets that should have low speeds based on residential or intense commercial land uses. Traffic calming measures may also help to reduce traffic volumes on residential streets, where children and casual cyclists ride and other activities are carried out.

There are also some circumstances where traffic calming measures may be effective tools to enhance bicyclist safety and access on collector and arterial streets – those meant to carry higher volumes of traffic at higher speeds. These situations will be discussed under the individual countermeasures.

Traffic calming and diversion should be implemented and evaluated on an area-wide basis to avoid "diverting" problems to other streets or neighborhoods. It is also imperative to involve the community and all stakeholders in the process.

Other Internet resources on traffic calming:

- http://www.ite.org/traffic/index.html—This traffic calming Web site was developed by the Institute of Transportation Engineers (ITE) with financial support from the Federal Highway Administration (FHWA) in the interest of information exchange.
- http://safety.fhwa.dot.gov/speed_manage/traffic_calming.htm—This is FHWA's speed management Web site.
- http://www.fhwa.dot.gov/environment/tcalm/—This FHWA site includes links to local traffic calming program sites.
- http://www.bikewalk.org/assets/pdf/CASE19.PDF—Case Study 19: *Traffic Calming, Auto-restricted Zones and other Traffic Management Techniques* [FHWA-PD-93-028]
- http://www.pps.org/buildings/info/how_to/transit_tool/livememtraffic—Project for Public Spaces

The countermeasures related to traffic calming include:

- Mini Traffic Circles
- Chicanes
- Speed Tables/Humps/Cushions
- Visual Narrowing
- Traffic Diversion
- Raised Intersection

PHOTO BY JOHNNY RANDALL

A mini traffic circle in Charlotte, NC.

25. MINI TRAFFIC CIRCLES

Mini traffic circles are raised circular islands constructed in the center of residential or local street intersections. Mini cricles are a traffic calming intersection treatment employing yield control. They may also be used at uncontrolled junctions. Signs should be installed directing motorists to proceed to the right around the circle before turning right, passing through or making a left turn. Entering traffic yields to traffic in the circle and both entering and exiting vehicles should yield to pedestrians crossing the legs of the approaches to the intersection. Mini circles are commonly landscaped (often with a center tree and low-growing shrubs, flowers, or grasses). In some communities, the city may require the neighborhood to maintain the plantings. In locations where landscaping is infeasible, traffic circles can be made more aesthetically pleasing by using special paving materials.

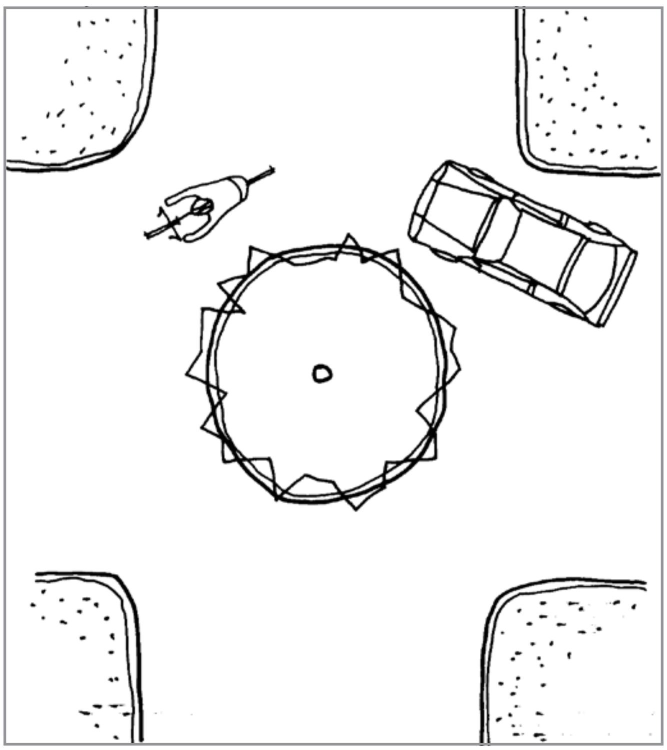


ILLUSTRATION BY A.J. SILVA

PHOTO BY PETER LAGERWEY

Mini traffic circles are widely used at neighborhood junctions in Seattle, WA.

Purposes

- Manage traffic at intersections where volumes do not warrant a stop sign or a signal.
- Reduce crash problems at the intersection of two local streets.
- Reduce vehicle speeds at the intersection.

Considerations

- Mini circles are typically not used on arterial streets.
- Consider whether bicyclists may be "squeezed" in traffic circles by overtaking motor vehicles.[1] This type of problem is not likely on low-volume streets, but should be considered where vehicle and bicycle volumes are higher.
- Keep the turning radii low to reduce turning speeds and improve pedestrian and bicyclist safety.
- Larger vehicles that need access to streets (e.g., school buses and fire engines) may need to make left turns in front of the circle, or accommodation may be made with mountable curbs on the perimeter of the circle.
- Use yield, not stop, controls.
- Midblock speeds may not decline, or may even rise, if intersections and mini circles are widely spaced and no midblock traffic calming measures are introduced. Traffic circles are primarily used to manage traffic flow at intersections and reduce intersection speeds, but may be combined with other measures or frequent mini circles to achieve street-long traffic calming.
- Pedestrians with vision impairments will find fewer cues to identify a gap to cross when traffic does not stop.

Estimated Cost

The cost is approximately $6,000 for a landscaped traffic mini circle on an asphalt street and about $8,000 to $12,000 for a landscaped mini circle on a concrete street (using existing curb radii).

Generally, mini circles are not intended for use where one or both streets are arterial streets (see section on Roundabouts, page 81). The primary benefit to bicyclists is that, like roundabouts, mini circles slow traffic approaching the junctions by forcing motorists to maneuver counterclockwise around them. Mini circles also reduce the number of conflict points at intersections. Mini circles have been found to reduce motor vehicle crashes at the involved intersections by 90 percent or more in Seattle, WA. Mini circles may provide one of the largest safety benefits of all the traffic calming devices. Most impact studies suggest they have a nominal impact on traffic volumes, so the reduction in crashes is apparently not due to diverting traffic to other streets.[2]

Mini circles must be properly designed with enough deflection to slow vehicles to provide safety benefits to bicyclists, pedestrians and motorists. Pedestrians with vision impairments will, however, find fewer cues to identify a gap to cross when traffic does not stop. Additionally, right-turning vehicles are not (stop) controlled at intersections with mini circles, potentially putting pedestrians at risk. Therefore, narrow curve radii should complement this treatment to discourage fast right-turn maneuvers. Adding splitter islands with pedestrian cuts to the legs of the intersection makes crossing easier for pedestrians, especially wheelchair users. Splitter islands also direct vehicles entering the intersection but require additional space.

The occasional larger vehicle going through an intersection with a traffic circle (e.g., a fire truck or moving van) can be accommodated by allowing these vehicles to make left turns in front of the circle or by creating a mountable curb in the outer portion of the circle. Other possible solutions are discussed in *Traffic Calming: State of the Practice*, chapter 7.[2]

PHOTO BY PETER LAGERWEY

Motor vehicles must slow to navigate through mini circles such as this one in a Seattle, WA, neighborhood.

26. CHICANES

Chicanes, as the term is used here, create a serpentine, horizontal shifting of travel lanes, without reducing the number of lanes or lane width, by alternating curb extensions from one side of the roadway to the other. Shifting a travel lane has an effect on travel speeds by interrupting straight stretches of roadway and forcing vehicles to shift laterally. Chicanes must be well designed so that the taper is not so gradual that motorists can maintain speeds through the curve or by cutting a shortcut path across the center line. For traffic calming, the taper lengths may be as much as half of what is suggested in traditional highway engineering. According to Ewing[2], "European design manuals recommend shifts in alignment of at least one lane width, deflection angles of at least 45 degrees, and center islands to prevent drivers from taking a straight 'racing line' through the feature."

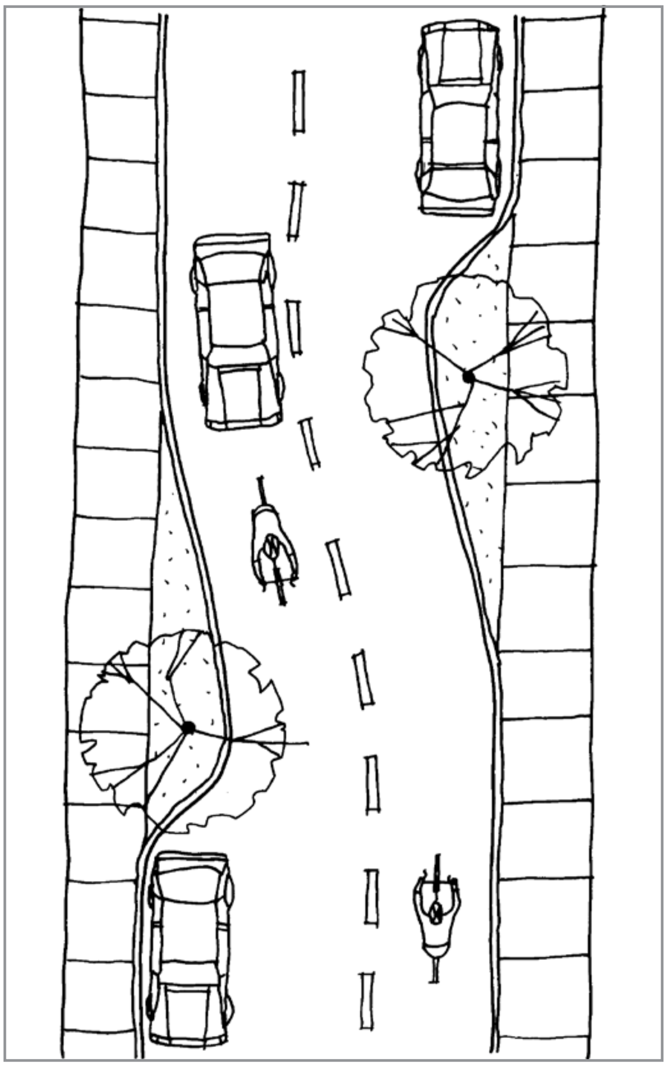


ILLUSTRATION BY A.J. SILVA

Alternating parking can provide a chicane-like effect.

Shifts in travel-ways can be created by building landscaped islands or extended walkways, or less expensively, by shifting parallel or angled parking from one side of the roadway to the other. Landscaped bulb-outs or expanded walkways can also effectively enclose parking bays and supplement the parking shift. If there is no restriction or narrowing (i.e., the number and width of lanes is maintained), chicanes can be created on streets with higher volumes, such as collectors or minor arterials, as well as on neighborhood streets.

A new or re-constructed roadway could also be designed in a serpentine fashion to keep sight lines short and force vehicles to make lateral shifts. Such a design could even be used where there is no curb such as in parks or rural areas where the scenic qualities also would support such a design.

Purposes

- Reduce vehicle speeds by interrupting straight stretches of roadway.
- Add more green (landscaping) to a street.

Considerations

- Chicanes may sometimes be used on minor arterial streets, but should not be used on high-speed, high-volume arterials.
- Chicanes may reduce on-street parking.
- Maintain good visibility by planting only low shrubs or trees with high canopies.
- Ensure that bicyclist safety and mobility are not diminished.
- Effect of chokers (with narrowing or lane restrictions) on bicyclists should be carefully evaluated prior to implementation; use should typically be restricted to lower-volume local streets to prevent bicyclist-motorist conflicts at pinch points. Chokers should not be used on streets heavily used by bicycles (or with bike lanes) unless design provides for bicyclist accommodation.

Estimated Cost

Costs for landscaped chicanes are approximately $10,000 (for a set of three chicanes) on an asphalt street and $15,000 to $30,000 on a concrete street. Costs should be far less for chicane-like parking configuration. Costs for chokers are estimated at $5,000 to $20,000. Drainage and utility relocation often represent the most significant cost consideration.

PHOTO BY DAN BURDEN

A serpentine design was created with landscaped islands. (Boulder, CO)

Chokers

Diverting the path of travel plus restricting the lanes (often called "chokers") usually consists of a series of midblock curb extensions, narrowing the street to two narrow lanes or one lane at selected points and forcing motorists to slow down to maneuver between them. Chokers or lateral shifts that create pinch points or reduce the number of lanes, which may be accomplished through the addition of landscaped islands or sidewalk bulb-outs, are intended for use only on local streets with low traffic volumes. Chokers may be used to simultaneously create a narrowed pedestrian crossing zone. Use of chokers should be carefully evaluated to avoid creating potential conflict zones between overtaking motorists and bicyclists.

