TRAFFIC CALMING
Do's and Don'ts to Encourage Bicycling

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INTRODUCTION

Traffic calming is the term applied to a variety of physical measures intended to reduce the dominance of automobile and truck traffic in urban areas. Traffic calming measures can be applied as spot improvements to treat an existing problem, such as speeding, or along a corridor to create a bicycle-preferential street, often called a bicycle boulevard. Traffic calming does not attempt to ban the automobile, but primarily to reduce the speed of automobile traffic. In some applications, traffic calming measures are employed to reduce the volume of "through" or non-neighborhood traffic on certain streets. Aiming for one of these goals usually has the desirable side effect of achieving the second goal as well as discouraging (but not preventing) the use of the automobile altogether.

In the past, when communities implemented traffic calming, the impacts on bicycling were often never considered. Any benefits to bicycling happened by chance and sometimes negative impacts were experienced instead. Bicycling and traffic calming, however, can be quite compatible. Many bicyclists prefer streets with few cars and slower traffic, which are qualities of a traffic-calmed street. If care is taken to select traffic calming strategies that do not impact bicyclists negatively, then bicyclists can also reap many benefits from the project.

It is reasonable to treat bicyclists differently from automobile traffic when designing traffic calming plans because:

- Most residents do not consider bicycle traffic on their streets a nuisance or hazard in the same way as they do automobiles.
- Many bicyclists prefer to ride on streets where automobile traffic is light, such as those that have been traffic-calmed.
- Many cities would like to actively promote bicycle travel as an environmentally sound method of transportation.

It should also be noted that traffic calming can be implemented specifically to encourage bicycling, as does the famous bicycle boulevard in Palo Alto. This paper first describes the concept of a bicycle priority street and how it can be realized through traffic calming strategies. It then describes bicycle-compatible traffic calming measures that can be implemented with the primary goal being either neighborhood traffic management or the creation of a bicycle priority street. Finally, this paper identifies measures that should be used as little as possible or never. This last category of measures adversely affects bicyclists in some way, and since bicyclists are legally allowed on every local street, these measures are to be discouraged.

BICYCLE PRIORITY STREET

As originally conceived in Palo Alto, California, a bicycle boulevard is a roadway where bicycle traffic has right-of-way priority over intersecting streets, and periodic full-width barriers discourage through motor vehicle traffic. It can be viewed as the exchange of a traffic-calming device unfriendly to bicycles–STOP signs–for another friendly to bicycles (if designed correctly)–traffic barriers.

Bicycle boulevards can be created on residential streets on which traditional bicycle facilities, such as bike paths and bike lanes are unsuitable. Bicycle boulevards confer traffic calming benefits on residents and pedestrians as well as on bicyclists who do not necessarily live in the neighborhood. Many bicyclists already use such residential streets, but their utility is often significantly decreased by STOP signs at nearly every intersection. The boulevard does not have to be a single straight route; it may combine several turns to better serve bicyclists' likely destinations.

Creating Bicycle Priority Streets Through Traffic Calming

Bicycle priority streets, as described in this paper, provide bicyclists with three advantages that usually do not exist simultaneously in the current street network:

- A low traffic volume alternative where bicycles and motor vehicles can share the roadway without conflicts;
- Significantly reduced travel time since bicyclists on the route are granted the right-of-way at as many intersections as possible. This is usually accomplished by converting four-way STOP signs to two-way stops or switching two-way STOP signs to stop the cross street rather than the bicycle priority street.
- A route where two or more bicyclists can safely ride side-by-side. This increases the attractiveness of bicycling to families

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and other cyclists who enjoy conversing during their transport just as motorists and pedestrians do.

Traffic calming strategies are needed to prevent the diversion of motor vehicle traffic to the bicycle priority street. Although the original concept in Palo Alto employed two motor vehicle barriers, an extension of the boulevard showed that forced turn channelization and traffic circles can also work to discourage through auto traffic. Portland has established a bicycle boulevard on Lincoln Street, an important link between Mt. Tabor Park and residential neighborhoods, using traffic circles and barriers. In fact, as this paper will discuss, a whole arsenal of bicycle-compatible traffic calming measures is available for use on bicycle priority streets. These measures vary considerably in the level of traffic restriction. The selection of specific measures can be tailored to provide exactly the degree of traffic control needed at the location where each is placed while minimizing interference with important vehicle turning movements.

