APPENDIX A

BICYCLE BOULEVARD DESIGN GUIDE

Sections of this guide that have been updated or added since the 2017 Bike Plan are noted accordingly.

WHAT IS A BICYCLE BOULEVARD? *(New Section)*

A bicycle boulevard is a roadway that has been modified, as needed, to enhance safety and convenience for people bicycling. It provides better conditions for bicycling while maintaining the neighborhood character and necessary emergency vehicle access. Berkeley's bicycle boulevards are intended to serve as the primary low-stress bikeway network, providing safe, direct, and convenient routes across Berkeley.

TYPICAL APPLICATION

- Parallel with and close to major thoroughfares (1/4 mile or less).
- Follow a desire line for bicycle travel that is ideally long and relatively continuous (2 to 5 miles).
- Avoid alignments with excessive zigzag or circuitous routing. The bikeway should have less than 10% out-of-direction travel compared to the shortest path of primary corridor.
- Local streets with traffic volumes of:
  - 20 mph = 1,000 - 2,000 ADT (average daily traffic)
  - 25 mph = 500 - 1,500 ADT,

  as well as less than 50 vehicles per hour in the peak direction at peak hour.

DESIGN FEATURES

- In addition to pavement markings and signs, bicycle boulevards must include features to enhance safety.
- Implement volume control treatments based on the context of the bicycle boulevard, using engineering judgment. Pay special attention to school zones to ensure bicycle boulevards are designed for low-speed and low-volume during all times of the day, and especially during pick up and drop off times.
- Intersection crossings should be designed to enhance safety and minimize delay for bicyclists, following crossing treatment progression to achieve Level of Traffic Stress 1 or 2 (see page A-21).

FURTHER CONSIDERATIONS

Bicycle boulevard retrofits to local streets are typically located on streets without existing signalized accommodation at crossings of collector and arterial roadways. Without treatments for bicyclists, these intersections can become major barriers along the bicycle boulevard and compromise safety.

Traffic calming can deter motorists from driving on a street, as well as help to maintain or establish low volumes and discourage vehicle cut through/speeding. Anticipate and monitor vehicle volumes on adjacent streets to determine whether traffic calming results in unintended and inappropriate volumes on arterial or collector streets adjacent to the bicycle boulevard. Traffic calming can be implemented on a trial basis.

Key elements of bicycle boulevards are unique signage and pavement markings, traffic calming features to maintain low vehicle volumes, and safe and convenient major street crossings.

CRASH REDUCTION

In a comparison of vehicle/bicyclist collision rates on traffic-calmed side streets signed and improved for cyclist use, compared to parallel and adjacent arterials with higher speeds and volumes, the bicycle boulevard was found to have a crash reduction factor of 63%, with rates two to eight times lower when controlling for volume (CMF ID: 3092[1]).

CONSTRUCTION COSTS

Costs vary depending on the type of treatments proposed for the corridor. Simple treatments such as wayfinding signage and markings are most cost-effective, but more intensive treatments will have greater impact at lowering speeds and volumes, at higher cost.

1 Crash Modification Factors Clearinghouse, "Install Bicycle Boulevard", (2011).

Elements of Bicycle Boulevards

DISTINCT VISUAL IDENTITY

Unique pavement markings and wayfinding signs increase visibility of bicycle boulevard routes, assist with navigation, and alert drivers that the roadway is a priority route for people bicycling.

Bicycle Boulevard Pavement Markings (Source: RB Landmark)

SAFE, CONVENIENT CROSSINGS

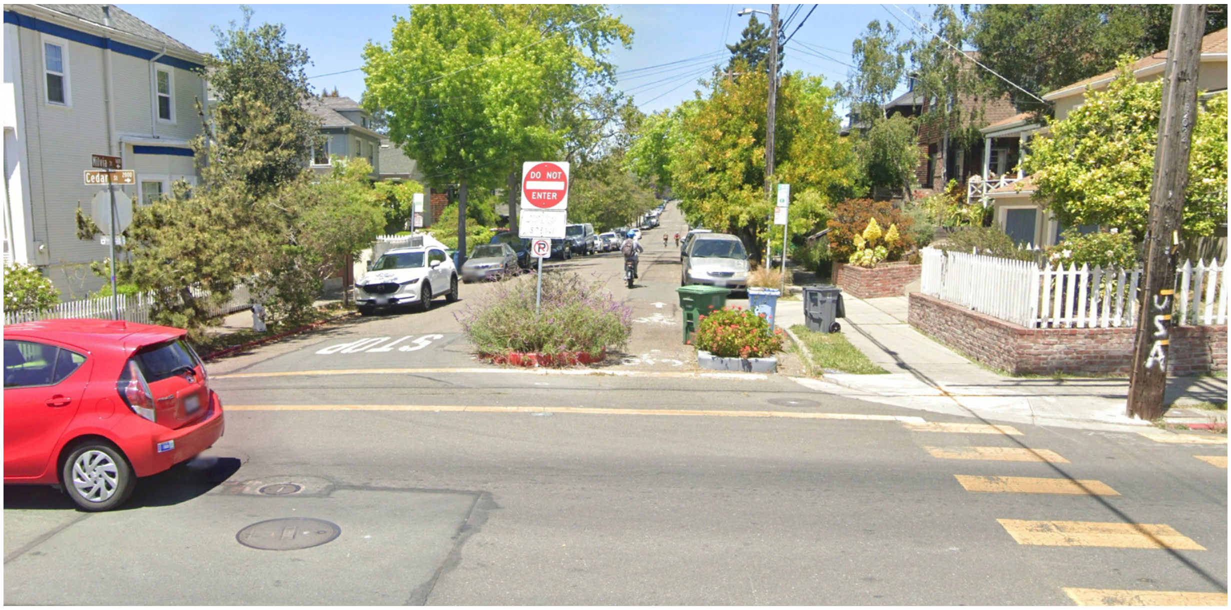
Traffic controls, warning devices, and separated facilities at intersections facilitate safe and convenient crossings of major streets along the bicycle boulevard network.

