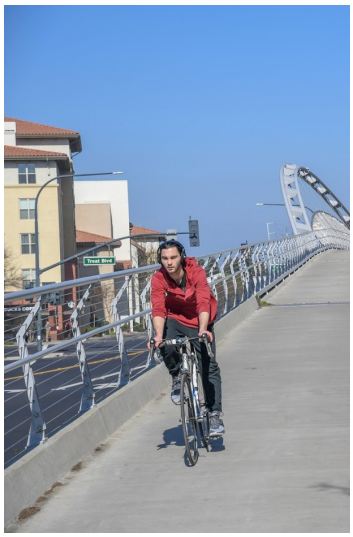

CONTRA COSTA

Countywide Bicycle
and Pedestrian Plan

Appendix C

Best Practices:
Pedestrian and Bicycle Treatments

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For

CONTRA COSTA transportation authority

C. Best Practices: Pedestrian and Bicycle Treatments

This appendix describes best practices in active transportation treatments that can be used in the implementation of the Countywide Bicycle and Pedestrian Plan. The section is broken up into three parts. The first section focuses on contextual design; this approach considers the interaction of transportation infrastructure and the surrounding context, the built environment, and other factors. The following two sections include toolboxes covering best practices for pedestrian and bicycle treatments. This includes information on signal design, striping, allocation of the right of way, and road geometry. Pedestrian treatments are presented in terms of uncontrolled and signalized intersections. Bicycle treatments are presented in terms of a variety of facility types as well as intersection and parking design.

Changing Practices to Improve Multimodal Safety

The implementation of the CBPP should involve national best practices in multi-modal complete streets design. The stakeholders involved in the CBBP realized a need to ensure all modes of transportation are included in design treatment selections. The following national best practice resources should be used when assessing potential treatments in multi-modal corridors:

- NACTO Urban Bikeway Guide, 2nd Edition
- NACTO Urban Streets Design Guide
- NACTO Transit Street Design Guide
- Federal High Administration (FHWA) Small and Rural Multi-modal Networks Guide
- AASHTO Guide for the Development of Bicycle Facilities, 4th Edition
- AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, 1st Edition
- U.S. Access Board Draft Guidelines for Accessible Public Rights-of-Way (PROWAG)
- Caltrans Highway Design Manual Chapter 1000 Bicycle Transportation Design
- Caltrans Class IV Bikeway Guidance
- Federal Highway Administration (FHWA) Separated Bicycle Lane Planning and Design Guide
- MassDOT Separated Bike Lane Planning and Design Guide
- CROW Design Manual for Bicycle Traffic 2017
- ITE Recommended Practices on Accommodating Pedestrian and Bicyclists at Interchanges
- NACTO Curb Appeal: Curbside Management Strategies for Improving Transit Reliability
- NACTO Blueprint for Autonomous Urbanism

The CBPP includes recommendations for newer facility types and treatment options such as Class IV Protected Bikeways and protected intersections that have not yet been implemented in Contra Costa. These facilities have begun to be implemented throughout California and in the Bay Area. These new treatments and resources can increase the safety of cyclists by providing adequate separation along heavily trafficked arterials or truck routes and have the ability to reduce vehicle conflicts at intersections. Priority use and safety considerations should be given to cyclists on corridors and at intersections identified as part of the regional network.

Recent trends in multi-modal safety revolve around Vision Zero planning efforts, which create strategies to eliminate all traffic fatalities and severe injuries while increasing safety, health, and equitable mobility for all users. Vision Zero projects identify high-injury networks by analyzing collision data and assessing future risk through predictive forecasting. Caltrans also introduced grants that can be geared toward Vision Zero planning known as the Systemic Safety Analysis Report Program (SSARP). Contra Costa County is undertaking Vision Zero planning and SSAR efforts in 2018. The Authority has future plans to consider a Vision Zero policy.

One of the key tenets of Vision Zero approaches is that people, whether walking, bicycling or driving, do not always follow the rules of the road. Designers need to recognize that fact to minimize the severity of collisions. Designers need to consider ways to design those improvements so that road users can more easily follow the rules of the road and that when they don't the results are less severe. Similarly, education and enforcement are needed to increase the efficacy of engineering treatments, especially new devices that may be less familiar to road users.

C.1 Context Sensitive Design

The Federal Highway Administration (FHWA) defines context sensitive design as a "collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility." In this way, context sensitive design considers the total context within which a transportation improvement project will exist.

The 2018 CBPP Best Practice Design Guidelines recognize that prioritizing and providing optimal service across all modes (e.g. vehicles, transit, bicyclists and pedestrians) on every street is not always practical or possible. Developing complete streets requires making tradeoffs across competing modal demands. For example:

- Increased automobile speeds may reduce pedestrian and bicycle safety

- Transit tracks can pose conflicts for both turning vehicles and bicyclists
- Pedestrian-priority treatments can reduce capacity for vehicles including trucks and buses
- Roadway designs that accommodate trucks can result in wide intersections that increase pedestrian crossing times
- Creation of exclusive bicycle or bus facilities can reduce capacity for automobile travel or street parking

To harmonize conflicts and competing demands, meaningful community engagement is essential. Community engagement helps communities to define priorities and performance measures in ways that are transparent, data-driven, and reflect community character and geographic context. This is especially important in cases where roadway right of way is constrained.

A layered network approach to transportation planning is one way to balance tradeoffs between different modes. This approach prioritizes certain modes on certain streets, providing continuity for the chosen mode while accommodating other modes or encouraging use on parallel streets. In this way, layered network planning takes a systems approach that assures that all modes are addressed in the larger system of roadways, but acknowledges that trying to serve competing modes on individual streets sometimes fails to result in facilities for either. Providing select treatments for a prioritized mode on designated streets can improve efficiency for that particular mode while ensuring increased safety for all modes.

For more information, please refer to the "Countywide Objectives & Plan Update Strategic White Paper" included in Appendix B, which discusses Innovative Public Engagement Strategies, Complete Streets Corridor Studies, Project Prioritization, Establishing Performance Metrics, and Data Collection and Monitoring.

C.2 Best Practice Pedestrian Treatment Toolbox

The Best Practice Pedestrian Treatment Toolbox presents the recommended tools in striping, signalization, signage, geometry and other categories for improving both uncontrolled and controlled crossing locations. It is organized into a table and includes each tool's name, description, and crash reduction factor (CRF). The table also includes recommended treatments based on average daily traffic (ADT), speed limit, and number of lanes.

Uncontrolled Locations - Basic Treatments

Striping Treatments

Treatment	Description

Yield Line (MUTCD Section 3B.16)

Yield lines (also referred to as "sharks' teeth") are placed 20 to 50 feet in advance of multi-lane marked, uncontrolled crosswalks (CA-MUTCD). When a roadway has 3 or more lanes, the yield line should be placed further from the crosswalk in an advanced position. "Yield Here to Pedestrian" (R1-5/R1-5a, white sign in photo) must be used in conjunction with advanced yield limit lines (CA-MUTCD). The MUTCD guidance is for yield lines to be placed four feet in advance of the crosswalk for single-lane approaches. For uncontrolled multi-lane approaches, the MUTCD guidance is that the yield lines should be placed 20' to 50' feet from the crosswalk.