Criteria for Bicycle Priority Streets

Since a bicycle priority street eliminates most STOP signs for through traffic, traffic calming measures are usually needed to prevent it from attracting motor vehicles as well as bicycles. Measures may also be needed to prioritize the preferred bicycle movements such as left or right-turns. As a rule, the primary goal of traffic calming measures on a bicycle priority street is either access control or speed control. Access control need be implemented at only a few points, spaced as widely as half a mile apart, while speed control measures to achieve one or the other of these goals are usually effective only in their own immediate vicinity.

Streets that are candidates for conversion to bicycle priority streets should meet the following criteria:

- The route should reduce delays to the bicyclist by assigning the right-of-way to travel on the route.
- The route should appeal to casual bicyclists by being located on streets with low traffic volumes.
- The route should appeal to experienced bicyclists by being as direct and fast as possible.
- The concept should have the support of residents.
- On low volume streets (less than about 2000 vpd), motor vehicle access should be restricted only enough so that autos are not diverted from other streets onto the bike route.
- Intersections with major streets are or could be controlled by traffic signals.

GUIDELINES FOR BICYCLE-COMPATIBLE TRAFFIC CALMING MEASURES

Since bicyclists in most states are permitted on all roadways except designated freeways, and therefore everywhere that traffic calming might be used, traffic calming measures should always, at a minimum, be safe for bicyclists. This paper discusses traffic calming measures that are not only safe but that can also be used effectively to bicyclists' benefit, for instance, on bicycle priority streets. Other measures that are incompatible with or potentially harmful to bicyclists, or neither helpful nor harmful, are listed at the end of this paper.

Design features are usually the most successful approach because they are self-enforcing while police enforcement is usually a short-term service whose benefits end when the police leave. It is also common for installations to implement several measures in combination.

The following sections discuss strategies for calming motor vehicle traffic that are compatible with bicycling .

1. Changes in Elevation

Speed Humps - Speed humps, also called pavement undulations or road bumps, are raised areas extending across the pavement surface, typically 3 to 4 inches high and 12 feet long in the direction of traffic flow. They are not the high, narrow speed bumps sometimes used in private parking lots and driveways, which traffic engineers do not recommend on city streets. Speed humps are used in numerous California cities.

Speed humps are meant to cause discomfort to occupants of vehicles that exceed the design speed, and are usually installed in a series of two or more. Improperly designed, speed humps and all speed bumps are dangerous for bicyclists. They can damage the wheels or frame, or can knock the bicyclist down. Fortunately, properly designed speed humps, with gentle approach and exit gradients, flush leading edges, and smooth surfaces, do not seem to pose a significant hazard to bicyclists. British government research found that 92 percent of users of two-wheeled vehicles had no trouble crossing 0.1-meter (4-inch) humps. The California Traffic Control Devices Committee's *Subcommittee Report on Pavement Undulations* found that bicyclists may experience loss of control at speeds approaching 20 mph for a 4-inch hump, or 25 mph for a 3-inch hump. The report found no problem at speeds of 15 mph or less. Also, ITE has published a recommended practice for the use of speed humps.

With one exception–hills–bicyclists are unlikely to exceed 25 mph on residential streets, and few will exceed 20 mph. Thus, both 3-inch and 4-inch humps are likely to be safe for bicyclists, although the 4-inch hump should probably be used with caution where bicycle traffic is frequent or rapid. Humps can be tapered near the curb or have cuts in them to allow bicyclists to bypass them, although this practice is not strictly necessary and can encourage

gutter-running (driving with one wheel in the gutter) by motorists. It is also important to ensure adequate warning signs and markings. The circumstance when bicyclists can exceed 25 mph is on hills. Bicyclists who inadvertently approach a hump at high speed might risk serious injury. It is also possible that a hump could cause a slow bicyclist to lose control on a steep uphill grade. The City of Oakland, California will install speed humps only on residential streets and only on streets with grades less than 5 percent. Speed humps are normally used only on local streets–usually residential streets, although Portland, Oregon has tested a 22-foot long speed hump for use on collector streets. Since 1988, the City of Palo Alto, California has experimented with 3-inch high humps on several residential streets. The humps do not appear to impede or pose a hazard to bicycle travel. Speed humps should be located far enough from intersections that turning cyclists are no longer leaning when they encounter the hump. Finally, maintenance should ensure that raveling of the hump's edge does not produce irregularities, gaps, or debris that could impede or endanger bicyclists.