Example of a traffic control sign at an intersection.

Example of a separated bike lane approaching an intersection.

BICYCLE PRIORITY

Traffic calming treatments such as traffic circles, speed tables, diverters, and chicanes, sometimes in place of existing stop signs, can help prioritize bicycle through-travel and discourage cut-through motor vehicle traffic.



Diverter at Milvia Street and Cedar Street in Berkeley (Source: Google Earth)

Design Needs of Bicyclists *(New Section)*

The facility designer must understand how bicyclists operate and how their bicycle influences that operation. Bicyclists, by nature, are much more affected by poor facility design, construction, and maintenance practices than motor vehicle drivers.

By understanding the unique characteristics and needs of bicyclists, a facility designer can provide quality facilities and minimize user risk.

BICYCLE AS A DESIGN VEHICLE

Similar to motor vehicles, bicyclists and their bicycles exist in a variety of sizes and configurations. The most common devices people ride in urban bikeways fit into one of these four categories:

- **Mini devices:** Electric and non-electric scooters, skateboards, rollerblades, and other devices under 20 inches wide that typically ride or roll upright on small wheels. This typically includes people who use wheelchairs and personal mobility devices in bikeways
- **Typical bikes:** Electric and conventional upright bikes and tricycles, as well as recumbent bikes, hand cycles, and any wheeled devices up to 2.5 feet wide. These are the most common bikeway users and a typical bike is the conventional design vehicle for bikeways.
- **Cargo bikes:** Electric and conventional bikes, tricycles, or any other wheeled device between 2.5 to 3 feet wide that has an extended wheelbase or is pulling a trailer.
- **Extra-large bikes:** Large freight tricycles, pedicabs, and other devices wider than 3 feet, and typically up to 4.5 feet wide. In addition to the design dimensions of a typical device the minimum and preferred rideable widths, shown below, ensure that each device type has enough space to operate within a bikeway.

Minimum and Preferred Rideable Widths

CONTROL DEVICE	ONE-WAY BIKE LANE: MINIMUM RECOMMENDED*	ONE-WAY BIKE LANE: PREFERRED	TWO-WAY BIKE LANE: MINIMUM RECOMMENDED*	TWO-WAY BIKE LANE: PREFERRED
Mini Device Widths cannot be less than a typical bike	6 feet	7-8 feet	8-10 feet	11-13 feet
Typical Bike Device width up to 2.5 feet	6 feet	7-8 feet	8-10 feet	11-13 feet
Cargo Bike Device width up to 3 feet	6.5 feet	8-9 feet	9-11 feet	12-14 feet
Extra-Large Bike Device width up to 4.5 feet	7 feet	11.5-12.5 feet	12-14 feet	15-17 feet

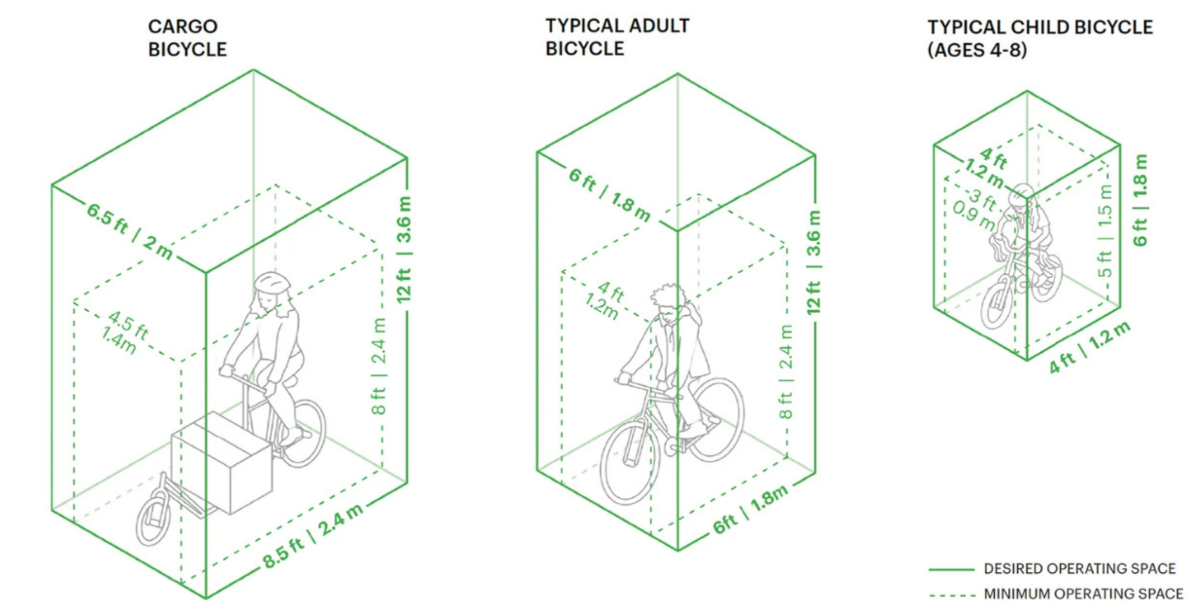
* Side-by-side riding and passing are not accommodated in minimum widths. Refer to NACTO's *Designing for Small Things With Wheels* publication for further design guidelines.