27. SPEED TABLES/HUMPS/CUSHIONS

Raised traffic calming devices are typically used on local streets, primarily to reduce traffic speeds. Raised devices may provide the greatest impact of traffic calming devices on lowering speeds, but effectiveness is dependent on the geometrics of the devices and how widely spaced they are.[2] Some traffic may also be diverted through the use of raised devices, depending on how much of current traffic is non-local, the availability of alternate routes, the extent of area-wide treatment, and the type of treatment implemented (that is, humps may divert more traffic than longer and greater tables). Designs should consider bicyclist needs. More gradual and/or longer humps are less uncomfortable for bicyclists as well as other vehicle drivers and passengers, but also tend to have somewhat less slowing effect. Bicyclists may pass between speed cushions, but this and the other devices should be clearly marked for visibility.

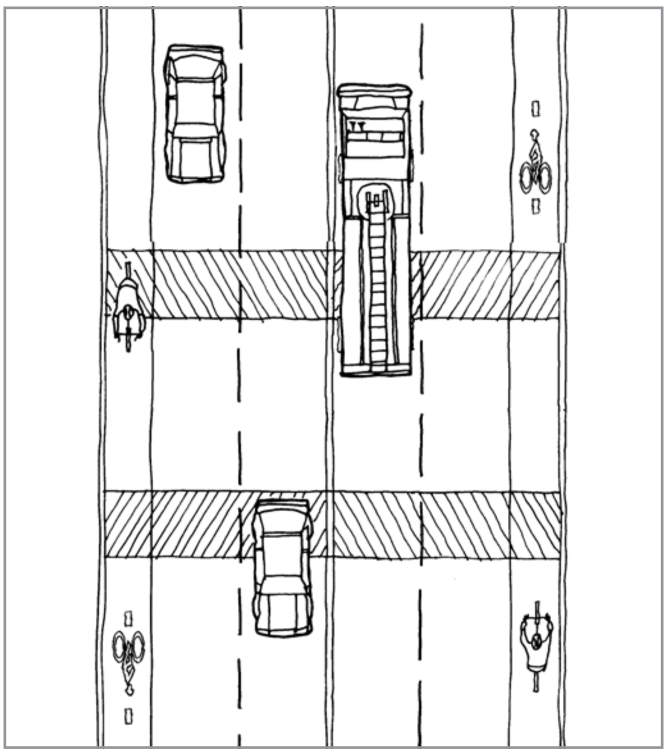


ILLUSTRATION BY A.J. SILVA

Raised devices may have the greatest impact on lowering traffic speeds.

Speed humps are paved (usually asphalt), approximately 7.6 to 10.2 cm (3 to 4 in) high at their center, and usually extend the full width of the street with height tapering near the gutter for drainage. (ITE suggests an approximate 3.5 in maximum height due to the jarring that occurs at 4 in.[1]) Space near the curb may also be provided to allow unimpeded bicycle travel or for a bike lane (but motorists may be tempted to use the area). (Speed humps should not be confused with the narrow speed "bump" that is often found in mall parking lots.) There are several designs for speed humps. The traditional 3.7 m (12 ft) hump has a design speed of 24 to 32 km/h (15 to 20 mi/h), a 4.3 m (14 ft) hump a few miles per hour higher.

Purposes

- Reduce vehicle speeds. Raised measures tend to have the most predictable speed reduction impacts.
- Enhance the pedestrian environment at crossings.
- May divert some (cut-through) traffic.

Considerations

- Raised treatments are not typically suitable for use on arterial streets.
- Do not use if on a sharp curve or if the street is on a steep grade.
- The effect on speed reduction is inversely related to the comfort of the device. Higher and shorter devices have the greatest slowing effect, but are the most uncomfortable to traverse.
- Markings and signs should promote nighttime visibility of raised devices for bicyclists and motorists.
- If the street is a bus route or primary emergency route, the design must be coordinated with operators. Speed cushions show promise here. Usually, some devices are acceptable if used prudently—one device may be appropriate and may serve the primary need (e.g., if there is a particular location along a street that is most in need of traffic slowing).
- The aesthetics of speed humps and speed tables can be improved through the use of color and special paving materials. Designs that complement neighborhood aesthetics will be more readily accepted by the public.
- Noise may increase, particularly if trucks use the route regularly, but some noise assessments have found little impact, and noise may be reduced overall because of cars traveling at lower speeds.
- Raised treatments such as speed tables may contribute to drainage problems on some streets.
- Speed humps, tables, and cushions should be properly designed and installed to reduce the chance of back problems or other physical discomfort experienced by vehicle occupants.

PHOTO BY PORTLAND OFFICE OF TRANSPORTATION

Speed humps should be clearly marked for visibility.

Speed table is a term used to describe a very long and broad, or flat-topped, speed hump. Sometimes a pedestrian crossing is provided in the highest or flat portion of the speed table. A speed table can either be parabolic, making it more like a speed hump, or trapezoidal, which is used more frequently in Europe. A 6.7 m (22 ft) table has a design speed of 40 to 48 km/h (25 to 30 mi/h). The longer humps/tables are much gentler for larger vehicles. Speed tables can also be used in combination with curb extensions, where parking exists, to create pedestrian crossings.

PHOTO BY DAN BURDEN

Midblock speed table, also serves as a pedestrian crossing.

Speed cushions, resembling a cushion or pillow placed longitudinally in the travel lane, are modified speed humps that do not span the entire roadway or lane width. The intent is to slow most motor vehicles similarly to speed humps and tables, but allow wide-axled vehicles such as buses and fire trucks to span and pass over the traffic calming device. These devices have been used to slow motor vehicles in Vancouver, WA, on a collector street used by emergency response and transit (see case study #30). Bicyclists typically ride between the cushions.

Speed humps and tables should probably be considered as "Plan B" on streets that are thoroughfares for bicyclists. Speed cushions may be somewhat more suitable for bicyclists. Use of other treatments such as mini circles, chi-

Estimated Cost

The cost for each speed hump is approximately $1,500 including markings. Speed tables are $2,000 to $15,000, depending on drainage conditions and materials used. Speed cushions also cost approximately $2,000 each.

PHOTO BY DAN BURDEN

A speed cushion is placed longitudinally in the travel lane. Vehicles with wider axles straddle the cushion.

canes or chicane-like parking treatments, median islands, and curb radii reduction should also be examined. Bicyclists may, however, be more concerned with traffic speeds on local streets than with traversing raised devices, but should be included in traffic calming planning processes.

28. VISUAL NARROWING

Some communities have begun combining traffic calming and other techniques with treatments designed to create a visual perception of a narrow, multi-use roadway in an effort to slow speeds and increase motorist attentiveness. Treatments such as adding street trees, vertical lighting elements, street furniture, special paving treatments or roadway markings, even striping bike lanes, that may create a perception of a narrow roadway or travel lanes (but do not necessarily physically narrow it) have been implemented. Effectiveness of these techniques at lowering speeds is somewhat inconclusive since multiple treatments are usually implemented simultaneously. Communities may nevertheless desire to implement such treatments as part of the overall design or aesthetic of the roadway and neighborhood.

PHOTO BY CHRIS HENRY, CITY OF EUGENE, OR

Street furniture was used to visually narrow the roadway through this plaza in Eugene, OR.

Use of contrasting paving materials might also enhance the functional separation of different portions of the roadway. For example, different paving treatment from that used for other lanes might emphasize a bike lane and increase motorists' perception that bicyclists should be expected.

Purpose

- Suggest to motorists that the street is a narrow, low-speed street and other users should be expected.

Considerations

- Maintain adequate sight distance, especially at intersections.
- Maintain adequate sidewalk clearance for pedestrian volume.

Estimated Cost

Costs, including maintenance costs, would vary widely depending on the specific treatments implemented.

PHOTO BY DAN BURDEN

Use of contrasting paving materials highlights this bike lane and visually narrows the roadway space in Sacramento, CA.

29. TRAFFIC DIVERSION

Traffic diversion techniques are remedies intended primarily to reduce traffic volumes on residential neighborhood streets when traffic calming or other measures have not sufficiently reduced cut-through traffic. Traffic diversion should only be used as a last resort, and then only in conjunction with area-wide traffic analyses and management. The prime beneficiaries of traffic diversion are bicyclists, pedestrians, and those who live on the treated streets, but local residents are also most negatively affected by traffic diversion.

Diverters should allow bicycle access.

Raised, island diverters may be used for area-wide traffic management. Four types of island diverters are diagonal, star, forced turn and truncated. A diagonal diverter breaks up cut-through movements and forces right or left turns in certain directions. A star diverter consists of a star-shaped island placed at the intersection, which forces right turns from each approach. A truncated diagonal diverter is a diverter with one end open to allow turning movements. Other types of island diverters can be placed on one or more approach legs to prevent through and left-turn movements and force vehicles to turn right. Neighborhoods with a grid-type pattern may benefit most from use of one or more of these types of diverters to reduce the appeal of neighborhood streets to cut-through traffic.

PHOTO BY RICHARD NASSI

Diverters and toucan signals help create a bicycle boulevard in Tucson, AZ.

Diverters may also be used in conjunction with other measures to create *bicycle boulevards*, specialized streets that give priority to through movement of bicyclists, but at intervals divert motorized traffic in order to provide a

Purposes

- Limit motor vehicle traffic on certain streets.
- Prevent turns from an arterial street onto a residential street.
- Reduce traffic volume by discouraging or preventing traffic from cutting through a neighborhood.
- Restrict access to a street without creating one-way streets.

Considerations

- Part of an overall traffic management strategy.
- Design diverters to allow bicycle, pedestrian, and emergency vehicle access. If this cannot be done and the street is a major bicycle corridor, a diverter should not be used.
- At full closures, provide a turnaround area for motor vehicles, including service vehicles, and provide for surface drainage.
- Full street closures may be considered for local streets, but are not appropriate for collector streets.
- Consider whether less restrictive measures would work. Local residents will be most affected.
- Assess whether other local streets would receive diverted traffic and/or access into or out of the neighborhood would be adequate.
- The impact on school bus routes and service vehicles should also be considered.
- Diverters generally do not effectively address midblock speeding problems[1]; use in conjunction with traffic calming measures if speeding is a problem.
- Diagonal diverters may be used in conjunction with other traffic management tools and are most effective when applied to the entire neighborhood street network.
- Partial or full street closures and area-wide use of diverters should have strong neighborhood support. There may be legal issues.

preferential bicycling environment. Local access for motor vehicles is maintained, but traffic calming and traffic control devices help to keep motorized speeds low and reduce conflicts between motor vehicles and bicycles. Examples of bicycle boulevards may be found in Palo Alto, CA (see case study #32).

A partial street closure uses a semi-diverter to physically close or block one direction of motor vehicle travel into or out of an intersection; it could also involve blocking one direction of a two-way street. Partial street closures at the entrance to a neighborhood or area should consider the traffic flow pattern of the surrounding streets as well. The design of this measure should allow for easy access by bicyclists and all pedestrians. A partial closure provides better emergency access than a full closure. Since this design also allows motorists to easily violate the prohibition, police enforcement may be required. If the partial closure only eliminates an entrance to a street, a turnaround is not needed; closing an exit will generally require a turnaround.

PHOTO BY PORTLAND OFFICE OF TRANSPORTATION

A partial closure limits cut-through traffic but allows bicyclist access.

A full street closure is accomplished by installing a physical barrier that blocks a street to motor vehicle traffic and provides some means for vehicles to turn around. There are a number of considerations before implementing a full street closure, which should be used only in the rarest of circumstances. Neighborhoods with cul-de-sac streets require extensive out-of-the-way travel, which is not a mere convenience issue, but has serious implications for impacts on other streets. All traffic is forced to travel on feeder streets, which has negative consequences for the people who live on those streets and forces higher levels of control at critical intersections. If a street closure is implemented, it should always allow for the free through movement of all pedestrians including wheelchair users, and bicyclists. Provision for emergency vehicle access should also be made. Such provision can be accomplished with a type of barrier or gate that is electronically operated, or by installing barriers that permit only large or wide-axled vehicles to traverse them.

Estimated Cost

The cost for a full, landscaped street closure varies from approximately $30,000 to $100,000, depending on conditions.

A well-designed, landscaped partial street closure at an intersection typically costs approximately $10,000 to $25,000. They can be installed for less if there are no major drainage issues and landscaping is minimal.

Diverters cost in the range of $15,000 to $45,000 each, depending on the type of diverter and the need to address drainage.