This is useful in areas where pedestrian or cyclist visibility is low and in areas with aggressive drivers. The Yield Line also addresses the multiple-threat collision on multilane roads.

CRF	ADT	Speed Limit	Number of Lanes
N/A	Any	Any	Any

High-Visibility Crosswalk (MUTCD Section 3B.18)

Crosswalks with thick stripes perpendicular to direction of vehicular traffic are at common application. CA-MUTCD guidance includes an option to mark crosswalks with diagonal white lines at a 45-degree angle to the line of the crosswalk in cases where "substantial numbers of pedestrians cross" at uncontrolled locations. Installation of a marked crosswalk only may not be appropriate for certain conditions. This is beneficial in areas with high pedestrian activity, such as near schools, in areas where travel speeds are high or motorist visibility is low, and crossings at uncontrolled locations.

CRF	ADT	Speed Limit	Number of Lanes
19 – 40%	Any	Any	Any

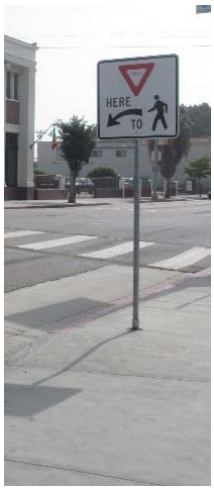
Uncontrolled Locations - Basic Treatments

Signal/Signage Treatments

Treatment	Description
In-Street Pedestrian Signage (MUTCD Section 2B.12) 	High-visibility pedestrian crossing signage placed in the street at a marked crosswalk. This pedestrian treatment is ideal for mid-block crosswalks, unsignalized intersections, low-speed areas, and two-lane roadways. If applicable, STATE LAW can appear at the top of the sign. The legend STOP FOR or YIELD TO can be used in conjunction with the appropriate symbol. The STOP FOR legend should be used in states where the law specifically requires that drivers stop for a pedestrian in a crosswalk.

CRF	ADT	Speed Limit	Number of Lanes
N/A	≤15,000	≤ 35 MPH	2- to 3-lane

MUTCD Roadside Signage (MUTCD Section 2B.11)



The 2014 California MUTCD permits the use of two primary roadside pedestrian crossing signs: *Yield Here to Pedestrians* (far left photo) and the *Pedestrian Crossing* (middle and right photo). The Pedestrian Crossing sign can be either fluorescent yellow-green or yellow and placed in advance of the crosswalk with an AHEAD placard or at the crosswalk with an arrow placard.

Roadside pedestrian crossing signage may be used in conjunction with in-street pedestrian signage (2014 California MUTCD).

CRF	ADT	Speed Limit	Number of Lanes
N/A	Any	Any	Any

Uncontrolled Locations - Basic Treatments

Geometric Treatments

Treatment	Description
Median, Refuge Island or Split Pedestrian Crossover (MUTCD Section 3I.06) 	Sections in the center of the roadway that are vertically or visually separated from vehicular traffic. Raised medians or refuge islands shorten crossing distances across wider roadways, and allow for pedestrians to cross a road while only focusing on one direction of vehicle traffic at a time. When enhanced as a Split Pedestrian Crossover, the crossing is staggered such that a pedestrian crosses half the street and then walks toward traffic to reach the second half of the crosswalk. Medians should be at least 4ft wide (preferably 6-10ft) and should be long enough to allow the expected number of pedestrian users to stand and wait to cross the second leg. The ideal length of a median is 40 feet, and it should extend past the crosswalk to further protect pedestrians and slow traffic. Recommended for multilane roads wide enough to accommodate an ADA-accessible median.

CRF	ADT	Speed Limit	Number of Lanes
29-73%	Any	Any	2-lane or more

Road Diets (Lane Reduction) 	Road diets reduce the number of lanes pedestrians must cross by reducing the number of roadway travel lanes from 2 lanes in each direction to 1 lane in each direction and a center turning lane. They may also allow for bike lanes. Road diets are appropriate on roadways with excess capacity (typically multilane roadways with less than 15,000 to 17,000 average daily traffic) and high bicycle volumes, and roadways that would benefit from traffic calming measures.

CRF	ADT	Speed Limit	Number of Lanes
29%	≤ 23,000	N/A	4-lane

Uncontrolled Locations - Basic Treatments

Other Treatments

Treatment	Description
Removal of Sight Distance Obstructions 	Items such as parked cars, signage, landscaping, fencing, and street furniture should be placed in a location that will not obstruct sight distance.

CRF	ADT	Speed Limit	Number of Lanes
11-56% *(vehicle collisions only)*	Any	Any	Any

Treatment	Description
Traffic Signal, with Pedestrian Signal, Where Warranted (MUTCD Section 4C.01) 	Standard traffic signal. A signal warrant does not, in itself, necessitate the installation of a traffic signal. Engineering judgment and an analysis of all road users, local land uses, and other external factors should be conducted before recommending a signal.

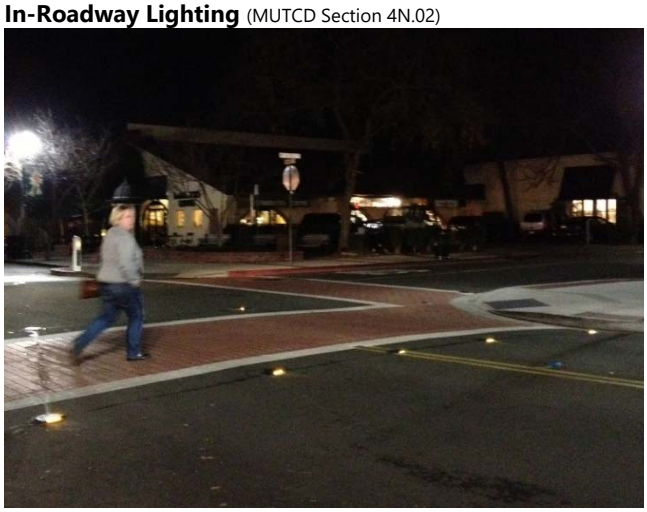
CRF	ADT	Speed Limit	Number of Lanes
24 – 44%	≥ 15,000	≥ 35 MPH	3-lane or more

Uncontrolled locations - Enhanced Treatments

Signal/Signage Treatments

Treatment	Description
Pedestrian Activated Warning Device  *Image source: FHWA MUTCD*	The rectangular rapid flashing beacon (RRFB) was developed to address the unique challenges associated with uncontrolled crossings of multi-lane, higher speed and higher volume roadways. Extensive research recently demonstrated its strong crash reduction efficacy. It is widely in use throughout the United States, including in jurisdictions across Contra Costa.