Speed Tables - A flat-topped hump is called a speed table; its length in the direction of travel is much greater than that of a conventional hump. Speed tables, usually distinctively paved, are often used at pedestrian crosswalks, where they must extend curb to curb and no cyclist bypass is possible. Otherwise, considerations for and benefits of speed tables are the same as those for speed humps and for textured surfaces.

Raised Intersections - A raised intersection is similar to a speed table, but extends across the full width of an intersection on all four approaches. Raised intersections have been used extensively in Europe for residential traffic management, and occasionally in the United States in shopping areas. As with speed humps and tables, the approach and exit gradients should be gentle, and the surface should be smooth but not slippery.

2. Roadway Narrowing

Lane Narrowing - Restriping of roadways to provide fewer lanes or narrower lanes can create enough room for a bike lane or a curb lane wide enough for bicyclists and motorists to share comfortably. For instance, Seattle, Washington has restriped some streets from four lanes to two plus a two-way left turn lane and bicycle lanes. At the same time, fewer or narrower lanes may tend to reduce vehicle speeds. Such modifications can be viewed either as the roadway being restriped to accommodate bicycles, or as bicycle lanes being used as a means to calm traffic. However, narrowing lanes that bicycles and motor vehicles are forced to share a lane less than 14 feet wide is not bicycle compatible and should not be considered.

Traffic Circles - (See Figure 1) Small traffic circles, also called mini-roundabouts or speed control islands, have been used with great success in Seattle's Neighborhood Traffic Control Program, where they are installed at the request of citizens. Located at the center of an intersection in place of STOP signs or traffic lights, traffic circles both narrow the roadway and force motorists to change direction. They may also produce the visual impression of a dead-end street, at least to strangers.

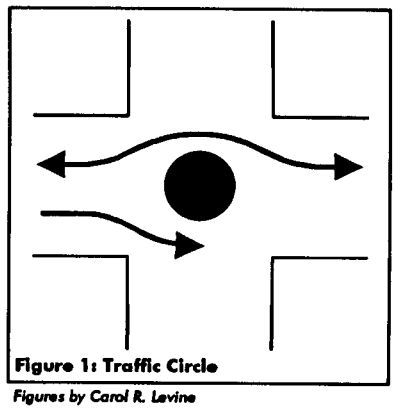

Figure 1: Traffic Circle

Figures by Carol R. Levine

The bicyclist's objection to all these means of narrowing the roadway is the same. Unless the narrowing is substantial and frequent, any reduction in vehicle speed is usually small. At the same time, the narrow lanes tend to squeeze motorists and bicyclists together. To avoid this conflict, the roadway should remain wide enough for lane-sharing - about 12 feet or wider, depending on traffic volume; otherwise additional traffic calming techniques should be used along with the narrowing, or a cyclist bypass should be provided if geometry permits.

Of all the roadway-narrowing measures, small traffic circles seem to be the most comfortable for bicyclists. This may be because they inherently combine several traffic-calming techniques; because they do not create a competition for the remaining space; or because they are often used on roadways that already carry relatively little traffic. In addition, the elimination of STOP signs that they make possible is highly beneficial to bicyclists. They are not, however, free of controversy. Some bicyclists object to the complication and confusion of turning and crossing movements, the decreased clearance between bicyclists and cross traffic, and the danger of left-turning motorists who shortcut the circle clockwise to avoid traveling counterclockwise three quarters of the way around it. In addition, bicyclists would be better served by stopping the side street traffic in order to give travel on the street in question the right-of-way. This is especially true if the side street has significant traffic volumes. Traffic circles used in conjunction with two-way STOP sign controls should, therefore, be considered.

A well-designed traffic circle employs a small size and sharp deflection at entry to force entering traffic to slow drastically and to continue slowly around the circle. A small triangular island at the entry can force a right turn, eliminating shortcuts, and also provides a pedestrian refuge.

3. Restricted Movements

Road Closures/Traffic Barriers/Cul-de-Sacs (See Figure 2) - As used here, "road closure" refers to closing a road at a single point, either at an intersection (creating a cul-de-sac) or midblock (creating two cul-de-sacs). The closure is usually accomplished by installing a barrier, whose design can vary from an asphalt berm to a set of posts or bollards to a sculptured and landscaped island to a full cul-de-sac with curb and gutter. These designs differ in

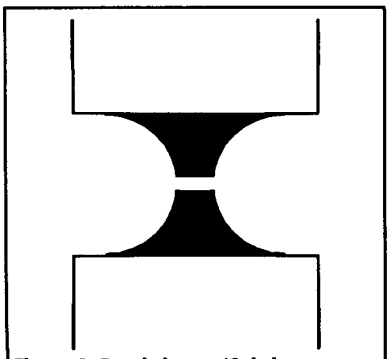

Figure 2: Road closure/Cul-de-sac

cost, appearance, and ease of maintenance but not in basic functionality.