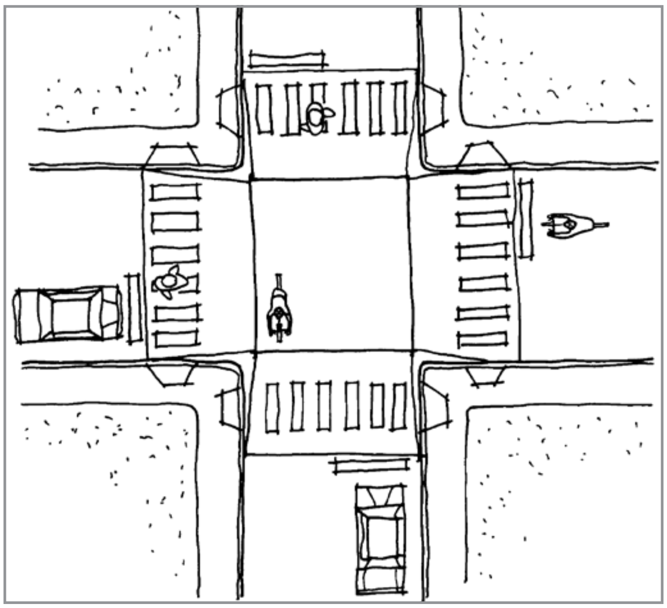
PHOTO BY DAN BURDEN

Bollards restrict motor vehicles from a neighborhood connector between cul-de-sac streets.

30. RAISED INTERSECTION

A raised intersection is essentially a speed table for the entire intersection. This treatment may improve intersection safety by forcing vehicles approaching the intersection to slow down and could be part of a street-wide traffic calming effort. Construction involves providing ramps on each vehicle approach, which elevates the entire intersection to the level of the sidewalk. They can be built with a variety of materials, including asphalt, concrete, stamped concrete or pavers. The crosswalks on each approach are usually also elevated as part of the treatment to enable pedestrians to cross the road at the same level as the sidewalk, eliminating the need for curb ramps. Detectable pedestrian warnings should be used to mark the boundary between the sidewalk and the street. Gradual approaches should reduce the impact on bicyclists.

ILLUSTRATION BY A.J. SILVA



Sketch of a raised intersection.

PHOTO BY ITE PEDESTRIAN BICYCLE COUNCIL

A warning sign and pavement markings alert traffic to this raised intersection.

Purposes

- Reduce vehicle speeds; improve intersection safety.
- Enhance the pedestrian environment at the crossings.

Considerations

- Considerations are generally the same as for other raised devices.
- Don’t use if on a sharp curve or if the street is on a steep grade.
- May not be appropriate if the street is a bus route or emergency route. One device may be necessary and serve the primary need. Several raised devices may be disruptive, so other measures should be considered.
- Speed tables and raised crosswalks and intersections can be an urban design element through the use of special paving materials.
- Detectable warning strips at edges enable pedestrians with vision impairments to detect the crossing.
- Care must be taken to manage drainage.

Estimated Cost

Raised crosswalks are approximately $2,000 to $15,000, depending on drainage conditions and material used. The cost of a raised intersection is highly dependent on the size of the roads. They can cost from $25,000 to $75,000.

TRAILS/SHARED-USE PATHS

Bike or shared-use paths are complementary to the road network and serve recreational, child, and perhaps commuter bicyclists if well-planned and connected to the street network and destinations. As with on-road facilities, junctions are a particular challenge to design and build so bicyclists and other users have safe access and crossings of roadways and other intersecting corridors. Additionally, providing for safe sharing of trails among diverse user groups requires good design and educational measures to promote good behavior.

Shared-use paths can enhance the quality of life in a community or region by providing additional opportunities for activity, recreational riding, or commuting choices. Trails should not be thought of as an alternative to providing safe on-street facilities for bicyclists since they can never connect to all the destinations reached by the street network. Some bicyclists will cycle preferentially on the street network since it suits their speed, skill, and trip needs better. Paths should nevertheless be designed to user-appropriate engineering standards, similarly to roadways, or safety will be compromised. Since it is rare to create a path that will be used by bikes only (perhaps some long-distance rural paths are an exception), guides, including the American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities*, now recommend that paths be designed for bi-directional mixed use, and recommend a minimum trail width of 3 m (10 ft) (up from 2.4 m (8 ft)) and encourages the use of 3.7 m (12 ft) or more where heavy or mixed uses are expected.[1]

Countermeasures described in this section include:

- Separate Shared-Use Path
- Path Intersection Treatments
- Intersection Warning Treatments
- Share the Path Treatments

PHOTO BY DAN BURDEN

Recreational riders are attracted to trails through natural and other scenic areas.

PHOTO BY DAN BURDEN

Diverse users, including child bicyclists, should be expected on shared-use paths.

PHOTO BY DAN BURDEN

Sign encourages slower cyclists to keep right on this Austin loop trail.

31. SEPARATE SHARED-USE PATH

Bike paths and shared-use paths are typically paved bi-directional pathways that are separate from the road right-of-way. Ideally, shared-use paths will follow a distinct course in a separate right-of-way, often along former railroad beds, along water courses or other rights-of-way that usually have few crossing roadways.[1] Trails immediately adjacent to roadways may cross numerous intersecting roads that create hazards and other problems for trail users (see http://www.bicyclinginfo.org/de/shared.htm for more information). There should, however, be sufficient access points from the road network.[2]

PHOTO BY CHUCK FLINK, GREENWAYS INC.

Separate shared-use paths provide opportunities for recreational riding for diverse bicyclists as well as potential utilitarian connections.

Bicycle paths or shared-use trails offer opportunities for recreational cycling and commuting that differ qualitatively from on-street riding. Paths may be designed to flow through natural or scenic areas, connect town to town or even region to region, or allow bicyclists to travel through urban areas away from motorized traffic. Bicycle and shared-use paths also may tend to attract bicyclists with a wide range of skill levels, including young children. A path, even if designed primarily as a bike facility, also likely will attract a mix of other users including pedestrians, in-line skaters and others, depending on location and access. Special care must therefore be taken in the planning and design of such trails to provide a satisfactory experience for bicyclists, and safe sharing of the facility with a variety of users of differing speeds and abilities.

Good planning and design of bicycle and shared-use paths are crucial to provide for safe use, to maximize long-term benefits, and reduce future maintenance problems (such as erosion, water or edge deterioration). Pathways will never replace the road network for connecting to destinations and some cyclists will prefer the road network for

Purposes

- Provide off-roadway recreational or commuting bicycling opportunities.
- Connect destinations that may be inaccessible for bicyclists via the road network.

Considerations

- Paths sited along roadways present numerous design safety challenges due to intersecting roadways.
- Good initial design will minimize future maintenance needs as well as access and safety problems.
- A good public process can help in designing a path that best meets local needs and suits local conditions.

Estimated Cost

Many factors, including regional materials and construction costs, topography, complexity of the environment and need for structures, and others affect trail costs. For a 3-km-wide (10-foot-wide) asphalt paved path with signs, minor drainage, and limited urban road crossings, the cost per kilometer could be around $155,300 ($250,000 per mile). Costs as high as $1,000,000 per mile have been reported.

Design typically runs about 18 percent of the total construction value.

PHOTO BY CHUCK FLINK, GREENWAYS INC.

The public planning process is important to establish bicycle paths and shared-use trails that meet local needs and suit local conditions.

most riding. Separate trails may be a destination for riding in themselves. Separate paths may also offer alternative routes for some bicyclists, provided they link origins and destinations or fill a gap that connects other bicycle facilities or routes on the street network. Creating safe and accessible intersections between paths and the road network is one of the most challenging aspects of design (see Path Intersection Treatments).

A good process that incorporates input from future users and property owners may be the most important element to realizing a path that will maximize recreational and travel benefits and minimize potential problems. Good initial design is also crucial for minimizing future maintenance costs and problems. The process should engage the community so that the facility that is ultimately designed fits with local needs and with the local cultural, natural, and built environments.

32. PATH INTERSECTION TREATMENTS

Since an off-road path lures users by the opportunity to bicycle away from traffic or through scenic settings, or to connect with destinations unavailable on the road network, it is important to minimize the number of roadway crossings or other intersections, both for safety reasons and to minimize delays and enhance patrons' enjoyment. Where paths must cross roadways, driveways, or other paths, it is important that the trail design facilitates the safest and most convenient crossing movements possible. Where there is a conflict between safety and convenience, safety should take precedence. Trail intersections with roadways offer special design challenges, especially since trail users may have a wide range of cycling skills and diverse characteristics. The AASHTO *Guide for the Development of Bicycle Facilities* provides design guidelines for midblock, adjacent path and complex intersection trail crossings where the path crosses a roadway at an existing intersection or driveway.[1] Signs and signals for the roadway and path, end of path transitions, markings, sight and stopping distance, ramp widths, and other intersection design issues are discussed, but each situation requires judgment on the part of the designer.

PHOTO BY DAN BURDEN

A median refuge enables path users to cross one direction of traffic at a time.

Both path-to-path and path-to-roadway intersections require careful planning and construction to maximize safety. Where crossings must occur, priority right-of-way should be established based on the type of intersecting travel-way, traffic volumes, speed, and other factors. Path users should be counted in the volumes, and where paths cross low-volume roadways or driveways and path use is high, priority should be given to the path. Warning and regulatory signs, traffic signals, and pavement treatments or markings should be used to clearly delineate which corridor has the right-of-way, coordinate interactions, and guide path users to safe crossing locations. A traffic control device (sign or signal) should be installed at all path-roadway intersections. Efforts should be made to minimize crossing delays to path users as some may be unwilling to tolerate significant delays.

Pathways must link to the street network and access points should be clearly marked and signed. Curb cuts should be flared to allow bicyclists to make safe turns onto or to exit the trail. On unpaved paths, a paved apron should extend at least 3 m (10 ft) from the edge of paved roadways. To prevent motorized traffic from inadvertently or

Purpose

- Provide safe multi-use path crossings of roadways and other corridors.

Considerations

- Design paths to minimize the number of crossings.
- Crossings should clearly delineate right-of-way; depending on use and type of facility being crossed, the trail may warrant the right-of-way.
- On occasion, directness may have to be sacrificed to maximize safety.
- Off-grade crossings may be safest for crossing some roadways, but good design is crucial to creating an appealing secure facility that will invite use. Expense of new off-grade crossings may be prohibitive.

Estimated Cost

Intersection costs are part of the overall cost of the trail. Some treatments may be incorporated into roadway or intersection upgrades.

PHOTO FROM ALTA PLANNING + DESIGN

Path users are directed to an existing signalized intersection for crossing.

intentionally accessing the trail, signs clearly noting that motorized traffic is prohibited, as well as brightly painted bollards or medians, should be installed in the center of a 3 m (10 ft) wide or less path, or no less than 1.5 m (5 ft) apart on a wider path. Access for maintenance and emergency vehicles must be provided.

Railroad corridors are often desirable locations for paths because they generally have few roadway crossings and built-in off-grade crossings (overpasses and underpasses) of roadways, streams, and other barriers where crossings do occur. At railroad crossings, active devices such as bells and flashing lights, or automatic gates triggered by the approach of a train may be warranted.[3] For new construction, the cost of off-grade crossings may be considered prohibitive but may be the best alternative where a trail needs to cross a busy or high-speed corridor or if trail use is expected to be high. Some communities such as Boulder, CO (see case study #35), have used off-grade crossings extensively for bike and pedestrian corridors. For safe and effective overpasses and underpasses, adequate lighting is important for travel and for personal safety. (See Tunnels/Underpasses countermeasure.)

When trails must cross roadways at grade, it may be desirable to design the crossing at an existing intersection to minimize incidences of wrong-way riding along the roadway to the trail access. The crossing distance should be minimized. If the trail crosses a busy, multi-lane or high-speed road, a refuge island is a treatment that enables trail users to cross one leg of the roadway at a time. The crossing may be angled so that trail users turn toward oncoming traffic to cross the second direction of travel lanes. Lighting can also enhance the safety of path intersections with roadways, railways, and other paths, especially if extensive nighttime use is expected (such as in a busy urban area or near a college or university campus).

PHOTO BY DAN BURDEN

A stop sign controls right-of-way, while crossing markings and warning signs on the roadway alert that path users should be expected.