CRF	ADT	Speed Limit	Number of Lanes
N/A	>12,000	<45 MPH	Any

Treatment	Description
In-Roadway Lighting (MUTCD Section 4N.02) 	Crosswalk lighting embedded in the roadway at even intervals, which lights upon being actuated by a pedestrian or pedestrian push-button, enhances the visibility of the pedestrian crossing to vehicles. Best in locations with low bicycle ridership, because the raised markers present a hazard. May not be appropriate in areas with extreme winter conditions because of high maintenance costs or in locations with bright sunlight. The lights may confuse drivers if pedestrians do not activate them or if the lights are falsely activated.

CRF	ADT	Speed Limit	Number of Lanes
N/A	>12,000	<45 MPH	Any

Uncontrolled locations - Enhanced Treatments

Signal/Signage Treatments (Continued)

Treatment	Description
LED-Enhanced Signage (MUTCD Section 2A.07) 	Pedestrian crossing signage, using MUTCD preferred style, with embedded or external lights to enhance the visibility of the signage.

CRF	ADT	Speed Limit	Number of Lanes
N/A	Any	<45 MPH	4-lane or more

Pedestrian Hybrid Beacon (HAWK) (MUTCD Section 4F)

Pedestrian-activated warning light located on a mast arm over a pedestrian crossing. The beacon stays dark until activated. It has one yellow lens and two red lenses to indicate to drivers that a pedestrian is in the crosswalk. The pedestrian hybrid beacon was included, for the first time, in the 2009 MUTCD. The 2014 CA-MUTCD includes a standard traffic signal (that does not meet a signal warrant) as an alternative to the standard pedestrian hybrid beacon. Useful in areas where it is difficult for pedestrians to find gaps in automobile traffic to cross safely, but where normal signal warrants are not met. HAWK is appropriate for multilane roadways.

CRF	ADT	Speed Limit	Number of Lanes
15-69%	>12,000	>45 MPH	4-lane or more

Uncontrolled locations - Enhanced Treatments

Signal/Signage Treatments (Continued)

Treatment	Description
Crosswalk Flags (Photo by Kailua Village Business Improvement District) 	Brightly colored removal flags are placed at crosswalk to increase pedestrian visibility and clearly communicate their desire to cross the street. The pedestrian carries the flag while crossing the roadway. Crosswalk flags are appropriate for mid-block and uncontrolled crosswalks with low visibility or poor sign distance.

CRF	ADT	Speed Limit	Number of Lanes
N/A	N/A	N/A	N/A

Uncontrolled locations - Enhanced Treatments

Geometric Treatments

Treatment	Description
Chicane 	Two or more alternating mid-block bulbouts which create an S-curve in the roadway and discourage vehicular speeding. Chicanes can be created on streets with high traffic volume if the number of through lanes is maintained. They can also be created on high-volume residential streets to slow traffic. They can be constructed by alternating parallel or angled parking in combination with curb extensions.

CRF	ADT	Speed Limit	Number of Lanes
N/A	< 15,000	<40 MPH	2-lane

Treatment	Description
Choker 	Two opposed mid-block bulb-outs which decrease the roadway width, discouraging vehicular speeding and provide a shorter crossing distance if paired with a crosswalk. Treatments with vertical or horizontal vehicle deflection (e.g. in-road signage, raised crosswalks, speed humps, chicane, and chokers) are recommended only for lower volume, lower speed locations.

CRF	ADT	Speed Limit	Number of Lanes
N/A	< 15,000	<40 MPH	2-lane or more

Uncontrolled locations - Enhanced Treatments

Geometric Treatments (Continued)

Treatment	Description

Corner Bulb Outs and Curb Extensions

Raised devices, usually constructed from concrete and/or landscaping, that reduce the corner radius and/or narrow the roadway to reduce traffic speeds, shorten pedestrian crossing distances, and improve visibility. Due to the high cost of installation, a curb extension/bulbout is suitable only for streets with high pedestrian activity, on-street parking, and frequent (or no) curb-edge transit service. It is often used in combination with crosswalks and other markings.

CRF	ADT	Speed Limit	Number of Lanes
N/A	Any	Any	2- to 4-lane

Lane Width Reduction

Reduction in vehicle travel lane width from 12-feet to 9-feet or 10-feet. In urban areas, lane widths of 10 feet are often appropriate as it increases the street's safety without an effect on traffic operations. Wider lanes have a greater likelihood of side-swipe collisions (NACTO 2013).

CRF	ADT	Speed Limit	Number of Lanes
38 – 56%* **for 12- to 9-feet lanes*	≤ 25,000	<35 MPH	Up to 4-lane

Uncontrolled locations - Enhanced Treatments

Geometric Treatments (Continued)

Treatment	Description

Raised Pedestrian Crossing/Speed Table (MUTCD Section 3B.25, Figure 3B-30)

Pedestrian crossings that are elevated to the level of the sidewalk. In-road grade change is similar to a speed hump. Beneficial on streets with high pedestrian activity, on-street parking, and no curb-edge transit service. More suitable for wider roadways and roadways with a low volume of heavy truck traffic.

CRF	ADT	Speed Limit	Number of Lanes
30-46%	≤15,000	<35 MPH	Any

Speed Humps (MUTCD Section 3B.25, 3B.26, Figure 3B-29, 3B-31)

Raised pavement areas, typically 12- to 14-feet long and 3- to 4-inches high. Traditionally, humps have pavement markings and advanced warning signage. Motorists are more likely to yield to pedestrians when traveling at lower speeds. Motorist speeds decrease 15-29 mph when speed humps are installed (NACTO, 2013).

CRF	ADT	Speed Limit	Number of Lanes
40-50%	≤15,000	<35 MPH	Any

Uncontrolled locations - Enhanced Treatments

Geometric Treatments (Continued)

Treatment	Description
Pedestrian Overpass or Underpass (Photo from pedbikeinfo.org) 	Complete separation of pedestrians from motor vehicle traffic, normally where no other pedestrian facility is available, and connects off-road trails and paths across major barriers. The device is recommended only where topography supports its use. Grade separation is most feasible and appropriate in extreme cases where pedestrians must cross roadways such as freeways and high-speed, high-volume arterials. This measure should be considered a last resort because it is expensive and visually intrusive (Berkeley, 2013). CRF is 100% assuming the conditions and design prevented illegal at-grade crossings.

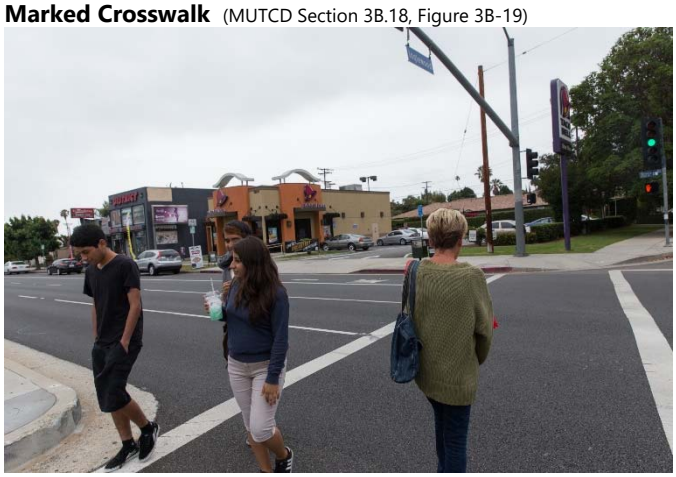
CRF	ADT	Speed Limit	Number of Lanes
100%*	Any	Any	Any

Rumble Strips (Photo from pedbikeinfo.org) 	Transverse grooved strips or raised ceramic pavement markers generally used to alert drivers to a change in roadway conditions through an audible and tactile vibration and rumbling. Rumble strips are great for pedestrians, but rumble strips can damage a bicycle wheel. Consequently, cyclists will avoid riding over them.