Design Speed Expectations

BICYCLE TYPE	FEATURE	TYPICAL SPEED
Upright Adult Bicyclist	Paved level surfacing	8-12 mph*
	Crossing	10 mph
	Downhill	30 mph
	Uphill	5-12 mph
E-Bike	Paved level surfacing	18 mph
Recumbent Bicyclist	Paved level surfacing	18 mph

* Typical speed for casual riders per AASHTO 2013.

Bicycle Rider - Typical Operating Dimensions



Source: NACTO *Design Controls for Bicycle Facilities*, Adapted from Urban Bikeway Design Guide 3rd Edition

02

TRAFFIC CALMING FEATURES

Speed Table at Milvia Bicycle Boulevard (Source: City of Berkeley)

Traffic calming may include elements intended to reduce the speeds of motor vehicle traffic to be closer to bicyclist travel speeds, or include design elements that restrict certain vehicle movements and discourage motorists from using bicycle boulevards as cut-through corridors.

Traffic calming treatments can cause drivers to slow down by constricting the roadway space for more careful maneuvering. Such measures may reduce the design speed of a street, and can be used in conjunction with reduced speed limits to reinforce the expectation of lowered speeds. They can also lower vehicle volumes by physically or operationally reconfiguring corridors and intersections along the route.

Typical Application

- City should study feasibility of implementing a posted target speed of 20 mph, allowable via AB 43. Use traffic calming to pursue a design speed of 20 mph (25 mph maximum). Traffic calming on bicycle boulevards will be implemented according to direction from the City Council regarding public notification and engagement thresholds.
- Pursue a 1,500-cars-per-day maximum. Bikeways with daily volumes above this limit should be considered for traffic calming measures.

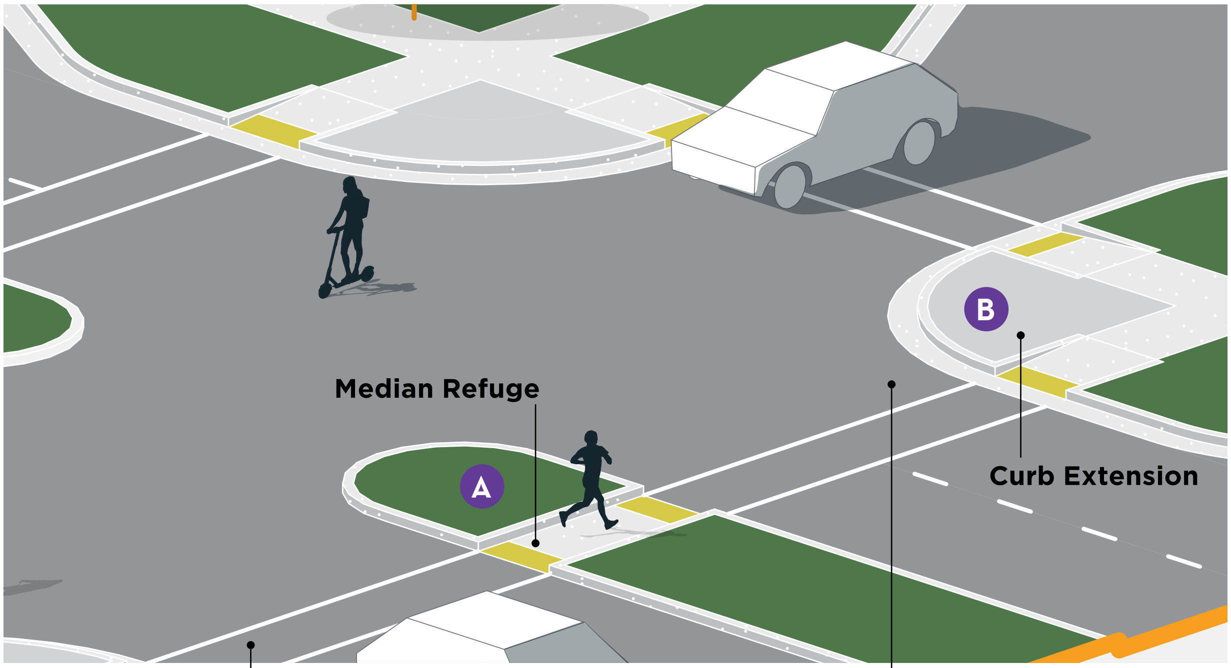
Design Features: Speed Management

A Median islands in the center of the roadway create a pinchpoint for vehicles and offer shorter crossing distances for pedestrians when used with a marked crossing.