33. INTERSECTION WARNING TREATMENTS

Advance warning treatments let bicyclist path users know they are approaching an intersection with a roadway, another path, a railway, or other crossing. Since some bicyclists will be among the highest speed users of paths, sight and stopping distance, signs, and intersection design guidelines for bicyclists should be used in designing shared-use paths, including intersection approaches.[1] Passive warning devices including pavement markings, special pavement "alerts" such as textured treatments, and warning signs may be used. See the *Manual of Uniform Traffic Control Devices* (MUTCD) for signs that may be appropriate for warning of at grade crossings, including railroad crossings.[4]

PHOTO BY DAN BURDEN

A flat grade and bollards with painted markings warn path users to slow on approach to junction, as well as prevent motor vehicle access to the path.

A flat grade should be used on intersection approaches to improve sight distance and provide bicyclists with a chance to reduce speed. Bollards should be placed so bicyclists have adequate clearance and the placement does not force bicyclists into an incorrect position on approach to the intersection. Vegetation and other obstructions should be kept clear near intersections for adequate sight distance.

Roadway treatments such as warning signs and pavement markings also let road users know they are approaching an area where bicyclists, pedestrians, and other path users may be crossing or present.

Purpose

- Warn bicyclists and other path users that they are approaching a junction where they should be prepared to stop or yield.

Considerations

- Assess sight distance requirements for path-roadway intersections.
- A flat grade on the path should precede junctions to provide good sight distance and sufficient stopping distance for bicyclists.
- Vegetation and other landscape features should allow adequate sight distance near intersections.

Estimated Cost

Costs would be included in overall path costs. Retrofit measures such as signs or changes in pavement markings would depend on treatment.

34. SHARE THE PATH TREATMENTS

The diverse types, multiple skill and age levels, and other characteristics of shared-use path users may contribute to conflicts, falls, and crashes. Good path design, as well as shared-use policies, education, and perhaps enforcement may help bicyclists and other path users share off-road paths more safely and enhance their enjoyment.

A number of treatments and markings are available to encourage safe shared use as needed.

Design and policies for accommodating multiple types of users should be developed on a case-by-case basis depending on local demand for different uses, expected volumes, and other factors. For example, if the path is expected to serve both commuter bicyclists and local pedestrians and child bicyclists, and there is sufficient corridor right-of-way, separate facilities may be desirable. For joggers, a gravel or dirt path may be provided beside a paved path. In most situations, separate facilities will, however, likely be considered infeasible or cost-prohibitive.

Other engineering treatments may encourage safer sharing of a single, two-way, multi-use facility. These include center-line striping to separate directions of travel with broken markings that indicate safe passing zones; special paving treatments to separate users; pavement markings at trail and roadway junctions that channelize users to appropriate crossings; signs, marking and paving treatments to clearly indicate right-of-way; and others.

Appropriate path use policies should also be developed since behaviors of users have much to do with preventing crashes and conflicts. Trail rules or etiquette may be posted at entrances and included on bicycling maps. Such path use guidelines include:

Purpose

- Reduce conflicts and crashes on multi-use trails.

Considerations

- Do not diminish the trail experience by over-designing specialized treatments.
- Incorporate various user groups in planning and programs to enhance shared-use cooperation and enjoyment.
- If enforcement is used, more positive, educational types of interventions may work better than penalizing trail users.

Estimated Cost

Costs depend on program but would at a minimum include funding for staff planning time.

- Slower users keep right
- Use audible signal when passing
- Pass only where sight-distance allows a safe maneuver
- Use caution when riding near young children, pets, and other unpredictable path users, etc.

User guidelines might be promoted through a variety of community resources in addition to postings along the

PHOTO BY TODD LITMAN, VICTORIA TRANSPORT POLICY INSTITUTE

Path use rules or guidelines are posted along the Galloping Goose Trail in Victoria, BC, Canada.

PHOTO BY DAN BURDEN

Pavement markings were used to designate separate spaces for shared use on this heavily used Long Beach, CA, path.

trail. Traditional traffic enforcement methods may be inappropriate for paths since non-motorized uses typically do not require a license and many users are children, but more positive, educational types of interventions may help if conflict or crash problems arise.

Guidelines for bicyclists produced by the League of American Bicyclists on sharing paths are available at http://www.bikeleague.org/educenter/factsheets/sharingthepath.htm. The International Bicycle Fund (http://www.ibike.org/education/trail-sharing.htm) has also posted guidelines for trail sharing including a model trail use ordinance.

MARKINGS, SIGNS, AND SIGNALS

Traffic control devices, including a variety of pavement markings, signs, and traffic signals, are used by traffic engineers to improve safety and access for bicyclists. Besides traditional treatments such as installation of a traffic signal, innovative treatments are also being installed and evaluated, including separate bicycle signal heads and bicycle and pedestrian crosswalk signals, sometimes known as toucan signals. School speed zone and traffic control devices may also be implemented to improve safety for children bicycling and walking to school along designated routes.

The countermeasures included in this section are:

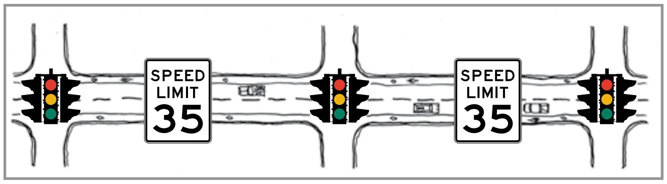
- Install Signal/Optimize Timing
- Bike-Activated Signal
- Sign Improvements
- Pavement Marking Improvements
- School Zone Improvements

Warning signs may enhance safety in special situations.

35. INSTALL SIGNAL/OPTIMIZE TIMING

Traffic signals create gaps in traffic flow, allowing bicyclists, pedestrians, and motorists to access or cross the street. Signals are particularly important for crossing higher speed roads, multi-lane roads or highly congested intersections. National warrants from the *Manual on Uniform Traffic Control Devices* (MUTCD) are typically used for new signal installation.[1] Part 9 of the MUTCD focuses on "Traffic Calming for Bicycle Facilities." Some states have their own supplement to the MUTCD.

ILLUSTRATION BY A.J. SILVA



Appropriate signal timing may help create gaps for bicyclists at midblock or unsignalized side streets as well as the signalized intersections.

Bicycle signals provide a distinct crossing phase for bicyclists in particular circumstances.

In downtown areas, signals are often closely spaced, sometimes at every block. A problem for bicycles is that signals are timed to accommodate typical motor vehicle speeds and flows. The motor vehicle speeds can be significantly faster than bicycle speeds. In addition, the clearance interval for motor vehicles crossing a wide intersection may not be long enough to ensure safe clearance by bicycles.

Although little research is available, timed sequencing of signals may take bicycling into account. Some cities time their downtown urban traffic signals to account for speeds of 20 to 25 km/h (12 to 16 mph), which allows bicycles to easily ride with traffic.

Purposes

- Optimize signal timing to slow down motorists trying to get through a signal at a high rate of speed.
- Provide intervals in a traffic stream where bicycles can cross streets safely.
- Provide enough time for a bicyclist to clear a wide street at the end of a green phase.
- Accommodate both motor vehicle and bicycle traffic in dense urban areas through optimal signal timing.

Considerations

- Studies are necessary to determine if a traffic signal is needed. However, warrants need to take into account local conditions, such as the volume of bicycle (and pedestrian) traffic.
- Determine if the signals in a dense urban area can be timed to accommodate both motor vehicle and bicycle flow.
- Determine if bicycle volumes are large enough to warrant a bicycle traffic signal.

Estimated Cost

Typical traffic signal costs range from $30,000 to $140,000.

PHOTO BY LIBBY THOMAS

Loops being installed in advance of intersection with limited sight distance may detect vehicles and delay the green indication for cross-street traffic. (Chapel Hill, NC)

In locations with high volumes of bicyclists, traffic signals for bicycles can be used. These have been popular in Europe and China for many years. The City of Davis, CA, where bicycling accounts for approximately 17 percent of the mode share, has effectively employed a bicycle traffic signal to reduce conflicts and crashes between bicycles and motor vehicles at a location with very high volumes of bicycles and pedestrians. The bicycle signal provides a separate phase for bicyclists and pedestrians, with motorists following after the intersection has cleared (see case study #39). "NO RIGHT TURN ON RED" signs are also used.

36. BIKE-ACTIVATED SIGNAL

Bicyclists often have difficulty crossing streets with high-speed and/or high-volume motor vehicle traffic. The problem is worsened if these streets have multiple lanes. These situations can be greatly improved by placing bike activation devices on the minor street. These give bicyclists preference on demand without causing undue delay to motorists. Activation devices can also be used on a main line street to prolong the green phase and extend the time needed for the bicycle to clear the intersection.

PHOTO BY CHERYL SCHMITT, CITY OF SANTA CRUZ

Pavement symbol shows bicyclists where to position to be detected for a signal change.

Bicycle loop detectors are the norm as the activation device. Loop detectors can be placed in a traffic lane or bike lane on the side street to trip the signal. These detectors can also be placed on the major street to prolong the green phase and allow a cyclist to clear a wide intersection. It may also be necessary to increase the sensitivity of existing loops, as well as paint stencils on the pavement to point out the most sensitive loop locations to cyclists. Another alternative is the use of push buttons near the roadway such that the cyclist does not have to get off the bike. Video cameras and infrared motion detection sensors are other options but are more expensive.

The City of Seattle, WA, has made extensive use of pedestrian/bicycle crosswalk signals (formerly called half-signals) in locations where bicyclists using residential streets have a need to cross an arterial street at an unsignalized intersection (see case study #40). These signals are actuated by bicyclists (or pedestrians) and stop traffic only on the arterial, leaving the lower volume cross street unsignalized. This allows bicyclists (and pedestrians) to cross safely upon demand without creating unnecessary delays on the arterial street. These crosswalk signals have also been used to facilitate "bicycle boulevards" in various communities. The boulevards are routes to facilitate fast and safe bike movement while discouraging through motor vehicle traffic.

Purposes

- Provide intervals in a traffic stream where bicycles can cross streets safely.
- Prolong the green phase to provide adequate time to clear the intersection.

Considerations

- Determine where activation devices are needed and the most appropriate type.
- Determine if activation devices are needed to prolong the green phase.

Estimated Cost

Costs will vary depending on size and complexity of the intersection, but in general are comparable to the installation of conventional traffic signals.

37. SIGN IMPROVEMENTS

Signs often convey important information that can improve road safety. The intent is to let bicyclists and motorists know what to expect, thus improving the chances that they will react and behave appropriately. For example, the use of a "No Parking in Bike Lane" sign is intended to keep this space clear for cyclists. Sign use and placement should be done carefully, in that overuse often results in non-compliance and/or disrespect. Excessive use of signs can also create visual clutter and lead to the intended sign and message getting "lost."

PHOTO BY MICHAEL KING

Regulatory sign restricts curb lane use to buses, bicycles, and right-turning vehicles.

Regulatory signs, such as STOP, YIELD or turn restrictions require driver actions and are enforceable. NO TURN ON RED signs can improve safety for bicyclists (and pedestrians). Problems often occur at RTOR locations as motorists look to the left for a gap in traffic, especially if bicyclists are riding wrong way either in the street or on a sidewalk or path.

PHOTO BY MICHAEL KING

Warning sign alerts bicyclists and motorists to an upcoming lane shift.

Warning signs can also provide useful information. An example is the SHARE THE ROAD sign, which serves to let motorists know that bicyclists may be on the road and that they have a legal right to use the road. This sign is typically placed along roads with significant bicycle traffic but relatively hazardous conditions for riding, such as narrow travel lanes with no shoulder, roads or streets with poor sight distance, or a bridge crossing with no accommodation for bicycles. Special signs are sometimes used to indicate the presence of a bicyclist.

All signs should be periodically checked to make sure that they are in good condition, free from graffiti, reflective at night, and continue to serve a purpose.

Purposes

- Provide warning and regulatory messages, as well as useful information.
- NO TURN ON RED signs can increase bicycle safety and decrease crashes with right-turning vehicles.
- SHARE THE ROAD signs can make motorists more aware of bicyclists on roads with poor bicycle accommodations.

Considerations

- Streets with bicycle traffic should be evaluated to determine if sign improvements could improve safety.
- Prohibiting RTOR is a simple, low-cost measure. The change can benefit bicyclists on streets with considerable through bicycle traffic with minimal impact on motor vehicle traffic.
- Part-time RTOR prohibitions during the busiest times of the day may be sufficient to address the problem.
- RTOR signs should be clearly visible to right-turning motorists stopped in the curb lane at the crosswalk.
- Carefully evaluate use of both regulatory and warning signs. Avoid overuse which may lead to non-compliance or visual clutter

Estimated Cost

Costs range from $30 to $150 per typical sign plus installation at $200 per sign. Electronic sign costs vary widely but tend to be significantly more expensive.