CRF	ADT	Speed Limit	Number of Lanes
34-36%	Any	Any	Any

Signalized Locations - Basic Treatments

Striping Treatments

Treatment	Description	
Marked Crosswalk (MUTCD Section 3B.18, Figure 3B-19) 	Striping on the far sides of a pedestrian crossing parallel to the direction of vehicular traffic, which denote the proper location to cross a street.	
	CRF	**Applicability**
	Varies	Recommended at all signalized or stop-controlled intersections.
Stop Line (MUTCD Section 3B.16) 	Standard advance stop bars must be placed a minimum of four feet in advance of marked crosswalks (CA-MUTCD). With this tool, a stop line is placed in advance of crosswalk to increase pedestrian visibility to vehicles and reduce vehicle encroachment upon the crosswalk. Advance stop bars indicate that a driver should stop before approaching the pedestrian crossing. They are usually placed 4-feet away from the crossing.	
	CRF	**Applicability**
	67%	Where space allows, recommended at all signalized or stop-controlled intersections.

Signalized Locations - Basic Treatments

Signal/Signage Treatments

Treatment	Description
Countdown Signal (MUTCD Section 4E.07) 	Displays a "countdown" of the number of seconds remaining for the pedestrian crossing interval. The 2012 MUTCD requires all pedestrian signals to incorporate countdown signals within 10 years.

CRF	Applicability
0-70%	Recommended at all signalized.

Treatment	Description
Increase Length of Pedestrian Phase (MUTCD Section 4E.06) 	The 2009 federal MUTCD requires reduction of the design pedestrian walking speed from 4.0 feet per second to 3.5 feet per second to reflect average observed pedestrian walking speeds. The walking speed may be further reduced to accommodate vulnerable populations such as children and the elderly.

CRF	Applicability
45-50%	The use of 3.5 ft. /sec standard walking speed is recommended at all signalized intersections. Additional reductions should be considered near a school or retirement facility.

Signalized Locations - Basic Treatments

Signal/Signage Treatments (Continued)

Treatment	Description
Pedestrian Recall (Peak Hour or Full Time) (MUTCD Section 4E.11) 	Provides a guaranteed walk phase for each crossing at a signal during peak hours, regardless of whether the pedestrian push button has been activated. **CRF:** N/A **Applicability:** Recommended in areas of high peak-hour or daily pedestrian activity, such as near a school, transit station, or downtown district.

GEOMETRIC TREATMENTS

Treatment	Description
Far-Side Bus Stops 	Far-side bus stops allow pedestrians to cross behind the bus, improving pedestrian visibility. Far side bus stops also enhance transit operations by provided a guaranteed merging opportunity for buses. Exceptions for far-side bus stops include considerations for bus routing, sufficient sidewalk area, and conflicts with parking, land uses, or driveways. Appropriate for all bus stops subject to sight distance and right-of-way constraints. **CRF:** N/A **Applicability:** Recommended at all signalized or stop-controlled intersections.

Signalized locations - Enhanced Treatments

Signal/Signage Treatments

Treatment	Description
All Red Clearance (MUTCD Section 4D.26) 	Provides a phase (1-2 seconds) where all vehicle indicators hold the red at an intersection, which allows for pedestrians to clear the intersection before conflicting vehicle movements are released.

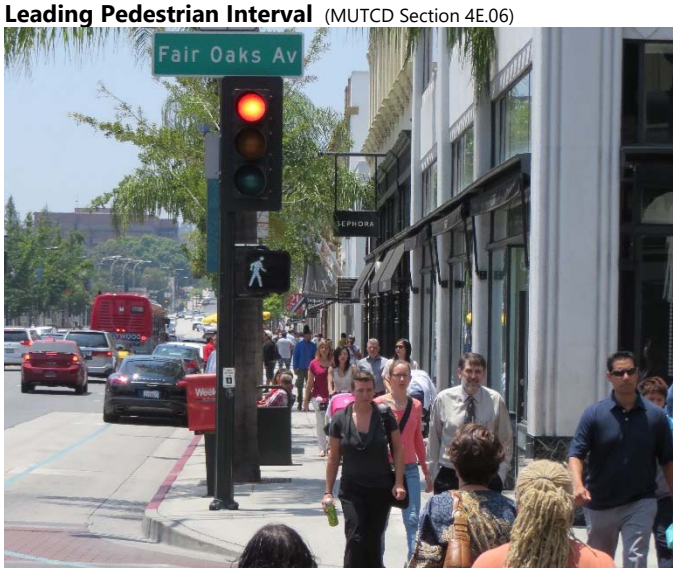
CRF	Applicability
14-20% *(vehicle collisions only)*	Recommended in areas of high pedestrian activity.

Treatment	Description
Flashing Yellow Left Arrow (MUTCD Section 4D.17, 4D.18) 	A flashing yellow left-turn arrow allows permissive left turns while warning motorists of potential conflicts with pedestrians in the crosswalk.

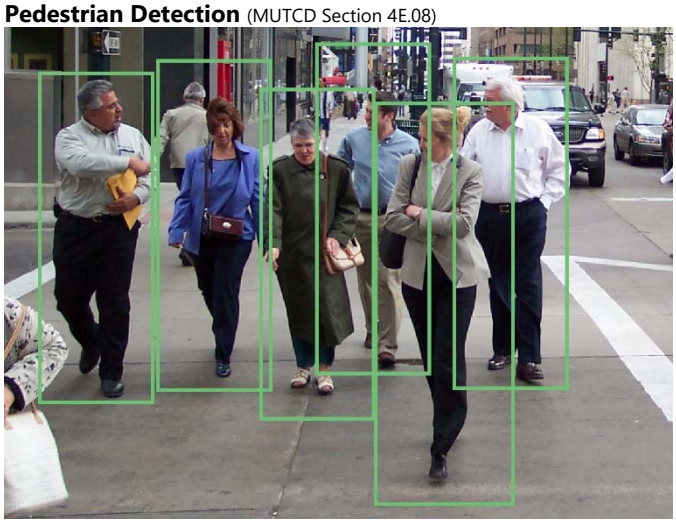
CRF	Applicability
10-14% *(vehicle collisions only)*	Recommended for permissive left turns at signalized intersections.