- Chicanes slow drivers by requiring vehicles to shift laterally through narrowed lanes, while preserving sightlines.

B Pinchpoints, chokers, or curb extensions restrict motorists from operating at high speeds on local streets by visually and physically narrowing the roadway.

- Neighborhood traffic circles reduce vehicle speed at intersections by requiring motorists to move cautiously through conflict points. Traffic circles can be landscaped but must be maintained to preserve sightlines.
- Street trees narrow a driver's visual field and create a consistent rhythm and canopy along the street, which provides a unified character and facilitates place recognition.
- Speed tables slow drivers through vertical deflection. Leave a gap between the table and the curb to have less impact on stormwater drainage.



Pedestrians can cross one lane or one direction of traffic at a time, wait on the refuge for traffic to clear in the other direction, and then continue crossing.

Narrows the crossing distance.

SPEED TABLES *(New Section)*

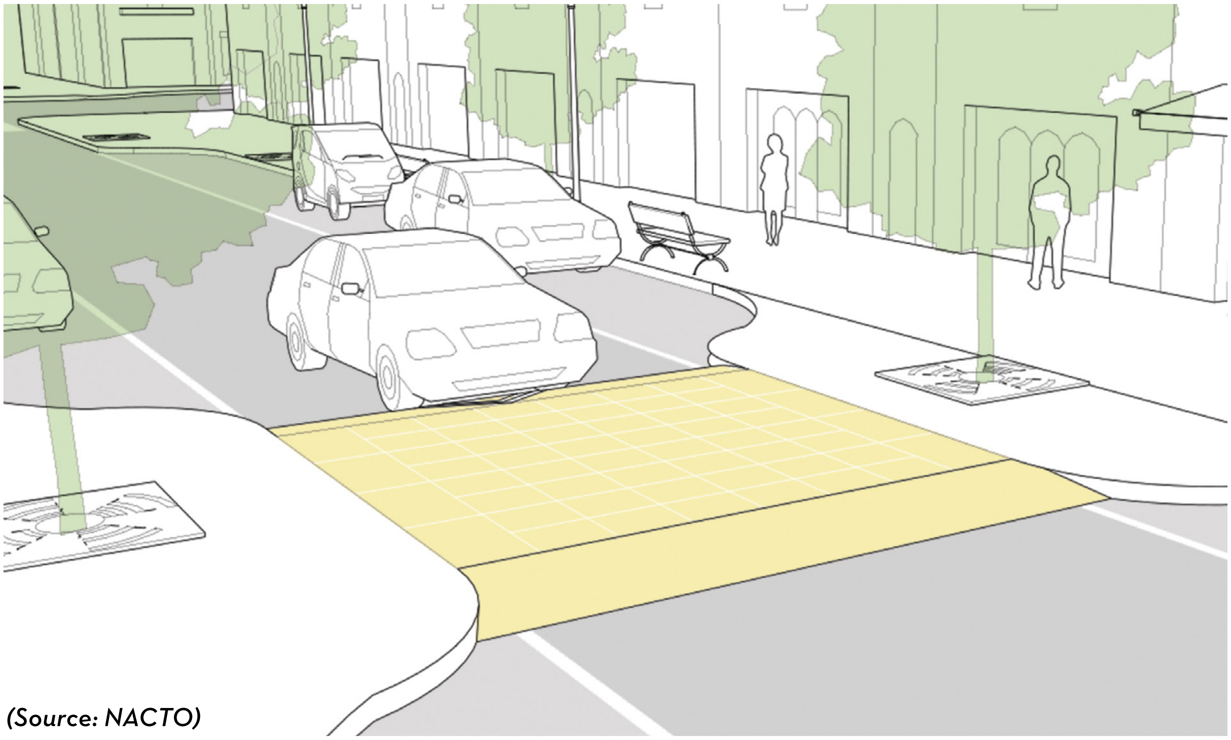
Speed tables are midblock traffic calming devices that raise the entire wheelbase of a vehicle to reduce its speed. Speed tables are longer than speed humps and flat-topped, and can be used on collector streets and transit and emergency response routes.

Placement Criteria

Minimum one speed table per block; can exceed this minimum consistent with the guidelines below:

- Speed tables located no further than 500 feet from another speed table in the same block.
- Speed tables located no closer than 50 feet from the nearest back of crosswalk.
- Speed tables must be placed so as not to interfere with residential or commercial driveways.

Multiple cities in the Bay Area have recently adopted standards for speed cushions as an alternative to speed tables. A speed cushion incorporates two wheel cutouts to allow large vehicles to pass through unaffected while still imposing traffic calming effects on regular passenger vehicles. Speed cushions can benefit operations for emergency responders, trash collectors, and transit operators while still providing traffic calming benefits. Speed cushions also allow a path of travel for people riding bikes or scooters which avoids the vertical deflection and discomfort of traveling over the speed cushion. Speed cushions are not currently an approved device by the City of Berkeley; any future implementation of speed cushions should include close coordination with the Berkeley Fire Department to develop design specifications that work with their vehicles while still achieving traffic calming goals.