PHOTO BY DAN BURDEN

Flashing warning signs such as this "Bicyclist on Bridge" sign could be used to alert motorists to the presence of bicyclists ahead.

38. PAVEMENT MARKING IMPROVEMENTS

A variety of pavement markings are available to make bicycling safer. Generally the markings are for lane separation, for indicating an assigned path or correct position for the bicyclist, and for information about upcoming turning and crossing maneuvers. The *Manual of Uniform Traffic Control Devices* (MUTCD) is the national standard for all pavement markings (as well as signs and signals), and Part 9 focuses on "Traffic Controls for Bicycle Facilities."[1] Some states may have their own supplement to the MUTCD.

Examples of pavement markings include the striping and identification associated with bike lanes, striping for paved shoulders, turning lanes at intersections, railroad crossings, and drainage grates or other pavement hazards or irregularities. A general guideline for improved bicycle safety is to make sure the markings are durable, visible, and non-skid. Markings are usually done with paint or thermoplastic. Paint is cheaper but tends to fade quickly, while thermoplastic lasts longer but may be slippery. If thermoplastic is used for bicycle markings, a thin, non-skid type is preferred. The State of Oregon has four different types of legend markings that can be used for bike lanes — hot poured thermoplastic, preformed thermoplastic, tape, and methyl methacrylate. Use varies by geography, weather, traffic volumes and pedestrian and bike counts. Amount of skid resistance varies with each product. Sometimes glass beads, crushed glass and aggregate can be added during placement to increase skid resistance, but the skid resistant particles tend to sink before the thermoplastic cools.

Blue pavement highlights a contraflow bike lane.

Purposes

- Indicate a traffic lane to be shared between motor vehicles and bicycles.
- Indicate the presence of a bike lane.
- Indicate an assigned path or correct position for the bicyclist.
- Provide information about upcoming turning and crossing maneuvers.
- Indicate other specialized bicycle facilities or situations.

Considerations

- Use of thin, durable, non-skid thermoplastic material improves conditions for bicyclists.
- Careful placement of markings (e.g., away from bus and truck traffic, away from driveways) will increase their longevity.

Estimated Cost

A rough cost estimate of labor and materials for arrow and chevron markings applied using methyl methacrylate is $100 each. Costs of other markings would depend on type and materials used.

The "bike and chevron," or SHARROW, is used to indicate both the presence of bicycles and the correct placement of bicycles in the traffic lane.

Care in the placement of painted markings will increase their longevity. For example, avoid placement of markings near far-side bus stops or near driveways or other locations, particularly those with high truck traffic, to avoid wear from tires.

More symbols are now being used to indicate the presence of bicycles in the traffic stream, as well as the correct riding position in the traffic lane. There are many international examples. In the United States, the City of Denver, CO, introduced the "bike-in-house" marking for shared lane situations many years ago. An experimental evaluation of a modified version of this symbol, the "Shared Arrow," was performed on a wide curb lane corridor in Gainesville, FL, in 1999.[2] In February 2004, the City of San Francisco completed an evaluation of a modified "bike-in-house" and "bike-and-chevron" markings (see case study #37). The Gainesville and San Francisco evaluations showed benefits for the markings. The "bike and chevron" markings have come to be known as the SHARROW, and this symbol has been approved by the California Traffic Control Device Committee for use in California.

Other known U.S. cities with some variation of the markings described above include Chicago, IL; Cambridge, MA; Portland, OR; Warren and Waitsfield, VT; Seattle, WA; and Sacramento, CA. There continues to be movement toward adoption of some form of the arrow or chevron as a national standard, but as of this writing this is not complete.

39. SCHOOL ZONE IMPROVEMENTS

A variety of roadway and other improvements may be used to enhance the safe mobility of children in school zones. The countermeasures pertinent to children walking to school also generally apply to children bicycling to school.

PHOTO BY DAN BURDEN

Young bicyclists as well as walkers will benefit from slow school zones and other safety improvements.

Purpose

- Provide enhanced safety around schools.

Considerations

- Safety must be a combined effort between local traffic officials, police, school officials, parents, and students.
- Care must be taken to make sure students understand the various signs and markings and not be lulled into a false sense of security.

Estimated Cost

Costs would depend on the school zone treatment selected. For example, if signs were chosen, costs might include $50 to $150 per sign plus installation costs. Adult crossing guards may cost around $10,000 each per year.

Sidewalks or separated walkways and paths are ingredients for a safe trip from home to school on foot or by bike. Children can also be taught safe riding techniques that will enable them to ride on low-volume neighborhood streets. Speeds of motor vehicles also need to be controlled on these streets. Signs and marking treatments to control motor vehicle speeds in and around schools include the school advance warning sign (which can be fluorescent yellow/green), school speed zone and flashing speed zone signs, flashing yellow warning signals, and in-street "Yield to Peds" signs (generally dropped into a holder in the street). Police enforcement in school zones may be needed in situations where drivers are speeding or not yielding to children in crosswalks. Sometimes localities double the fines for speeding in school zones.

Other helpful measures include parking prohibitions near intersections and crosswalks near schools. Marked crosswalks can help guide children to the best routes to school. Sometimes these crosswalks have additional pedestrian crossing signs mounted at the side of the street as well as overhead. Flashing beacons may also be used. School administrators and parent-teacher organizations need to educate students and parents about school safety and access to and from school. Education, enforcement, and well-designed roads must all be in place to encourage motorists to drive appropriately. Safe Routes to School Communities are using Safe Routes to School (SR2S) programs to work toward making walking and bicycling safe and appealing ways for children to get to school. A new course developed by the Pedestrian and Bicycle Information Center (PBIC) for FHWA is designed to help communities and states create sound programs that are based on community conditions, best practices and responsible use of resources. The course concludes with participants developing an action plan. The course is supported through a partnership of funding from the Federal Highway Administration, the National Highway Traffic Safety Administration, the Centers for Disease Control and Prevention and the Environmental Protection Agency. (See http://www.pedbikeinfo.org/sr2s/ for more.)

The use of well-trained adult crossing guards has been found to be one of the most effective measures for assisting children, whether bicyclists or walkers, in crossing

PHOTO BY DAN BURDEN

A crossing guard helps child bicyclists and walkers safely cross an intersection.

streets safely. Adult crossing guards require training and monitoring and should be equipped with a bright and reflective safety vest and a STOP paddle. Florida has a state-level crossing guard program. The Florida School Crossing Guard Training Guidelines, produced by the Florida DOT and administered by the Florida Department of Highway Safety and Motor Vehicles, are available at http://www.dot.state.fl.us/Safety/ped_bike/training/ped_bike_training.htm.

One of the biggest safety hazards around schools is parents or caretakers dropping off and picking up their children. There are two immediate solutions: (1) there needs to be a clearly marked area where parents are permitted to drop off and pick up their children, and (2) drop-off/pick-up regulations must be provided to parents on the first day of school. Drop-off areas must be located away from where children on foot or bicycle cross streets or access the school. Parent drop-off zones must also be separated from bus drop-off zones. If parents can be trained to do it right at the start of the school year, they are likely to continue good behavior throughout the year.

For a longer-term solution, it is preferable to create an environment where children can walk or bicycle safely to school, provided they live within a suitable distance. One concept that has been successful in some communities is the concept of a "walking bus," where an adult(s) accompanies children to school, starting at one location and picking children up along the way. Soon, a fairly sizeable group of children are walking in a regular formation, two by two, under the supervision of responsible adults, who are mindful of street crossings. Parents take turns accompanying the "walking school bus" in ways that fit their schedules.

EDUCATION AND ENFORCEMENT

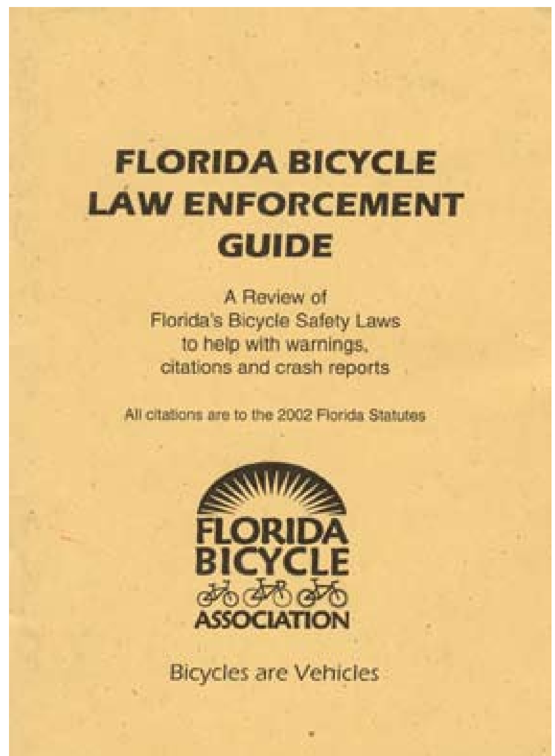
Providing education, training, and reinforcement are key strategies in improving bicyclist and motorist traffic skills and behavior. The primary goal of an educational strategy is to give people both the means and the motivation to alter their behavior and reduce reckless actions and crashes. To implement the strategy, an integrated, multidisciplinary approach that links hard policies (for example, changes in infrastructure) and soft policies (for example, public relations campaigns) and addresses both bicyclists and motorists has the greatest chance of success.

Police enforcement is a primary component in reinforcing proper behaviors and maintaining a safe environment for all modes of travel. Well-publicized enforcement campaigns, combined with public education programs, can be effective in deterring careless and reckless driving and encouraging drivers to share the roadway with bicyclists (and pedestrians). Most importantly, by enforcing the traffic code, police reinforce a sense of right and wrong in the general public and lend credibility to traffic safety educational programs and traffic laws and control devices. Law enforcement officers sometimes find it difficult to "ticket" bicyclists, and even to stop a young child. However, warnings, in lieu of citations, can be effective in deterring inappropriate bicyclist behaviors. The education and enforcement countermeasures covered in this section include:

- Law Enforcement
- Bicyclist Education
- Motorist Education
- Practitioner Professional Education

PHOTO FROM DUVAL COUNTY INJURY PREVENTION PROGRAM OFFICE

A wide range of bicycle safety training programs is available for adaptation. These children are participating in an on-bicycle program in Duval County, FL.



FLORIDA BICYCLE LAW ENFORCEMENT GUIDE

A Review of Florida's Bicycle Safety Laws to help with warnings, citations and crash reports

All citations are to the 2002 Florida Statutes

FLORIDA BICYCLE ASSOCIATION

Bicycles are Vehicles

Law enforcement should play an active role in supporting a safe bicycling environment. Funding for this brochure was provided by sales of a special "Share the Road" license plate (see case study #57).

40. LAW ENFORCEMENT

Along with engineering and education approaches to improving bicyclist safety, enforcement of traffic laws can help to create a safer riding environment, whether this enforcement is directed at the motorist or the bicyclist. With respect to motorists, efforts to reduce speeding in residential areas and along roadways frequented by bicyclists, and to enforce proper yielding, passing and overtaking maneuvers, can make roadways safer places for bicyclists, and also safer for other motorists and pedestrians sharing the roadway. Similarly, efforts to curb running of red lights at intersections will benefit all road users.

PHOTO BY DAN BURDEN

On-bike police officers set a good example and can help to reinforce obedience to traffic laws by communication as well as direct enforcement.

Although law enforcement officers sometimes find it difficult to "ticket" bicyclists, and even to stop a young child, such actions as riding facing traffic, weaving in and out of traffic, ignoring stop signs, and riding without proper lights at night are dangerous, and they can create ill will with motorists. Law enforcement officers can take advantage of the opportunity to stop and educate the offending bicyclist about the importance of obeying traffic laws. It is especially critical that officers enforce any helmet wearing law in effect, in order to increase the effectiveness of the laws.

A judicial program especially targeted to the intended audience can be a key to encouraging greater participation by police in bicycle law enforcement activities. On college campuses, a special "student court" can be set up to address traffic violators, including bicyclists. Young children (and their parents) might be asked to attend a bicycle safety education class in lieu of paying a traffic fine. Typically, the focus of special bicycle judicial programs is on education rather than punishment.

Purposes

- Educate law enforcement officers about factors contributing to bicyclist crashes and about ways they can interact with the public to reduce these factors and ultimately the number of bicycle-motor vehicle traffic crashes.
- Improve cyclists' knowledge, attitudes, and behaviors with respect to safe bicycling.
- Educate the motoring public about their rights and responsibilities when sharing the road with bicyclists.
- Deal effectively with young children as bicyclists.