Signalized locations - Enhanced Treatments

Signal/Signage Treatments (Continued)

Treatment	Description
Leading Pedestrian Interval (MUTCD Section 4E.06) 	A signal modification that begins the pedestrian walk phase 3 seconds before permitted left-turn or right-turn movements of turning vehicles. The objective is to permit pedestrians to cross several seconds before potentially conflicting motor vehicles receive a green indication.

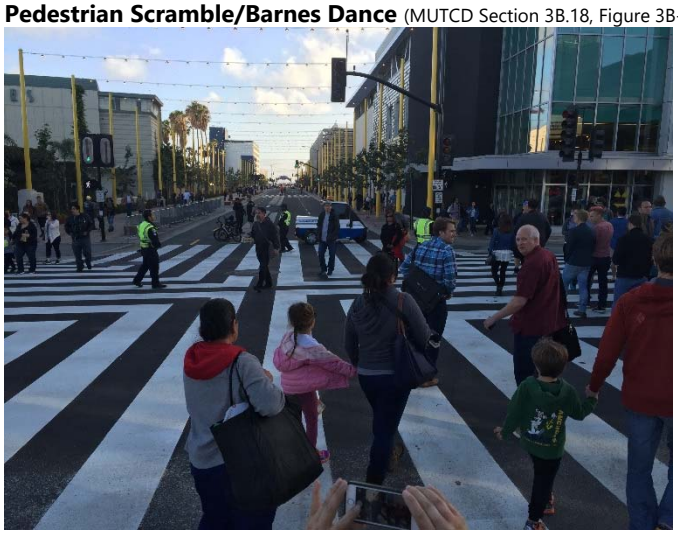
CRF	Applicability
29-45%	Recommended in areas of high pedestrian and/or high vehicular activity.

Pedestrian Detection (MUTCD Section 4E.08) 	Infrared, microwave, or video detectors installed at signalized intersections to detect pedestrians.

CRF	Applicability
N/A	Recommended in areas of high pedestrian and/or high vehicular activity.

Signalized locations - Enhanced Treatments

Signal/Signage Treatments (Continued)

Treatment	Description
Pedestrian Scramble/Barnes Dance (MUTCD Section 3B.18, Figure 3B-20) 	A pedestrian scramble (or Barnes Dance) is a phase during which no vehicles are allowed in the intersection, so pedestrians can cross diagonally or conventionally.

CRF	Applicability
51-66%	Recommended in areas of high pedestrian and/or high vehicular activity.

Prohibited Right-Turn on Red (MUTCD Section 2B.54) 	Prohibits vehicles from turning right when signal has a red indication.

CRF	Applicability
11-69%	Recommended in areas of high pedestrian, high vehicular activity, or locations with a demonstrated crash history involving right-hooks.

Signalized locations - Enhanced Treatments

Signal/Signage Treatments (Continued)

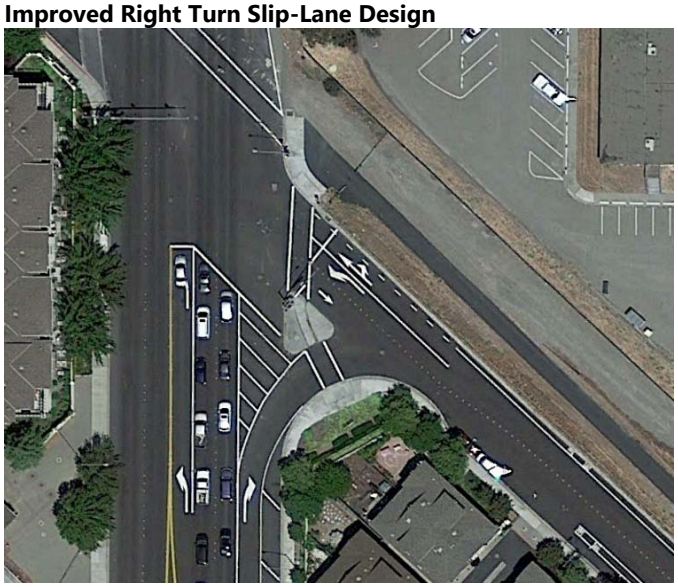
Treatment	Description
Prohibited Left-Turn (MUTCD Section 4D.17 - 4D.20)  	Prohibits vehicles from turning left at a signal to allow pedestrians to cross without conflicts with vehicle turning movements. Left-turning drivers must turn at a different identified location either before or after the intersection. **CRF**: N/A **Applicability**: Recommended in areas of high pedestrian and lower vehicular activity. Consider use at locations with a history of left-turn vehicle-pedestrian crashes.
Protected Left Turn (MUTCD Section 4D.17, 4D.19) 	Protected left turns give vehicles that are turning left an exclusive phase that does not coincide with the pedestrian walk phase. This eliminates the pedestrian-vehicle conflict between permissive lefts and pedestrians in a crosswalk. **CRF**: 11-99% **Applicability**: Recommended in areas of high pedestrian and/or high vehicular activity.

Signalized locations - Enhanced Treatments

Geometric Treatments

Treatment	Description
Intersection Conversion to Roundabout (MUTCD Section 3C.01) 	Roundabout installed at a previously unsignalized intersections or to replace a traffic signal. They are large circular islands, placed in the middle of an intersection, that direct flow in a continuous circular direction around the intersection. Roundabouts can reduce the number of conflict points, compared to an uncontrolled intersection, and decrease vehicle speeds.

CRF	Applicability
29%	Recommended in areas of high vehicular activity.

Treatment	Description
Improved Right Turn Slip-Lane Design 	Well-designed right-turn slip lanes discourage high-speed vehicle turns by reducing turning radii and redesigning medians to make pedestrians more visible to drivers. The triangular "pork chop" island that results should have the "tail" pointing to approaching traffic. This design also narrows the distance that a pedestrian has to cross while reducing the speed of turning vehicles.

CRF	Applicability
5%	Recommended in areas with high volumes of right-turning vehicles

Application of Treatments at Uncontrolled Locations

Once a decision to mark a crosswalk has been made, staff must assess whether additional countermeasures are necessary or may be useful to improve safety. Countermeasure identification should first be based on roadway characteristics, with ultimate suitability determined by site context and engineering judgement.

Twelve effective countermeasures[6] that are appropriate in specific roadway contexts are grouped into nine treatments below. Three of these tools—high-visibility crosswalk markings, parking restrictions at crosswalk approach, and adequate nighttime lighting levels—should be used at all uncontrolled crosswalks. See the Best Treatments Toolbox above for a detailed description of these countermeasures.

1. High-visibility crosswalk markings, parking restriction at crosswalk approach, and adequate nighttime lighting levels
2. "Yield Here To Pedestrians" and "Stop Here For Pedestrians" signs and yield (stop) line
3. In-street pedestrian crossing sign
4. Raised crosswalk
5. Median refuge island
6. Curb extensions
7. Road diet
8. Rectangular rapid flashing beacon (RRFB)
9. Pedestrian hybrid beacon

Determining which safety countermeasures to install at uncontrolled crosswalks should be conducted in three steps. First, roadway characteristics should be used with **Table C-1** to identify countermeasures that should always be strongly considered at uncontrolled crossings of that roadway type. Next, **Table C-2** should be used to identify additional candidate treatments that may also be appropriate, depending on the specific context of the intersection. Finally, once treatments have been selected using these two tables, **Table C-3** should be used to assess whether they address all identified safety issues. If they do not, additional candidate treatments that do address those issues should also be included.