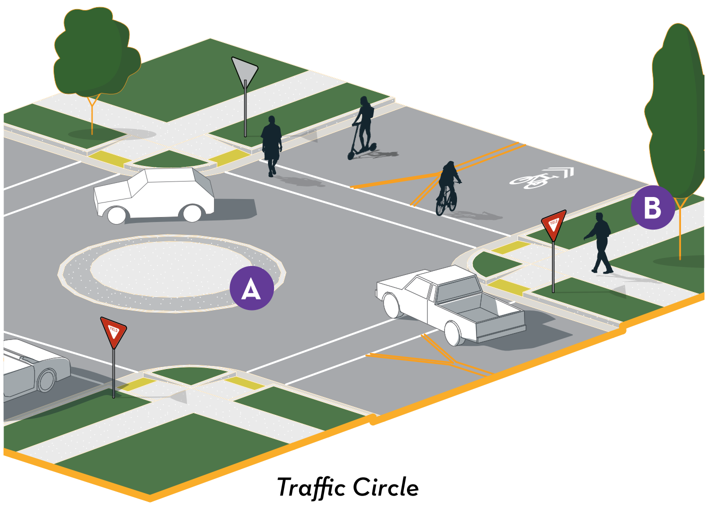
(Source: NACTO)

TRAFFIC CIRCLES *(Updated Section)*

Traffic circles are a type of horizontal speed management typically installed along low-speed, low-volume streets, and bicycle boulevards. They are raised islands located in the center of intersections that narrow the roadway and require motorists and bicyclists to reduce their speed in order to navigate around.

Purpose

- Slowing vehicle through- and turn-movements.
- Discouraging non-local or cut-through traffic.
- Reducing turn-movement conflicts between bicycles and vehicles.
- Facilitating movements and reducing conflicts at intersections of two bicycle boulevards.
- Providing opportunities for neighborhood greening/landscaping and potential green infrastructure.



Traffic Circle

Typical Application

- An effective traffic calming tool on bicycle boulevards and low-speed, low-volume bicycle routes.
- Often installed to replace stop signs at intersections along a bike boulevard.
- Should be installed in consultation with neighborhood residents and emergency vehicle operators.
- Traffic circles feature raised curbs and/or mountable aprons to provide access for emergency vehicles.
- Approaches can feature mini channelization islands or pavement markings to further narrow the roadway and delineate travelways.

A The visual footprint of the traffic circle can be expanded in the intersection with integral colored pavement, or visually patterned surface treatments.

B Traffic circles can be landscaped but must be maintained to preserve sightlines.

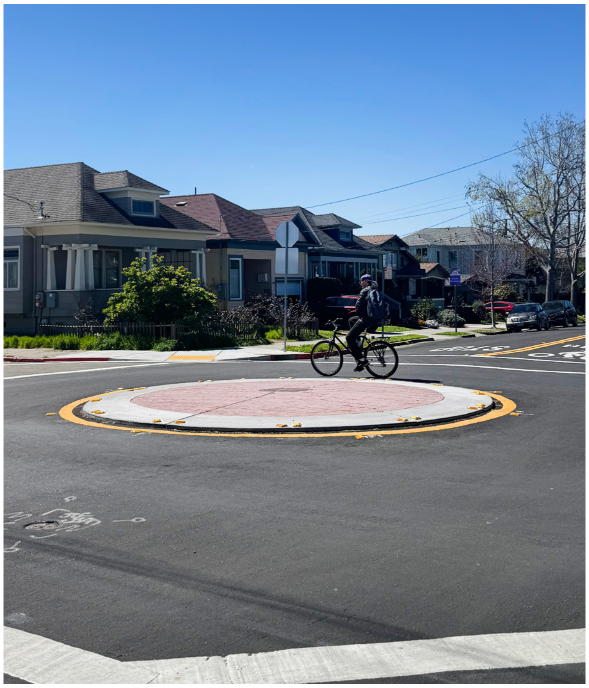
Design Features

- Multiple traffic circles in series at adjacent intersections may not be needed due to the incorporation of speed tables, and should be avoided if there is not a strong justification.
- Traffic circle radius depends on roadway width, and curb radii, to provide adequate horizontal deflection.
- Consider including a vertical element to traffic circles
- Individual intersections should be assessed based on the above criteria to determine whether through-/turn-movement conflicts or adjacent destinations are a factor.

PLACEMENT CRITERIA

Traffic circles may be considered at any residential street along a bicycle boulevard, but particularly at:

- Intersections of bicycle boulevards and local streets with higher traffic volumes.
- Locations near a collector or arterial street intersection without nearby diversion—to discourage non-local or cut-through traffic.