Traffic barriers are sometimes called diverters, since when traffic is blocked from one street it does not usually disappear, but is instead diverted to another nearby street. This paper uses the term "barrier" for a device that blocks movement completely, and reserves "diverter" for a device that restricts some movements, usually the through movement, but allows other traffic to continue. Many California cities have installed traffic barriers, notably Berkeley and Palo Alto, to prevent commute traffic from cutting through neighborhoods. Barriers are the most extreme traffic calming measure, and are, of course, highly successful in reducing traffic volume and speed near the installation point. Barriers also tend to be highly controversial and are unpopular with some citizens since they restrict access for residents and visitors as well as outsiders.

Barriers can create two kinds of problems for bicyclists:

- They often eliminate bicycle access as well as motorized vehicle access. This is primarily a matter of barrier design. If the barriers are constructed with bicyclists in mind, they can continue to allow unrestricted bicycle access.

- Because motorists look in directions where they expect to see other motorists, they fail to anticipate bicyclists who suddenly enter an intersection across or through a barrier. This problem is primarily a matter of barrier placement. It can be avoided with proper placement and with notification to either bicyclists or motorists that they must yield.

In order to prevent these potential problems as well as potential neighborhood opposition, exceptional attention must be paid to the selection of a location for barriers as well as the details of the design and placement.

Barrier Design - Every barrier should have a gap or opening to allow bicycle passage. To allow for trailers and adult tricycles, the gap should provide a clear width of at least 5 feet (California Highway Design Manual, Topic 1003.1), although as little as 4 feet can be workable. The practical maximum is 5 feet 6 inches, set by the width of an automobile. On a two-way street this clear width should be provided for each direction of bicycle travel, either by two separate approximately 5-foot openings or a single approximately 10-foot opening in the center, divided by a concrete block or a 4-inch diameter, 4-foot high locking barrier post. The single opening has the advantage that it can allow passage of emergency vehicles.

The barrier itself should be liberally identified, as appropriate, with single white or yellow reflectors, diagonal reflector arrays, edge reflectors, and reflective tape or paint. The upper half of posts should be wrapped diagonally with parallel stripes of orange and white reflective tape for maximum visibility day and night, and a 2-by-10-foot envelope should be painted on the pavement around the post.

Plantings on landscaped barriers or closures should not obstruct sight lines, and should minimize the shedding of leaves, seeds, fruit, or nuts onto the roadway.

Barrier Placement - The relevant principle is that on the far side of a barrier, bicyclists should not immediately encounter cross traffic at intersections or driveways. This means that full barriers should not be placed directly at intersections, but set back at least 50 feet from any cross street or business driveway. (Fifty feet is a reasonable stopping distance, including reaction time, for a bicyclist traveling at 15 mph.) With some designs and at some locations, it may be necessary to prohibit on-street parking or to trim foliage to provide adequate sight lines. This placement also ensures that bicyclists who are leaning to turn onto a street with a barrier have a chance to return to an upright position by the time they encounter the barrier, and therefore to pass through the barrier safely.

Half Closures (See Figure 3) -A half-closure is defined as a road closure at a single point but across only half its width. This is almost always done at the street entrance, allowing traffic to exit but blocking it from entering and creating a *de facto* one-way street for one block (except for traffic that originates within the block). Where the half closure includes a bypass for bicycles to enter, the result resembles a contraflow bike lane without that design's inherent disadvantages.

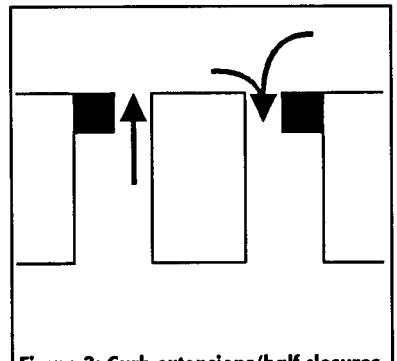

Figure 3: Curb extensions/half closures

The same design considerations for bicycles apply to half closures as to full closures, although a half-width barrier needs only one opening. The preferred location at a street entrance is satisfactory, since there is no conflict with cross traffic on the far side of the barrier.