[6] Based on the FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*. The guidelines are anticipated to be updated soon to include RRFBs and combine high-visibility markings, parking restrictions, and nighttime lighting into one countermeasure.

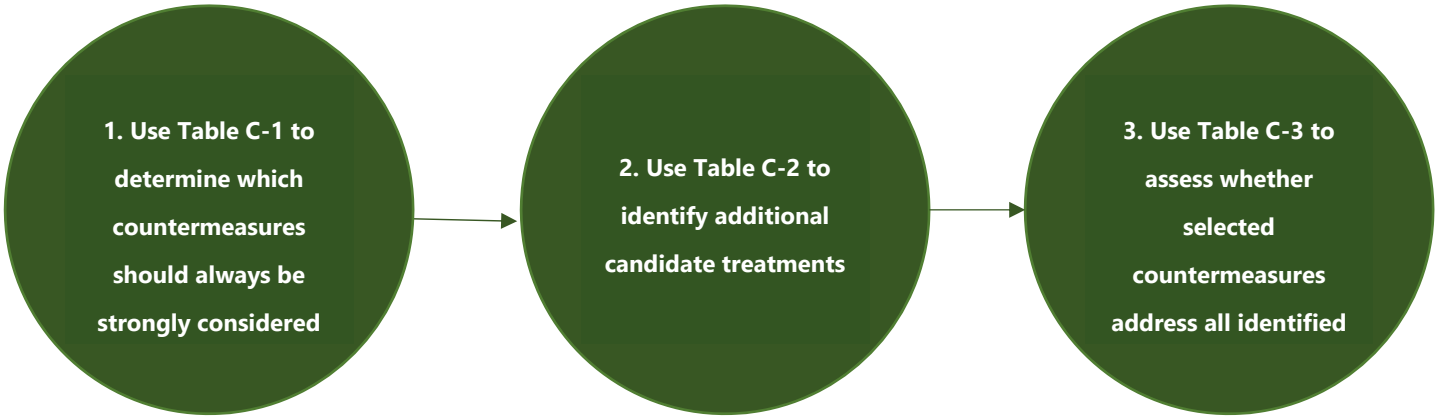


Table C-1 identifies whether additional countermeasures may be needed to provide safer uncontrolled crosswalks based on average daily traffic (ADT), posted or observed speeds, the number of travel lanes, and the presence of a median. The enhancements documented in Table C-1 represent safety countermeasures that should always be strongly considered at uncontrolled crosswalks across roadways with the given roadway characteristics. Recommendations are organized into four levels of enhancement:

- **Level A**: These are the most basic improvements that should be implemented at *all* uncontrolled crosswalks, regardless of roadway characteristics. Level A improvements include high-visibility continental striping, parking restrictions at the crosswalk approach, adequate nighttime lighting levels, and the removal of sight distance obstructions. Directional curb ramps and tight curb radii should also be implemented if the crosswalk is at an intersection.

- **Level B**: All Level A treatments, plus advanced yield (stop) markings with "Yield Here to (Stop Here for) Pedestrians" signs.

- **Level C**: All Level A and Level B treatments, plus rectangular rapid flashing beacon (RRFB). This introduces high-efficacy flashing beacons to further enhance the signing, striping, and geometric improvements of Levels A and B.

- **Level D**: All Level A and Level B treatments, plus pedestrian hybrid beacon (PHB). This stronger traffic control device is needed on wider roadways with higher speeds and greater ADT. Pedestrian signals should be considered as an alternative to PHBs where warrants are met.

Table C-2 identifies additional candidate treatments that may be appropriate, based on the reported roadway characteristics. Each numbered countermeasure in Tables C-1 and C-2 corresponds to the countermeasure numbering above**.** The reported and near-miss collisions documented at the crosswalk should also be compared against **TableC-3** to determine if the proposed countermeasures address those

collision trends. If they do not, Tables C-2 and C-3 should then be used to identify potential additional treatments to address the documented safety record.

Table C-1: Recommended Countermeasure Enhancements at Uncontrolled Crosswalks

Roadway Type	Vehicle ADT ≤ 9,000			9,000 < Vehicle ADT ≤ 15,000			Vehicle ADT ≥ 15,000		
	≤30 mph	31-39 mph	≥40 mph	≤30 mph	31-39 mph	≥40 mph	≤30 mph	31-39 mph	≥40 mph
2 Lanes	A	B	C	A	B	C	A	B	D
3 Lanes with Raised Median	A	B	C	A	C	C	B	D	D
3 Lanes without Raised Median	A	B	C	A	C	C	B	D	D
4+ Lanes with Raised Median	B	B	D	B	C	D	D	D	D
4+ Lanes without Raised Median	B	B*	D*	B*	C*	D*	D*	D*	D*

Notes:

- Level A: high-visibility crosswalk markings, parking restriction on crosswalk approach, adequate nighttime lighting levels, and removal of sight-distance obstructions (Countermeasure #1)
- Level B: all Level A countermeasures, plus advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line (Countermeasure #2)
- Level C: all Level A and Level B countermeasures, plus rectangular rapid flashing beacons (Countermeasure #8)
- Level D: all Level A and Level B countermeasures, plus pedestrian hybrid beacon (Countermeasure #9)

*: countermeasures indicated by level, plus pedestrian refuge island (Countermeasure #5)

Source: Table adapted from FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations (February 2018) to include RRFBs. Upon Contra Costa County review, this should be updated once a version that includes RRFBs is released for consistency.

Table C-2: Potential Additional Countermeasure Enhancements at Uncontrolled Crosswalks

Roadway Type	Vehicle ADT ≤ 9,000			9,000 < Vehicle ADT ≤ 15,000			Vehicle ADT ≥ 15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 Lanes	2 3 4 5 6	5 6 8	5 6 9	2 3 5 6	5 6 8	5 6 9	2 3 5 6 8	5 6 8	5 6
3 Lanes with Raised Median	2 3 4 6	6 8	6 9	2 3 6 8	6 9	6 9	3 6 8	6	6
3 Lanes without Raised Median	2 3 4 5 6 8	5 6 8	5 6 9	2 3 5 6 8	5 6 9	5 6 9	3 5 6 8	5 6	5 6
4+ Lanes with Raised Median	6	6 9	6	6 8	6 9	6	6	6	6
4+ Lanes without Raised Median	5 6 7 8	6 7 8	6 7	6 7 8	6 7 9	6 7	6 7	6 7	6 7