Considerations

- Because of the many demands placed on law enforcement officials' time, it may be difficult to convince police departments of the importance of officers receiving training in enforcement of laws relating to bicycle safety.
- Although "education" is emphasized over "ticketing," the problem of how to handle young offenders especially can be a roadblock to effective bicycle law enforcement. (See case study #47.)
- Bicycle law enforcement programs are most needed in communities and areas with high levels of bicycling, such as on and around college campuses.

Estimated Cost

The estimated cost for an officer to participate in the two-day Wisconsin officer training course is $90 to $100, with discounts available to sponsoring departments and some training costs covered by the state. If another state wanted to initiate a similar program, there would be startup costs involved, primarily associated with "train the trainer" activities. WE BIKE, the developer of the course, also offers instructor training (see case study #44). NHTSA has recently begun to offer a similar program.

Special educational programs offered to bicyclists in lieu of conviction or traffic court appearances are a form of diversion program since the offender (often a juvenile) is diverted from normal court procedures. Diversion programs have long been used with respect to juveniles, teens, and other special populations. There are a number of examples of bicyclist diversion programs in place across the country, including programs in:

- Corvallis, OR, http://www.bicyclefriendlycommunity.org/press_corvallis.htm
- Palo Alto, CA, http://www.city.palo-alto.ca.us/transportation-division/safe-bicycle-pedestrian-edu.html
- Walnut Creek, CA, http://www.nhtsa.dot.gov/people/outreach/safedige/spring2000/spr00-16.html

A recent article appearing in the International Police Mountain Bike Association newsletter supported increased police enforcement of traffic laws for bicyclists. It states:

> The focus of any bicycle enforcement program should be educational, not punitive. A successful enforcement program should improve a cyclist's knowledge and attitudes, and, most importantly, behavior. A good program also educates the motoring public concerning their rights and responsibilities when sharing the road with bicyclists (see http://www.ipmba.org/printables/case-for-bike-enforcement.PDF).[1]

Although law enforcement officers are trained to make traffic stops for speeding, red light running, and other dangerous behaviors by motorists, they typically do not receive any special training with respect to bicycle safety. It is not surprising, then, that there is very little active enforcement of traffic laws affecting bicyclists in U.S. communities. In the state of Wisconsin, however, the situation is improving because of an innovative training program that is offered upon request to individual police departments. Officers who participate in the two-day Enforcement for Bicycle Safety Course significantly improve both their knowledge and attitudes about enforcement for bicycle safety, and are more likely to make enforcement contacts in their communities (see case study #44).

On a national level, the National Highway Traffic Safety Administration (NHTSA) now offers a similar course entitled "Community Bicycle Safety for Law Enforcement" to provide guidance to officers interested in working with their communities to encourage bicycling and improve bicycle safety. A CD-ROM training course is also under development that may be offered by a training officer or taken via self-instruction on a personal computer. (See http://www.bicyclinginfo.org/ee/enforce_officer03.htm.) Another source of support to law enforcement officers is the Law Enforcement Bicycle Association (LEBA), an organization "run by cops for cops" (http://www.leba.org).

PHOTO FROM AAA

"Cops on Bikes" have a conspicuous presence in the community and may interact with bicyclists and pedestrians more readily.

Trained, adult crossing guards are another fairly benign but effective method of providing correction and education to motorists, bicyclists, and pedestrians, particularly children en route to and from school. Crossing guards educate on safe walking and bicycling behaviors, assist children in crossing at certain locations, and may help to encourage use of these modes in traveling to school since they provide a measure of safety that engineering treatments alone cannot provide. Additionally, well-trained adult guards may assist in enforcing motorist speed limits, yielding, and other laws (through reporting offending motorists). Since 1992, the State of Florida requires most localities to provide minimum training by using the Florida School Crossing Guard Training Guidelines (see http://www.dot.state.fl.us/Safety/ped_bike/training/ped_bike_training.htm).

Finally, NHTSA has compiled a resource guide on laws related to pedestrian and bicycle safety. The guide is available for downloading at http://www.nhtsa.gov/people/injury/pedbimot/bike/resourceguide/index.html.

41. BICYCLIST EDUCATION

Although many of the countermeasures identified in this guide have focused on improving the roadway environment for bicyclists, a comprehensive approach to bicyclist safety encompasses education and enforcement as well as engineering. Not only do bicyclists need safe places to ride, they need to know how to ride skillfully and how to interact safely with motorists on the roadway, whether at intersections or midblock. This is true regardless of the age of the bicyclist. For example, bicyclists can be taught the importance of following traffic rules and regulations, the hazards of riding at night without proper lights, the hazards of wrong-way and sidewalk riding, and other skills and behaviors important to safe riding. Bicyclists can also be trained to be aware of maneuvers motorists tend to make at intersections that can be dangerous for a bicyclist, such as speeding through an amber signal indication or running a red light, turning right on red, making a right turn soon after overtaking a cyclist, etc. Similarly, bicyclists need to be aware of potentially dangerous midblock motorist maneuvers, such as turning across lanes of traffic, turning into or out of a driveway, turning into or out of a parking space, etc.

PHOTO BY LIBBY THOMAS

The BikeEd Hawaii program offers five lessons of on-bike training geared toward teaching safe neighborhood riding skills.

Bicyclist educational programs can be carried out at many levels, from distributing brochures or showing videos to comprehensive school-based on-bike programs, and target audiences can range from young preschool-age children to seniors.

In 1998, the Federal Highway Administration (FHWA) convened a steering group of bicycle safety experts to develop a National Bicycle Safety Education Curriculum.[2] The resulting guide (also available on CD-ROM from NHTSA) identifies and prioritizes the specific topic areas that should be addressed for various target audiences, and includes a resource catalog with information on training programs that address each of the various topics. The Resource Catalog is also available as an online search-

Purposes

- Teach cyclists of all ages safe bicycling skills, including how to interact with motorists in traffic, both at intersections and midblock.
- Teach cyclists the importance of having a bike that fits, maintaining the bike in good condition, and always wearing a helmet when riding.
- Encourage bicycling as part of a healthy lifestyle.

Considerations

- Although many bicycle safety education materials and programs exist, it is important to choose the right program for your particular needs and situation.
- For children, a comprehensive bicycle safety education program should include an on-bike component.
- Available funding, time, space, and teacher education and training are all important considerations when selecting a bicycle safety education program.
- It is also important that once implemented, program effectiveness be evaluated.
- As with other education and enforcement initiatives, a long-term commitment is required, both to reinforce learned behaviors and to accommodate new bicyclists.

PHOTO BY LIBBY THOMAS

Students in the BikeEd Hawaii program practice signalling right turns on neighborhood streets.

able database (http://www.bicyclinginfo.org/ee/fhwa.html). Users can search the database by key word(s), by a specific target audience (e.g., young bicyclists ages nine through 12; adult bicyclists; motorists), and by selected topic or subtopic areas (bicycle-riding skills, rules of the road, essential equipment, riding for health and fitness, etc.) to find an education curriculum that is suited to their needs.

More recently, FHWA has developed a *Good Practices Guide for Bicycle Safety Education* (http://www.bicyclinginfo.org/ee/bestguide.cfm) that contains case study descriptions of 16 programs spanning riders of all ages, along with helpful information on planning, funding, implementing, and evaluating a program in your own community or state.[3]

FHWA's bicyclinginfo.org Web site also contains links to many bicyclist safety education programs, tools and resources that can be used by professionals planning a program as well as by individual bicyclists (http://www.bicyclinginfo.org/ee/index.htm). For example, the section for young cyclists ages nine through 12 contains links to sites with information on choosing the right bike and helmet and how to park and secure your bike, among others. The section for adult cyclists contains links to materials available from the League of American Bicyclists covering areas ranging from "A Guide to Commuting for the Employee" to "How to Shift and Change Gears" to "Bike Maintenance 101." With ready access to these resources, program developers do not need to reinvent the wheel to implement a bicycle safety education program, and young and old riders alike can readily find the information they need to be safer riders.

PHOTO BY LIBBY THOMAS

Specialized equipment helps make on-bicycle training available to more students in this school-based program in a Nevada community.

Estimated Cost

Costs will vary greatly, depending upon the type and scope of the educational activity. Disseminating safety brochures or simply showing a bike safety video will be much less expensive than, for example, a system-wide school-based program that includes on-bike instruction.

Among coalition-provided programs, the Hawaii Bicycling League estimates that Bike Ed Hawaii costs between $23 and $28 per student which provides three instructors per class for a week-long on-bicycle safety and skills training course of approximately 45 minutes per day. All instructor salaries, equipment (fleet of bikes, helmets, safety jerseys), vehicle costs, and a percentage of office support is covered under the Bike Ed budget. Bikes and helmets are replaced every other year. The Oregon Bicycle Transportatiaon Alliance estimates that their Bicycle Safety Education Program, a 7 to 10 day course of 45 to 60 minutes daily involving classroom and on-bicycle training, costs approximately $800 per class (for anywhere from 12 to 30 students). This program also provides instructors (one per class), bikes and helmets, and transportation of the bikes to program sites.

In North Carolina, the Office of Pedestrian and Bicycle Transportation provided $5,000 mini-grants to elementary schools wanting to teach the Basics of Bicycling, an on-bike bicycle safety education program for elementary school age children. The amount covered the cost of trailers for storing and transporting bicycles ($2,000 to $2,500 depending on length); the purchase of 20 to 30 bicycles at $105 to $120 each (a discounted price negotiated with a local bicycle shop); and helmets at a cost of $5 each (recommend purchasing 35 helmets for a class of 30 students, with varying sizes to allow for proper fitting). The program also required some props (traffic signs, bike fronts, etc.), which schools generally made themselves for a minimal cost.

42. MOTORIST EDUCATION

In addition to educating bicyclists about how to ride safely in traffic, it is important that motorists be educated about how to share the road with bicyclists. This is especially important for motorists who are not bicyclists themselves and who may be less familiar with the risks bicyclists face when operating in traffic.

The FHWA Bicycling Safety Education Resource Guide and Database described in the section on Bicyclist Education also contains information on programs and materials for educating motorists.[2] Example topic areas of importance to motorists are communications and sharing the road, the impact of large motor vehicles on bicycles, children's basic riding skills, how to pass groups of bicyclists, and how to operate in the presence of bike lanes.

PHOTO BY DAN BURDEN

Motorist educational materials may include information on the importance of obeying low speed limits in neighborhoods and being alert for child bicyclists who may ride out without yielding.

FHWA's bicyclinginfo.org Web site contains additional tips for educating motorists about cycling, along with links to Web-based resources and materials (http://www.bicyclinginfo.org/ee/ed_motorist.htm). In discussing education programs for motorists, the site urges that emphasis be given to the benefits of sharing the road (safer, more inviting streets, a better environment, etc.), the fact that bicycling is a viable means of transportation, and the bicyclists' right to use the roadway. The Web site also contains links to many bicyclist safety education programs, tools and resources that can be used by professionals planning a program as well as by individual bicyclists. For motorists, there is a section on "Understanding Cyclist Behavior in Traffic" with links to the following materials from the League of American Bicyclists:

- 10 Commandments of Cycling
- Principles of Traffic
- How to Avoid Motorist Errors
- Bike Lanes—What They Are and How They Work
- Riding Right—On the Right
- Driving at Night—Look for Their Lights

In addition to providing information in the form of brochures and other print materials, motorists can also be educated through signs (e.g., reminders to "Share the Road") (see case studies #41, 45, and 47), through information provided on walking or bicycling maps (see case study #51), and through information contained in driver license handbooks. The primary goal of these efforts is to create a safer, more positive climate for cycling among the general motoring public and possibly to recruit additional cyclists.

Purposes

- Educate motorists about how to safely share the road with bicyclists and motivate them to act on this knowledge.
- Promote bicycling among motorists who otherwise might not consider bicycling as a viable transportation mode and a way to be physically active.

Considerations

- The target audience of motorists is much broader than that of bicyclists, and not all may have a positive mindset towards bicyclists. It is important that bicyclists not aggravate the situation by disobeying traffic laws or otherwise not riding responsibly in traffic.
- As with bicyclist education, motorist education requires a long-term commitment.

Estimated Cost

Costs for motorist education programs or initiatives are generally less than those for bicyclist education, especially on-road bicycling instruction. The primary cost is for any print materials and any additional costs associated with updating educational materials (such as the state driver license manual or state driver education program materials).