Fully Mountable Traffic Circle at Virginia Street and McGee Street (Source: City of Berkeley)

Vegetated Traffic Circle at Prince Street and King Street in Berkeley (Source: City of Berkeley)

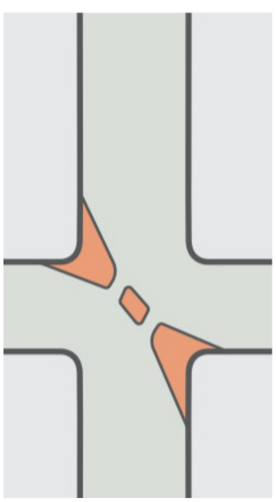
TRAFFIC DIVERTERS *(Updated Section)*

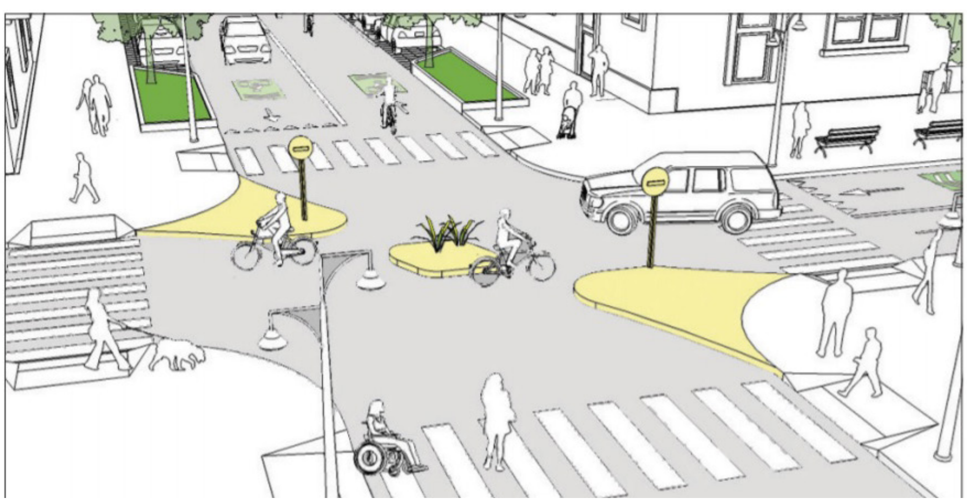
Traffic diverters are an effective traffic volume management tool that allow bicycles and emergency vehicles to proceed through an intersection, but restrict all other vehicle through-movements (requiring vehicles to turn right). Traffic diverters are installed on local roadways designated as bicycle boulevards.

Typical Application

- Traffic diversion reduces vehicle volumes on bicycle boulevards.
- Existing non-landscaped traffic diverters without cut-throughs can be retrofitted to allow through-access for bicycles and emergency vehicles.
- Traffic diverter designs should be developed in consultation with neighborhood residents and emergency vehicle operators.
- Design and neighborhood outreach processes should inform the type and precise location of diverters, with consideration given to traffic volume, and the direction of the diversion, with the goal of routing motorized traffic to the nearest collector or major street.
- Design and placement should consider potential impacts to evacuation routes

Full Diverter at Berkeley Way and Trader Joe's (Source: City of Berkeley)





Diagonal Diverter (Source: NACTO)

Purpose

- Slowing or eliminating vehicle turn-movements.
- Discouraging non-local or cut-through traffic on bicycle boulevards, which are intended as low-volume streets.
- Reducing turn-movement conflicts between bicycles and vehicles.
- Providing opportunities for neighborhood greening/landscaping and potential green infrastructure.
- When placed as median intersections, diverters offer pedestrian and bicycle crossing refuges.

Design Features

- Traffic diverters can be landscaped to enhance the overall attractiveness of the bike boulevard.
- Colored concrete pavers and visually dramatic striping should be used to further delineate the diverter from the roadway, and reinforce the vehicle turn restriction.
- At-grade curb cuts, or mountable curbs, provide convenient access for bicycles.
- Bollards, stanchions, and remaining metal and concrete "staples" on existing traffic diverters should be removed. These obstacles pose a crash hazard to cyclists. They can be replaced with small, properly designed median islands.

PLACEMENT CRITERIA FOR MAJOR STREET CROSSING

At major street crossings, diverters are designed as median crossings.

Two configurations for median islands are described below:

- Approach islands, which require "right-in/right-out" turn-movement restriction, but allow left turns from the main street into the side street (bike boulevard); sometimes used in conjunction with pedestrian hybrid beacon (PHB) or traffic signal. **See illustration B on the next page**.
- Approach islands, which require "right-in/right-out" turn-movement restriction, while also prohibiting left turns from the main street into the side street (bike boulevard); typically used alone or in conjunction with rectangular rapid flashing beacon (RRFB). **See illustration C on the next page**.

PLACEMENT CRITERIA FOR RESIDENTIAL NEIGHBORHOOD STREETS

At residential street intersections, a partial, full, or diagonal diverter may be considered:

- Minimum one diverter per bike boulevard segment between collector or arterial street crossings.
- May not be necessary if diversion has been provided at collector or arterial street crossings along a particular segment.

Design Features: Volume Management

A **Partial closure diverters** allow bicyclists to proceed straight across the intersection but require motorists to turn left or right. All turns from the major street onto the bikeway are prohibited. Curb extensions with stormwater management features and/or a mountable island can be included.

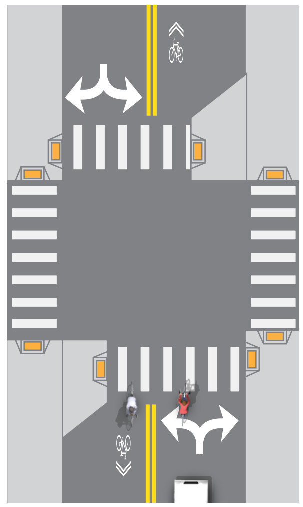
B **Right-in/right-out diverters** require motorists to turn right while bicyclists can continue straight through the intersection. The island can provide a through bike lane or bicycle access to reduce conflicts with right-turning vehicles. Left turns from the major street onto the bikeway are prohibited, while right turns are still allowed.