1. High-visibility crosswalk markings, parking restriction at crosswalk approach, and adequate nighttime lighting levels
2. "Yield Here To Pedestrians" and "Stop Here For Pedestrians" signs and yield (stop) line
3. In-street pedestrian crossing sign
4. Raised crosswalk
5. Median refuge island
6. Curb extensions
7. Road diet
8. Rectangular rapid flashing beacon (RRFB)
9. Pedestrian hybrid beacon

Table C-3: Safety Issues Addressed by Each Countermeasure

Counter-Measure ID	Countermeasure	Reported, Near-Miss, or Observed Collision Trends				
		Conflicts at crossing locations	Excessive vehicle speed	Inadequate conspicuity/visibility	Drivers not yielding to pedestrians in crosswalks	Insufficient separation from traffic
1	High-visibility crosswalk markings	X		X	X	
1	Parking restriction on crosswalk approach	X		X	X	
1	Improved nighttime lighting	X		X		
2	Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line	X		X	X	X
3	In-Street Pedestrian Crossing sign	X	X	X	X	
4	Raised Crosswalk	X	X	X	X	
5	Pedestrian Refuge Island	X	X	X		X
6	Curb extension	X	X	X		X
7	Road Diet	X	X	X		X
8	RRFB	X			X	
9	Pedestrian Hybrid Beacon	X			X	

C.3 Best Practice Bicycle Design Guidelines

The bicycle facility designs included in this guide are important for creating an all ages and abilities network in Contra Costa. Creating a network of facilities that is comfortable for users of all ages is a key step in encouraging "interested but concerned" bicyclists to ride. These design guidelines supplement the bicycle network recommendations presented in the Plan.

This section presents preferred treatments and preferred and minimum dimensions for all bikeways with emphasis on those in the low-stress CBN such as protected bikeways, neighborhood bikeways, and protected intersections. In addition to those guidelines, this chapter includes clarifying policies and preferred and minimum dimensions for select active transportation facilities.

Travel Lane Widths

Contra Costa County and local agencies should accept 10- to 11-foot lane widths on most roadways. At turn pockets, the local agencies should consider 9- to 10-foot pocket widths.

Bicycle Facility Selection

Selection of the most appropriate type of bicycle facility requires consideration of a variety of factors. On the regional network, this decision is critical, as the facility must be comfortable enough for bicyclists representing a wide range of experience levels. Characteristics of the roadway such as auto volumes, number of travel lanes, typical auto speeds, and available roadway width are also important considerations that significantly influence bicyclist safety and comfort. While other engineering and feasibility considerations also influence the type of bicycle facility proposed, **Table D-1** presents the key bicycle facility selection criteria for the All Ages and Abilities Network. If the bikeway type does not meet these criteria, it likely is not comfortable enough to be considered part of the All Ages and Abilities Network. As development throughout the region is ongoing, this section should be used to select bikeway facilities for roadways that are not depicted on the regional network.

The following guidelines should also be considered when selecting bicycle facilities for facilities not located on the regional network:

- Proposed facilities should provide access with logical start and end points that facilitate connections to schools, major employment centers, services, or connect to the Countywide Bikeway Network.

- Proposed facilities should strive to implement all ages and abilities treatments recommended in the design guidelines in Table C-1.
- When roadway resurfacing or other maintenance projects occur, new bikeway facilities should be considered. The new facilities should connect with other bikeway facilities or destinations even if the new bikeway treatments extend beyond the original project limits to ensure they tie in with other facilities and/or the larger regional network.

Table C.3-1: All Ages and Abilities Bicycle Facility Select Based on Speed, Volume, and Number of Travel Lanes

Typical Speed	Max. Vehicle Volume (ADT)	Motor Vehicle Lanes	Key Operational Considerations	All Ages & Abilities Bicycle Facility
Any		Any	Any of the following: motor vehicle congestion, turning conflicts, high curbside activity, frequent buses	Protected Bicycle Lane
Less than 10 mph	Less relevant	No centerline, or single lane one-way	Pedestrians share the roadway	Shared Street
20 mph or less	≤ 1,000 - 2,000		< 50 vehicles per hour in the peak direction at peak hour	Shared Street
25 mph or less	≤ 500 - 1,500			Bicycle Boulevard
	≤ 1,500 - 3,000	Single lane each direction, or single lane one-way	Low congestion pressure, or low curbside activity	Conventional or Buffered Bicycle Lane, or Protected Bicycle Lanes
	≤ 3,000 - 6,000			Buffered or Protected Bicycle Lanes
	Greater than 6,000			Protected Bicycle Lane
	Any	Multiple lanes per direction		
Greater than 26 mph	≤ 6,000	Single lane each direction	Low congestion pressure, or low curbside activity	Protected Bicycle Lane, or Reduce Speed

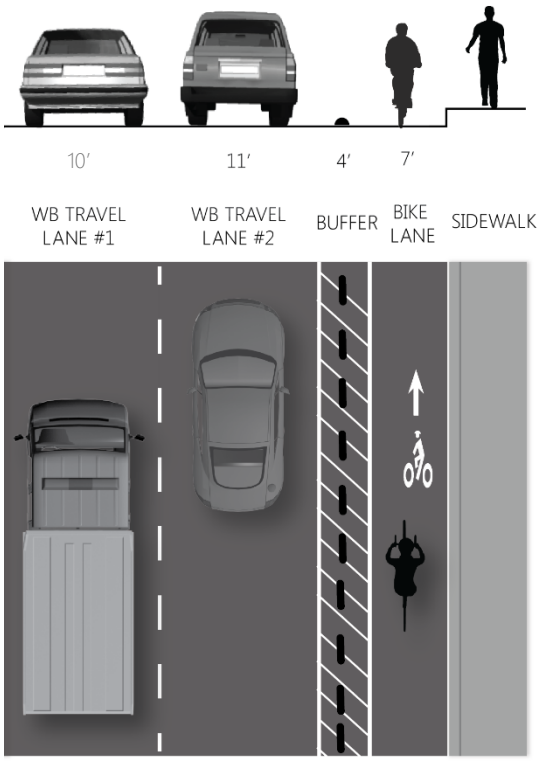
Typical Speed	Max. Vehicle Volume (ADT)	Motor Vehicle Lanes	Key Operational Considerations	All Ages & Abilities Bicycle Facility
		Multiple lanes per direction		Protected Bicycle Lane, or Reduce to Single Lane & Reduce Speed
	Greater than 6,000	*Any*	*Any*	Protected Bicycle Lane, or Bicycle Path
High-speed limited access roadways, natural corridors, or low-density areas with limited conflicts		Any	High pedestrian volume	Bike Path with Separate Walkway or Protected Bicycle Lane
			Low pedestrian volume	Shared-Use Path or Protected Bicycle Lane

Note: Additional roadway characteristics and engineering study should always be considered, particularly for separated bikeways. This table was developed for a large city context and may require some local calibration in each city.

Protected Bikeways

This section defines the preferred cross-section and materials for protected bikeways in Contra Costa. The NACTO *Urban Bikeway Guide, 2nd Edition,* FHWA *Protected Bicycle Lane Planning and Design Guide*, and MassDOT *Separated Bike Lane Planning and Design Guide* should also be consulted when planning for and designing protected bikeways in Contra Costa County.