43. PRACTITIONER EDUCATION

State and local bicycle coordinators and other professionals whose responsibilities include planning, designing, building, and maintaining safe facilities for bicycling need current information upon which to base their decisions and guide their actions. The 1999 American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities* remains the primary resource for bicycle transportation professionals responsible for planning, designing, and building facilities to enhance and encourage safe bicycle travel.[4] The *Manual on Uniform Traffic Control Devices* (MUTCD) also contains guidance with respect to recommended signs and pavement markings for bicyclists and bicycle facilities.[5]

Workshops and other training opportunities can increase effectiveness of professionals involved in bicycle planning, design, engineering, education, or enforcement.

The Association of Pedestrian and Bicycle Professionals (APBP) offers a one-day training course to "bring bicycle and pedestrian professionals up-to-date with the very latest technical information: the AASHTO Guide for the Development of Bicycle Facilities, the MUTCD, TEA-21, and the Uniform Vehicle Code." It also sponsors professional development seminars that provide an opportunity for professionals to discuss specific technical issues in greater depth (http://www.apbp.org/).

FHWA has also developed a training course for graduate and undergraduate transportation planning and design students. The course "provides current information on pedestrian and bicycle planning and design techniques, as well as practical lessons on how to increase bicycling and walking through land-use practices and engineering design" (see http://safety.fhwa.dot.gov/ped_bike/univcourse/pbcrsbroch.htm). The course contains 24 modules that can form the basis for a "stand alone" course or be incorporated into other courses.

Purpose

- Provide transportation planners, designers, and others the training and tools needed to create safer, more inviting environments for bicycling.

Considerations

- Availability of training opportunities, costs to participate, and time requirements are important considerations in efforts to encourage greater professional training. Also, professionals must first be motivated to want to engage in such training.

Estimated Cost

The resources and materials identified in this section are generally available in electronic format at no cost, or can be ordered from their developers at minimal cost.

NHTSA and FHWA have combined to produce the NHTSA/FHWA Bicycle Safety Resource Guide, which contains information about problem areas, bicyclist and motorist errors, target groups, and countermeasures. The resource guide (over 15,000 pages of material), now available entirely on the FHWA Web site, also contains information on facility design, planning, guidelines, good practices, tools and outreach materials to aid in problem identification, countermeasures development and raising awareness (see http://safety.fhwa.dot.gov/tools/docs/welcome_bsg.pdf).

Other initiatives such as Safe Routes to School training programs and even on-bicycle tours for planners and engineers are being used to train practitioners (see case study #9).

SUPPORT FACILITIES AND PROGRAMS

The measures discussed in this section support access to bicycling by providing trip beginning or destination necessities such as bicycling maps for trip planning, secure bicycle parking, showers, lockers and other facilities. To enable longer multi-modal trips, providing access to transit and space for bicycles on transit is also necessary. These measures, plus promotional activities and programs, may help to increase the amount of riding in a community. Support activities or policies can take many forms, some of which naturally fall in line with a comprehensive community program. For example, provision of nice places to ride with wayfinding or destination signs is one way that a community can promote or encourage riding. In addition, special events such as "Bike to Work Days" or mentoring programs help to support bicyclists and encourage new bicyclists to give it a "spin." Other programs may help to raise money to support bicycling.

Specific countermeasures in this section include:

- Bike Parking
- Transit Access
- Bicyclist Personal Facilities
- Bike Maps
- Wayfinding
- Events/Activities
- Aesthetics/Landscaping

PHOTO BY DAN BURDEN

Ramps such as this one in Japan facilitate bicyclists' access to off-street-level parking.

PHOTO BY DAN BURDEN

Transit access expands the reach of bicyclists.

44. BIKE PARKING

Access to secure bike parking is critical to encouraging greater use of bicycles. Without safe and convenient places to park, bicyclists are much less likely to commute to work or school, run errands, and engage in other utilitarian trips by bike. Bicycle parking facilities run the gamut from simple hitching posts installed outside buildings or on downtown sidewalks to covered parking facilities, bike lockers, and full service bike stations.

PHOTO FROM AAA

Bike lockers provide secure parking at this D.C. area metro station.

As with other strategies for promoting bicycling, this is an area where much of the legwork has already been done by others, and helpful guidance is only a mouse-click away on the Internet. The International Bicycle Fund provides helpful information on its Web site, including guidance on locating bicycle parking facilities, choosing the most suitable parking device to install, and publicizing parking once it is available. Properly locating bicycle parking facilities can help reduce bicyclist-pedestrian conflicts and crashes and enhance utility of bike parking. The site also maintains a list of bicycle parking suppliers along with their contact information. See http://www.ibike.org/engineering/parking.htm. *Bicycle Parking Guidelines* from the American Association of Pedestrian and Bicycle Professionals is also available from http://www.bicyclinginfo.org/pdf/bikepark.pdf with guidance on racks and location and design of parking areas.

Another good source of information is the City of Portland's Bicycle Master Plan (http://www.portlandonline.com/shared/cfm/image.cfm?id=40414). The plan describes Portland's assessment of short- and long-term bicycle parking needs and facilities and resulting objective and action items for addressing deficiencies.

Purpose

- Encourage greater use of bicycles by providing secure and convenient parking at destination sites (shopping, schools, libraries, parks, businesses, etc.).

Considerations

- It is important that the right parking equipment be installed for a given location and purpose. In general, the more long-term the parking, the more secure (and expensive) the required equipment. See Web sites in main text for guidance.
- To help determine where parking is needed, look for where bikes are already being parked illegally, and survey bike club members to learn what destinations are most lacking in parking.

Estimated Cost

Costs depend on the type of facility provided. In general, bike racks will cost about $50 to $100 per bike, while bike lockers will cost from $500 to $1,500 per bike. Locker costs can sometimes be offset by charging rental fees, although these should not be so high as to discourage would-be commuters. Employers and businesses can also be encouraged to support bicycle parking facilities, since providing even the best locker facilities is much cheaper than providing motor vehicle parking. (A good Web site for cost information is http://www.bikeparking.com.)

PHOTO BY CHRIS HENRY, CITY OF EUGENE, OR

Convenient parking should be located out of the pedestrian throughway. Demand should be periodically re-assessed.

In general, for meeting short-term parking needs, such as at shopping locations, a sturdy bike rack will suffice. The bike rack should be located near an entrance, in a location that is protected from pedestrian and vehicle traffic but still visible enough to passers-by to increase security. For longer-term parking, such as at transit stations or workplaces, bicycle lockers are generally recommended. In addition to providing safe parking that is protected from the elements, lockers allow bicyclists to leave extraneous gear (helmet, lights, panniers, tool bags, etc.) with their bikes, rather than having to carry it with them.

PHOTO BY PAUL DEMAIO, TRAFFIC CALMING COORDINATOR

A functional U-style rack may still be creative, such as this one in Alexandria, VA.

45. TRANSIT ACCESS

In cities that have bus, light rail or subway service, making these services bicycle-friendly can greatly expand options for bicyclists, allowing them to commute longer distances while also reducing car traffic to and from commuter stations. For buses, the most frequent option is an exterior rack mounted on the front of the bus that can accommodate two bicycles; however, other options exist, including interior bike racks or simply allowing bicyclists to bring their bike onboard an unequipped bus when conditions are not crowded.

PHOTO BY DAN BURDEN

A two-bike, front-mounted bus rack is the most commonly used rack. The driver can see bicyclists mounting their bikes. (Phoenix, AZ)

For rail transit, selected cars are generally equipped with interior bike racks, with the number of racks dependent on demand. During off-peak travel times and on weekends, bikes may be allowed on all cars. Each transit system sets its own policies and rules. In most cases, no additional fee is charged to carry a bike on board.

PHOTO FROM PETER TANNEN

A decal on the outside of the train lets bicyclists know which car to use.

Purposes

- This strategy promotes bicycling by greatly expanding the range of accessible destinations.
- It also promotes transit use, by expanding options for accessing and using transit.

Considerations

- Successful integration of bikes and transit requires a comprehensive approach that begins with an assessment of needs.
- In addition to providing direct access to transit (e.g., via bike racks on buses or in trains), consideration should be given to improving safe and convenient bike access to transit locations and providing secure bike parking facilities at all transit locations.
- Although liability is always a potential concern, at this point there is sufficient accumulated experience and sufficient product safety evidence that it should not be a deterrent to providing bike access on transit.

Estimated Cost

The *TDM Encyclopedia* notes that bicycle racks suitable for buses typically cost $500 to $1,000 for a high-quality model that can carry two bicycles. The Nashua, NH, transit plan developed in December 2003 included an estimate of $1,000 per bike rack, installed.

While somewhat dated, the http://www.BikeMap.com Web site contains a listing of all locations in the U.S. where bikes are accommodated on transit, either on intercity rail, intercity bus, local transit, or ferries (see http://www.bikemap.com/transit/usa.pdf). The site also offers a discussion of why bikes should be linked with transit and offers examples of bikes on transit solutions. In the future, the developer of the site hopes to offer a searchable database where one can type in a location and find information on available bike and transit options.[1]

According to information on the BikeMap.com Web site, the two most active regions of the country for providing bike access to transit are the West Coast states (California, Oregon and Washington), and the Northeast corridor, especially along the Atlantic coast from eastern Virginia to southern Maine. Many cities and local planning authorities have excellent Web sites providing information on available services, maps, hours of operation, fares, etc.

A good example is the Santa Clara Valley Transportation Authority (VTA) in California (see http://www.vta.org/services/bikes.html).

It should be noted that even if bike access on transit (rail or subway) is not an option, transit can still support bicycling by providing lockers or other secure parking at transit stations, as well as providing safe routes to the transit station from nearby residences and destinations.

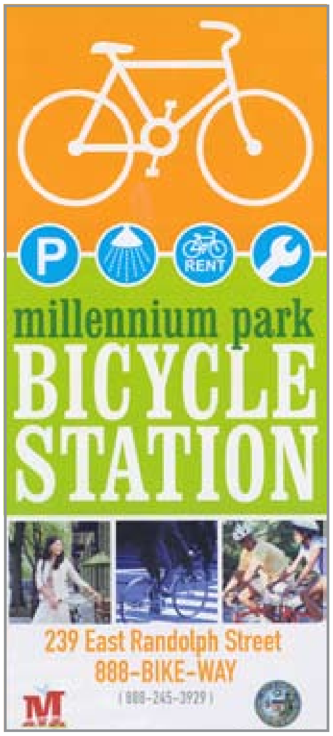
A good resource on this topic is the *Online TDM* [Transportation Demand Management] *Encyclopedia*, maintained by the Victoria Transport Policy Institute (see http://www.vtpi.org/tdm/tdm2.htm). The chapter on bike/transit integration discusses bikes on transit, bicycle parking at transit stops, bicycle access to transit stations, bikes on taxis, and bicycle rentals. It also summarizes available data on how integration of bikes with transit has promoted transit use and provides information with respect to costs and benefits. Another resource is the Pedestrian and Bicycle Information Center (http://www.bicyclinginfo.org/transit/index.htm). Transit Cooperative Research Program Synthesis 62, *Integration of Bicycles and Transit*, is also available online at http://gulliver.trb.org/publications/tcrp/tcrp_syn_62.pdf.

PHOTO BY PETER TANNEN

Bicycle cars on CalTrain may accommodate up to 32 bicycles.

46. BICYCLIST PERSONAL FACILITIES

Along with secure and convenient bike parking and transit access, another prerequisite for encouraging bicycle commuting is facilities for cyclists to shower, change clothes, or otherwise "freshen up" once they arrive at the workplace. Ideally, such facilities will be located on or very near to the worksite premises and will also include lockers for storing clothing and personal items.



More communities and bicycling organizations are developing bike stations as a way of providing facilities for bicyclists in urban areas.

Since constructing showers and locker rooms can be an expensive undertaking, especially for smaller employers, some creative options might be to partner with other nearby businesses to provide facilities, or make arrangements with a nearby health club to allow bicyclists to use its facilities for a nominal fee (which the employer can opt to cover). For larger employers interested in promoting a healthy work force, bicyclists can be given free or discounted use of a company health club or workout facility. Another high-end option is to incorporate changing facilities and bike rental and repair options along with parking facilities, such as is done at the privately operated Bike Station in Long Beach, CA, and other facilities (see http://www.bikestation.org).