C **Median refuge island diverters** restrict through and left-turn vehicle movements along the bikeway and provide a refuge for bicyclists to cross one direction of traffic at a time. This treatment prohibits left turns from the major street onto the bikeway, while right turns are still allowed.

D **Full/diagonal diverters** block all motor vehicles from continuing on a neighborhood bikeway, while bicyclists can continue unrestricted. Full closures can be constructed to preserve emergency vehicle access.

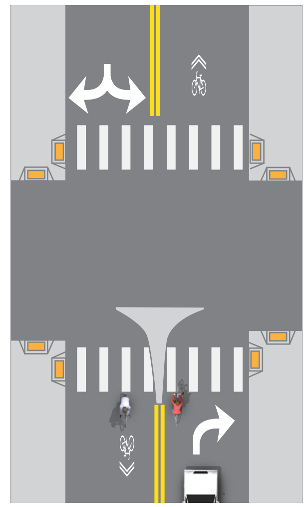
Traffic Calming Treatments to Reduce Motor Vehicle Volumes

A



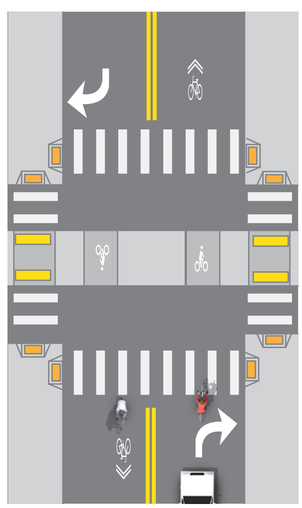
Partial Closure Diverter

B



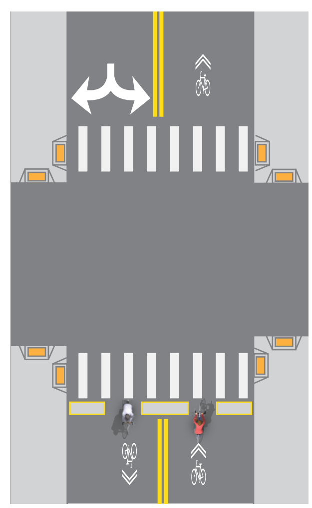
Right-In/Right-Out Diverter

C



Median Refuge Island Diverter

D



Full Diverter

Field Examples of Traffic Diverters

Partial Diverters (See illustration A on page 15)

Older Installation with Concrete Barrels at Wheeler and Ashby (Source: City of Berkeley)

Newer Installation at Cedar and Milvia (Source: City of Berkeley)

Full Diverters (See illustration D on page 15)

Older Installation with Concrete Barrels at Fulton and Ashby (Source: City of Berkeley)

Newer Installation at Berkeley Way and Trader Joe's (Source: City of Berkeley)

Diagonal Diverters

Older Installation at Virginia and Acton
(Source: City of Berkeley)

Newer Installation at Virginia and McGee
(Source: City of Berkeley)

Newer Installation at Roosevelt and Channing
(Source: City of Berkeley)

03

BICYCLE BOULEVARD CROSSING TREATMENTS

Safe Crossing Recommendations

The following are recommendations to inform future design. All projects will comply with design requirements established by the CA MUTCD, PROWAG, and other relevant guidelines.

Major street crossings are a critical piece of the bicycle boulevard network. One of the three goals for bicycle boulevards is to "develop a network of efficient routes for bicyclists," which means reducing the number of times that a cyclist must stop along the route, and improving the ability to cross major intersections.

Many bicycle boulevard corridors are low stress within the neighborhood until a person on a bicycle must cross a major street such as Sacramento Street or San Pablo Avenue. These high-stress crossings are barriers to getting more people to bicycle; a single high-stress crossing point along an otherwise low-stress bicycle boulevard route can be a major deterrent to use.

The following are recommendations to inform future design. All projects will comply with design requirements established by the CA MUTCD, PROWAG, and other relevant guidelines.

The treatment progression table on the following page provides guidance on the appropriate crossing treatment to achieve a suitably low-stress experience for users on the bicycle boulevard network.