Half closures have the advantage of greater flexibility in placement than full closures. Although they can be physically violated by motorists fairly easily, the rate of violation would probably still be relatively low, since motorists must consciously decide, for example, to enter a one-way opening. By the same token, they offer easy passage to emergency vehicles.

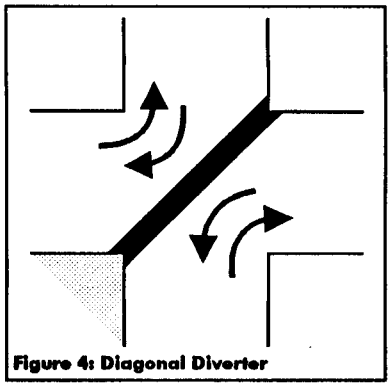

Figure 4: Diagonal Diverter

Diagonal Diverters (See Figure 4) - A diagonal diverter is a barrier placed diagonally across the full width of an intersection, creating two L-shaped streets touching but not connected at the corners. Diagonal diverters also used in Berkeley, California; Eugene, Oregon; and Seattle, Washington.

Diverters may be less objectionable to motorists than barriers, but they can be unsatisfactory to through bicyclists, who (depending on the diverter geometry and bicyclist maneuver) may be exposed to unsuspecting cross traffic on both sides of the diverter. Since they function only in intersections, there is no flexibility in diverter placement. The design should therefore provide an opening that is both wide enough for passage and long enough in the direction of travel to create a refuge: 6 feet for a bicycle, or 10 feet for a bicycle plus trailer. This length can most easily be provided if the diverter is constructed as a tapered island or as a permanent landscaped closure, although it can also be created by a double row of bollards.

Since the purpose of the diagonal diverter is to track most of the traffic into a forced right- or left-turn, it is suggested that bicycles allowed through the diverter be required to yield to on-coming traffic on the other side, either motor vehicle or bicycle.

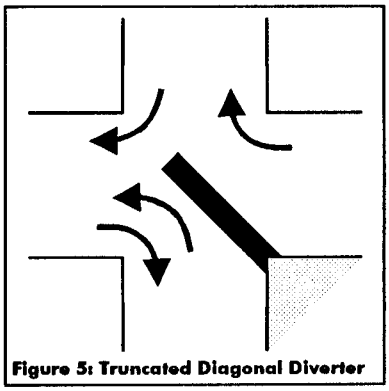

Figure 5: Truncated Diagonal Diverter

Truncated Diagonal Diverters (See Figure 5) - As used in Seattle, one end of the diagonal diverter does not extend fully to the corner, permitting right turns as well as left turns on one of the four streets, while continuing to prevent all through movements. It would be possible to vary the design even further to widen this gap, permitting left turns as well as right turns on the intersecting street, or to provide gaps at both ends, creating a kind of diagonal median barrier. These may need to be used in conjunction with STOP signs to assign right-of-way to certain movements.

Median Barriers - Median barriers are currently used in virtually every city on major arterials, where they separate opposing directions of traffic and prevent left turns to and from minor streets. For traffic management purposes, short median barriers can also be placed at intersections to prevent through movements. These barriers differ from the median islands discussed above under "Roadway Narrowing". Median islands are placed along the traffic-calmed street to narrow it, while median barriers are placed perpendicular to it along the centerline of the cross street to prevent traffic from entering or continuing. (A single barrier can serve both purposes on intersecting streets.) The usual median barrier permits right turns and prevents left turns, but design modifications can add one or two of the four possible left turns according to need. To accommodate bicyclists, the barrier must have a bicycle bypass (or two, depending on design). If it crosses a busy uncontrolled intersection, it is best designed as an island that includes a bicycle refuge.

Forced Turns - Traffic can be forced to turn right rather than continue straight by a pork-chop shaped island, similar to the familiar type used for free right-turns, but extending further to the left to block through travel. It is easy to incorporate a bicyclist bypass around or through the island. With some geometries it might be possible to force left turns as well - for instance, offset intersections, turns from one-way streets, and turns from the right arm of a T intersection.

Unlike diagonal diverters and median barriers, this method leaves the interior of the intersection clear. The right-hand curb radius may need to be increased to accommodate the forced turn, and large trucks may not be able to negotiate it.