At Stanford University in Palo Alto, CA, over 21 percent of the staff bikes to work. Showers are available in several buildings and gymnasiums on campus, and most buildings also have commuter clothes lockers that can be rented for $16 per year. Other "perks" for nonmotorized commuters include a "Clean Air Cash Reward" and a guaranteed ride home in case of an emergency (see http://transportation.stanford.edu/alt_transportation/BikingAtStanford.shtml).

Purpose

- Encourage bicycle commuting by providing places where employees can shower and change clothes once they arrive at the workplace.

Considerations

- Before investing in facilities, employers should take stock of what is already available (both at the workplace and nearby) and survey employees to learn what facility characteristics are most important to them.
- Like other countermeasures included under the general heading of support facilities and programs, this countermeasure is most likely to be successful if combined with other measures that make it easier or more attractive to bicycle to work. Examples include bike parking (especially bike lockers), cash incentives or other rewards, and bike to work days.

Estimated Cost

Costs will be highly variable depending upon the level of existing resources and the type of facility provided.

47. BIKE MAPS

Bike maps can be a useful tool for helping bicyclists get around in a new or unfamiliar riding environment, whether seeking a different route for getting to their destination, exploring a new section of town, or negotiating another city or town while on a vacation. Bike maps come in many shapes and sizes, from small "strip maps" designed to fit in the pocket of a front pannier so they can be read while riding, to larger fold-out maps looking much like a traditional road map. They can be statewide maps, regional, or local.


ILLUSTRATION FROM NCDOT

Detail of Raleigh, NC, bike map.

There are two primary types of bike maps: route maps, which indicate preferred roadways for bicyclists, and suitability maps, which are more like regular maps, but with the roadways coded (through the use of colors, dashed or dotted lines, etc.) based upon their relative safety or attractiveness to bicyclists. Both types can be extremely beneficial to bicyclists (and even non-bicyclists simply looking for the best way to negotiate a new city environment).

A well-designed bike map is typically in high demand and can serve many functions. In addition to showing the best route for getting places, bike maps often contain information or advertising for a variety of resources including a calendar of bike events, locations of bike shops, points of interest in the community, laws and local ordinances pertaining to bicycles, and safety tips for the rider and motor vehicle driver. Thus, a good bike map can be a tool for promoting bicycling as well as for educating and informing riders and motorists.

Purposes

- Encourage and enable bicyclists to ride in new environments.
- Assist bicyclists in selecting appropriate roadways for their skill level.
- Provide safety tips for bicyclists as well as motorists.
- Inform bicyclists about available resources within a community, region, or state.

Considerations

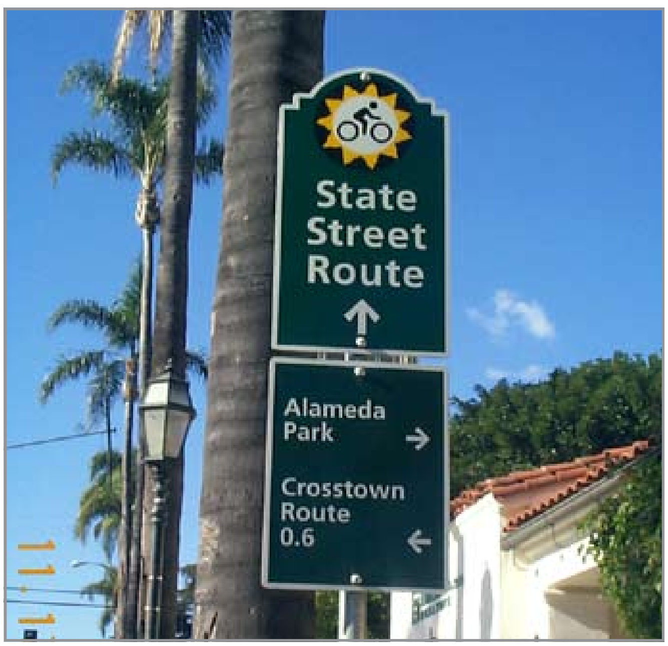
- Computer mapping capabilities have greatly reduced the costs involved in producing attractive bike maps, and today many bike maps may be downloaded from the Internet. Still, care must be taken in recommending specific routes for bicyclists. For suitability maps, care must be taken in developing guidelines and a rating system for distinguishing among the various roadways their suitability for bicycling.

Estimated Cost

The primary cost lies in the development of the map. In North Carolina, cost for the trip-tics (strip maps) for the original "Bicycling Highways" maps were minimal — just ink and paper. Recent updates include digitizing the information, undertaken by a consulting cartographer at an average cost of $1,000 per segment for two-color artwork. The four-color map/brochures for county route systems, produced by outside cartographers and graphic designers, cost $20,000 for production and about $.50 for each printed copy. Urban maps produced by outside cartographers and graphic designers have ranged from $30,000 to $60,000 for production and $.34 to $.78 per copy for printing. These costs do not reflect staff time spent in administering the projects, developing routes, coordinating with local committees, preparing text, or reviewing and proofing the product throughout the production process.

48. WAYFINDING

Wayfinding pertains to directional signs, distance markers, posted maps, information kiosks and other aides for getting people places. In their broadest application, wayfinding systems help all road users (including motorists and pedestrians as well as bicyclists) find their way in a city. For example, as part of its downtown improvement efforts, the City of Atlanta is developing a wayfinding sign system that will include uniform geographically oriented maps, signs, and kiosks designed to serve all modes of transportation accessing the area (see http://www.atlantadowntown.com/CapAdidInitiatives_Wayfinding.asp). Another example is the City of Seattle, which has been awarded a three-part Federal Transit Administration (FTA) grant to design and implement a downtown wayfinding system. When completed, the system will include kiosks, signs, maps, and a Web site "to enhance everyone's ability to navigate the Center City and find destinations whether by foot, transit, bicycle or car" (see http://www.ci.seattle.wa.us/dclu/CityDesign/DesignLeadership/Conn_n_Places/).



Wayfinding signs help bicyclists navigate or discover new routes to common destinations.

Wayfinding systems can also be more narrowly focused. For example, Contra Costa County in California is working to develop a wayfinding system to guide pedestrians and cyclists in and around its Bay Area Rapid Transit (BART) system station, and many communities with well-defined bike networks are looking to wayfinding signs both to publicize their system and to help people access and use it. When placed along bike trails or routes, wayfinding signs typically include easy-to-read arrows pointed toward specific nearby destinations and distances to these destinations. A frequent location for such signs is where a bike path may cross or intersect with a roadway—the sign both informs the bicyclist and alerts passing motorists and pedestrians of the existence of the bike path.

Purposes

- Provide travel information (nearby destinations, directions, distances) to users of a given pathway or facility.
- Publicize the existence of a bicycle network.
- Make it easier for people to find and access bicycle facilities.

Considerations

- Wayfinding projects can be carried out at many levels; however, it is important that a systemwide approach be taken so that different signs, maps, information kiosks, etc. do not appear in different parts of a city, thereby confusing rather than enlightening users.
- Web sites containing wayfinding information are becoming more important.

Estimated Cost

Estimated costs will be variable, depending on the nature and scope of the system being developed. More elaborate kiosks and map postings will be more expensive depending on materials and installation costs.

49. EVENTS/ACTIVITIES

Special bicycle events and activities lie at the heart of bicycle promotion. They reinforce the efforts of current bicyclists and seek to attract new bicyclists to the fold. Sample events include bike to work days, fun rides, bicycling competitions or races, trail openings, commuting help lines, and "short courses" on how to ride in traffic. Bicycling can also be promoted at health fairs as part of a more active and healthy lifestyle and at environmental events like Earth Day as a form of transportation that is good for the environment.

Many of these events are planned by local, state, or national advocacy groups and are just one part of a larger plan to promote increased bicycling for transportation as well as recreation, fun and fitness. For example, the Chicagoland Bicycle Federation hosts an annual car-free "Bike the Drive" Sunday. In 2002, over 16,000 bicyclists participated, taking over the city's famous Lake Shore Drive (see http://www.bikethedrive.org/). During the months of May and June, the Chicago Mayor's Office of Special Events helps sponsor over 100 separate events promoting the health, economic and environmental benefits of bicycling as part of its annual Bike Chicago.

"Bike to Work" days are well-established events in many communities. They typically draw a mix of established and first-time commuters and can be combined with other activities such as competitions, "how to ride in traffic" workshops, and breakfast gatherings. The events raise community awareness of bicycling as a legitimate mode of transportation, bring cyclists together, and, ideally, convert some participants to regular bike commuters.

Also included under the general topic of supporting activities and programs are efforts to raise community awareness of and support for bicycling and investment in bicycling facilities and activities or safety. Two example case studies are included: (1) a program that used financial incentives to encourage developers to build higher-density neighborhoods near transit stations, thus increasing the opportunity for bicycling, and (2) a special vehicle license plate program that serves as a source of sustained financial support for improving bicycle safety (see case studies #57 and 58).

Purposes

- Promote bicycling through support programs and activities.
- Help to establish bicycling as a legitimate form of transportation.
- Help attract people to bicycling.

Considerations

- The primary consideration for this countermeasure is deciding what type of promotional event or activity to conduct. Factors impacting this decision include the target audience to be reached by the event, level of community support, the membership and goals of the sponsoring organization(s), available funding, and even weather conditions.

Estimated Cost

Estimated cost will vary depending on the particular event or program selected, the scope and time frame for the event, level of volunteer involvement, etc. As an example, the total cost of a Bike to Work promotion held in Hartford, CT, in 2002 was just under $12,500, which covered the costs of food, two advertising banners, a brochure, a payroll insert, signs on buses, T-shirts, and a bicycle to raffle (see case study #53).

50. AESTHETICS/LANDSCAPING

Well-designed and well-landscaped bicycle facilities can be an important attraction, especially for the recreational bicyclist. Whereas bicycle commuters will typically choose routes based upon their directness and safety, recreational riders are more likely to be drawn to routes that are aesthetically pleasing and where they feel comfortable riding. The aesthetic of the riding environment is also of critical importance to attracting new riders—an individual is much more likely to try commuting to work if his route takes him along an attractively maintained greenway or roadway than along an unkempt, urban street.

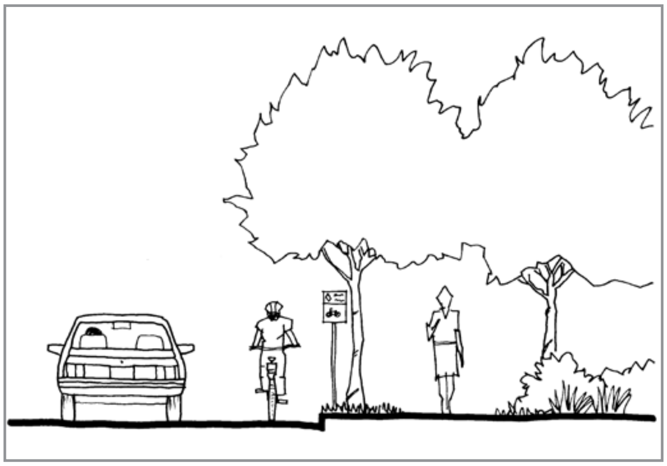


ILLUSTRATION BY A.J. SILVA

Aesthetics are an integral part of building a livable, bikeable, and walkable community. Streets and bicycle facilities that are well-designed and well-maintained, buffered from traffic, attractively landscaped, and that are either a destination in their own right (e.g., a popular off-road trail in a park) or that connect popular destinations (e.g., houses with shopping, neighborhoods with schools) will attract bicyclists.

PHOTO FROM ITE PEDESTRIAN BICYCLE COUNCIL

Downtown areas can be appealing bicycling locations.

Purposes

- The primary goal in designing and building aesthetically pleasing bicycle facilities is to create an attractive environment—not only for bicyclists, but for everyone.
- By building such environments, one hopes to encourage more people to bike for recreation, fitness, and trip-making.

Considerations

- Landscaping is integral to good design. It is important for the overall aesthetics of a project, but also the day-to-day safety, operation and maintenance of the project.
- The services of a landscape architect or other professional may be beneficial in planning and building a facility that is aesthetically pleasing and that contributes to the overall goal of a livable community.

Estimated Cost

Estimated costs will vary widely, depending on the specific type of facility, its location, original conditions at the site, the overall scope and timeframe for the project, availability of volunteer labor, etc.

Well-designed and landscaped facilities are also easier to maintain, lead to fewer safety and security problems, and are more likely to be supported by the neighborhoods and businesses they access.

PHOTO BY DAN NABORS

Shoreline Park bike path in Santa Barbara, CA, provides an off-road option connecting a park with a business district.