Table 1: *Uncontrolled Crossing Treatment Progression Table*

CROSSING TREATMENT	TRAFFIC VOLUMES (ADT)[1] VERY LOW	LOW		MEDIUM		HIGH	
Cross Street	Up to 3 lanes	Up to 3 lanes	4 or 5 lanes	Up to 3 lanes	4 or 5 lanes	Up to 3 lanes	4 or 5 lanes
Marked Crossing	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4
All-way STOP[2]	LTS 1	LTS 1	LTS 2	LTS 2			
Median Refuge Island[3]	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
Median with RRFB[3]	X	LTS 1	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3
Pedestrian Hybrid Beacon (PHB)[4]	X	X	LTS 1	LTS 1	LTS 1	LTS 1	LTS 1
Traffic Signal	X	X	X	LTS 1	LTS 1	LTS 1	LTS 1

1: Very Low: 0-1,500; Low: 1,501-5,000; Medium: 5,001-12,500; High: >12,500
2: Requires meeting a CA MUTCD STOP warrant before implementation
3: Minimum 6-foot-wide median to meet LTS benefit
4: Subject to successful warrant analysis

Definitions:

X: No additional benefit

Black: Not advisable or not applicable

LTS: Level of Traffic Stress, with LTS 1 or 2 ideal for low-stress crossings. See the "Low-Stress Bicycling and Network Connectivity" study at https://transweb.sjsu.edu/research/Low-Stress-Bicycling-and-Network-Connectivity for detailed discussion of LTS. For more information, see Berkeley Bicycle Plan 2017 Appendix C Level of Traffic Stress

This plan contains, as proposed projects, multiple RRFB locations that were designed, approved, and funded prior to the update of the Unsignalized Crossing Treatment Progression Table (**Table 1**). In each of these instances, design efforts were made to incorporate additional traffic calming elements (such as curb extensions or raised crossings) to supplement visibility, safety and comfort for crossing users.

In the years following the adoption of the 2017 *City of Berkeley Bicycle Plan*, City of Berkeley staff have been able to validate the effectiveness of recommended crossing treatments for different types of cross streets on the bicycle boulevard network. Through implementation and public feedback, the City learned residents felt uncomfortable with the application of RRFBs on busier streets, instead preferring median crossing islands. The Unsignalized Crossing Treatment Progression Table has been subsequently updated to keep in line with observed results, best practices, and updated standards and guidelines for the City of Berkeley. These changes can be summarized as:

- No stand-alone use of RRFBs. RRFBs should either be implemented in tandem with a median crossing or should include other traffic calming features such as raised crosswalks or curb extensions. This reduces crossing distances and improves visibility.
- Use of an All-Way STOP sign as stand-alone option for local street intersections, collector street intersections, and minor arterial intersections that are no more than three lanes of travel. The intersection must meet a CA MUTCD STOP warrant before being considered for this treatment.
- Consider the feasibility of using median crossings as diverters for the bicycle boulevard route, whether paired with RRFBs or PHBs. The City of Berkeley has developed designs for median crossings that divert vehicle traffic off bicycle boulevard routes while still permitting through movements by emergency vehicles.

Examples of existing bicycle boulevard crossing treatments throughout the City of Berkeley can be found on the following pages.

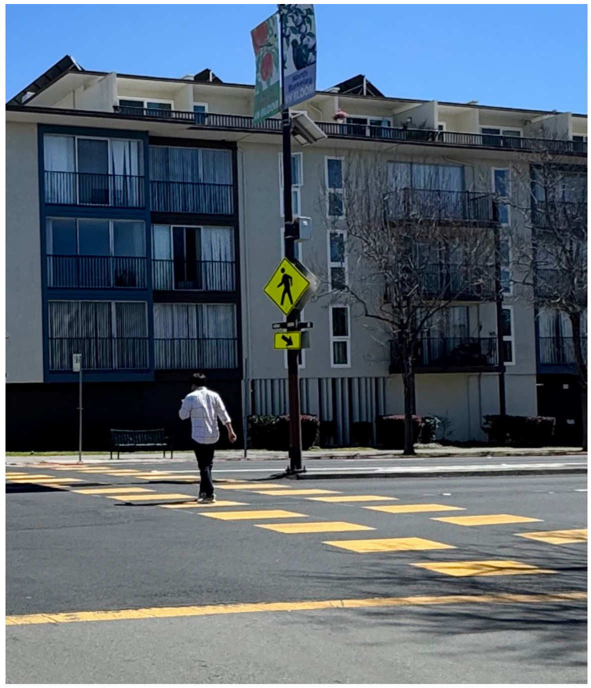
Transit Integration: Some crossing recommendations are at intersections currently served by various AC Transit routes. The City of Berkeley should coordinate early with AC Transit to ensure crossing improvements minimize impacts to AC Transit operations and stop locations. This is especially the case in locations where median crossings may require parking removal, stop relocation, and the general reconfiguration of travel lanes to accommodate a median crossing.

Field Examples of Bicycle Boulevard Crossing Treatments

(Updated Section)

Rectangular Rapid Flashing Beacon (RRFB)

RRFB at MLK Jr. Way and Virginia Avenue (Source: City of Berkeley)



RRFB at Shattuck Avenue and Virginia Avenue (Source: City of Berkeley)

RRFB + Median Island

RRFB and a Median Island at MLK Jr. Way and Addison Street (Source: City of Berkeley)

Median Island

Median Islands at California Street and Dwight Way
(Source: City of Berkeley)

Pedestrian Hybrid Beacon (PHB)

PHB at Hillegass Avenue and Ashby Avenue (Source: City of Berkeley)

PHB at Virginia Avenue and San Pablo Avenue (Source: City of Berkeley)

Traffic Signal with Diversion

Traffic Signal with Diversion at MLK Jr. Way and Channing Way (Source: City of Berkeley)

Traffic Signal with Diversion

Traffic Signal with Diversion at Sacramento Street and Virginia Street (Source: City of Berkeley)