4. Coordinated Traffic Lights - This strategy is usually thought of as facilitating traffic flow, not calming it. It is usually employed to enable traffic to travel at a higher average speed than it could without coordination. But coordinated traffic signal timing also removes any advantage for motor vehicles to travel faster than the speed for which the traffic signals are timed. Of particular relevance to bicyclists is that a signalized arterial could be coordinated for bicycle speeds rather than motor vehicle speeds. This has been done in Portland, where downtown streets are timed at 14 mph. Air quality impacts should be minimal as motorists will quickly learn the optimal travel speed to avoid excessive idling. Supplemental signing posting the speed for which the signals are timed would shorten the learning curve.

5. Other

Irregular or Textured Surfaces - Brickwork or pavers of various colors, shapes and patterns can be used to set off a crosswalk, the entrance to a pedestrian area, or the entire area itself. The warning is primarily visual, although motorists may notice mild noise or vibration. For bicycle safety, the surface should be free of steps, longitudinal or diagonal grooves, or other irregularities that could cause a fall, should not be slippery or become so when wet, and should not be so rough that it causes an uncomfortable ride. These concerns are not a problem with some common designs. Any proposed use of such textured pavements should be done in consultation with the area bicyclists.

Reduced Corner Radii

Reduced corner radii can slow the speed of turning traffic. They are most likely to be useful on a bicycle priority street in combination with other measures that operate midblock. But they can also be useful in making junctions with on- and off-ramps safer for bicyclists. The elimination or redesign of right-turn channelization pork chop islands would also slow turning traffic if the curb radii were also reduced.

BICYCLE-COMPATIBLE SUMMARY OF MEASURES

Assuming that the design guidelines just described are observed, the most bicycle-compatible traffic calming measures are the following:

- Speed humps, speed tables, and raised intersections can produce small but consistent speed and volume reductions, but only in their immediate vicinity.
- Traffic circles are acceptable on streets whose volume is already fairly low, and moderately effective in reducing both speed and volume.
- Road closures (traffic barriers) are the most effective of all traffic calming measures.
- Half closures are less intrusive, offer greater flexibility in placement, and allow emergency vehicles to pass.
- Forced turn channelization can be highly effective if existing geometry permits it to be used, and is less coercive than road closures. It is a good substitute for diagonal diverters.
- Median barriers, like half closures and forced turns, prevent through vehicular movements but can be configured to permit other movements. If there is significant uncontrolled cross traffic, the median can include a bicycle refuge.
- Traffic signals can be coordinated for a speed suitable to bicycle travel, e.g. 8-15 mph.
- Textured surfaces have little effect by themselves, and would be most useful as a visual cue to reinforce more restrictive design features.
- Reduced corner radii slow traffic and, therefore, improve safety at intersections.

MEASURES NOT RECOMMENDED

The following measures are not recommended as traffic calming techniques in general as other measures described elsewhere can provide the same effects. They should never be used on a bicycle priority street (except, of course, warranted STOP signs - which may be needed at major intersections.

Meandering Roadways - Tend to cause erratic movements by motorists and increased travel distances for bicyclists.

Chicanes - tend to force motorists and bicyclists into a narrow space, and thus are appropriate only where traffic volumes are very low (<1,000 vpd).

STOP Signs - used as traffic calming devices dramatically increase delay to bicyclists unnecessarily.

Rumble Strips - pavement indentations that warn motorists also cause a very uncomfortable ride for bicyclists , which can lead to steering difficulties, loss of control, and falls.

MEASURES THAT SHOULD BE USED WITH CARE

The following measures can be effective but care must be taken not to adversely bicyclists.

Curb Extensions - also known as bulbouts, narrow the roadway usually to two narrow lanes. This results in less room for motorists and bicyclists to share, but benefits pedestrians by reducing crossing width and increasing visibility. They are acceptable as long as 14 feet of travel lane width remains for bikes and cars to share.

Median Islands - are used to provide a refuge for pedestrians and/or reduce roadway width. By continuing a median through an intersection, they also restrict access to a street. By retaining adequate curb lane width (14 feet minimum) and providing curb cuts, they can be made compatible with bicycling.

Turn Restrictions - are usually used to prevent motor vehicle traffic from diverting onto side streets during peak hours or from increasing the congestion at certain intersections. In either case, bicyclists should be exempted from turn restrictions as long as turns can be made safely.