Protected bikeways are needed to provide all ages and abilities facilities on most major roadways in Contra Costa. For example, multi-lane roadways with speeds over 30 MPH generally need a separated bikeway to provide a comfortable bikeway for the average rider. Protected bikeways can also be considered on narrower or slower roadways where vulnerable roadway users such as children near schools may be riding, or to provide important and/or complex connections between bikeways.



Preferred Protected Bikeways Dimensions

Preferred Design

A Class IV Protected Bikeway is an on-street bicycle facility that is both physically separated from automobile traffic and distinct from the sidewalk. These facilities offer a higher level of safety and comfort than bicycle lanes. While all Class IV facilities separate bicyclists from motor vehicle travel lanes, many different designs are possible. They may be at street level ("in roadway"), sidewalk level, or intermediate level. They are always separated from auto traffic by a raised element such as plastic delineators, median islands, on-street parking, and/or landscaping. Pavement material, streetscape elements, or landscaping may separate the facility from the sidewalk. Typically, protected bikeways run in the same direction as adjoining traffic, one in each direction on two-way streets. Sometimes two-way protected bikeways are appropriate, where both protected bikeways are located side-by-side. Directional or "one-way" protected bikeways are usually preferred.

The minimum width of the buffer depends on the type of buffer used. In the CBPP, the preferred design of the protected bikeway is typically a striped buffer with flexible delineator posts. As additional funding becomes available, these can be replaced with concrete islands or landscape islands to provide high-quality streetscapes.

The preferred protected bikeway design has a three- to four-foot striped buffer with vertical barriers and a seven-foot bicycle lane. The minimum striped buffer width is 1.5 feet with a five-foot bicycle lane. A minimum of four feet of rideable surface must be clear of gutter pans. Posts are recommended to be placed

consistently every 20 to 24 feet, on center, and require low initial capital cost at $8 per linear foot. As grant funding or developer funding is available, raised concrete buffers with decorative stamped pavement can be phased in. The protected bikeway must remain wide enough to allow street sweepers to maintain the area or specially sized street sweepers can be purchased as well.

Preferred Barrier Separation: Interim Design

The preferred interim design is a "paint and plastic" that will allow Contra Costa County to build out its protected bikeway network sooner. Alternatively, companies such as Dero[7] are developing innovative, cost-effective modular infrastructure options that physically separate vehicle traffic and bike lanes. As larger funding sources become available, high-quality improvements such as median islands and, where feasible, landscape islands, can replace the striped buffer and plastic posts.

"Armadillo" or "zebra" traffic separators

Rubber curb traffic separator

Flexible Delineator/Soft-Tipped Posts

[7] Dero (2017). "Protected Bikeway and Pedestrian Solutions." Accessed at https://www.dero.com/news/protected-bikeway-and-pedestrian-solutions/

Preferred Barrier Separation: Long-Term or Grant-Funded Design

Reconfiguring streetscapes to use raised medians, on-street parking, curbs, bollards, planters, or other features to separate the bikeway is more expensive and labor-intensive. As such, these design options are considered for long-term or grant-funded implementation.

Bikeway separated by landscaping and raised concrete curb

Protected Bikeways and Transit

When protected bikeways are provided along a bus route, the preferred design is for bus boarding islands to separate bicycle, pedestrian, and bus movements as much as possible. Where roadways have a higher speed limit, consideration should be given to whether or not in-lane stopping should be encouraged. Bus boarding islands should be wide enough to house a bus shelter and provide ADA clear paths of travel and a comfortable pedestrian waiting environment. To reduce bicycle-pedestrian interactions, fencing is encouraged to channelize pedestrians to clearly marked crosswalks across the protected bikeway.

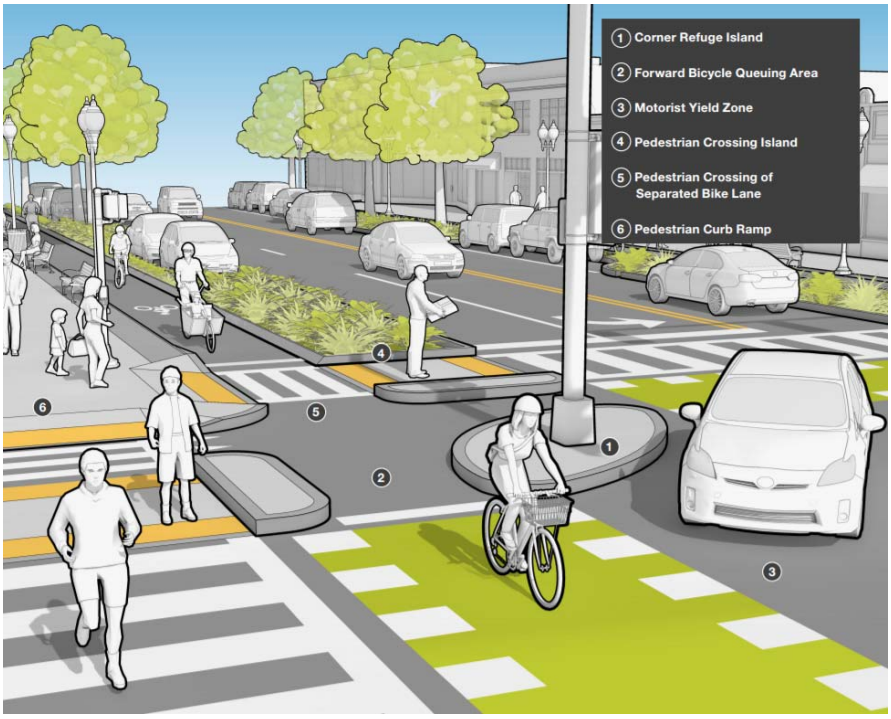
Protected Bikeway Intersection Control

Protected bikeways require special design consideration at intersections to ensure the facility is safe and comfortable for bicyclists. Signalized intersections require additional design treatment to ensure turning automobiles do not conflict with bicycle traffic, as the protected bikeway places bicyclists to the right of turning vehicles. Preferred solutions include protected intersections or protected right and left turns to remove the right-hook conflict between bicyclists and autos. Protected bikeways should continue up to an

intersection to maximize protection for bicyclists and to truly be considered an All Ages and Abilities facility. A variety of design solutions are available at both signalized and unsignalized locations. For more information, see the FHWA *Separated Bike Lane Planning and Design Guide*, MassDOT *Separated Bike Lane Planning and Design Guide*, and the NACTO *Urban Bikeway Guide*, 2nd edition.

Protected Intersections

Protected intersections should be provided wherever Protected Bikeways and/or Buffered Bike Lanes intersect, wherever room allows. Protected intersections give bicyclists a head start at intersections, improve sight lines between drivers and bicyclists, and reduce pedestrian exposure to automobiles. They also facilitate left-turns for bicyclists. Protected intersections continue the protected bikeway all the way to the intersection and include additional islands that provide queuing space for turning bicyclists and refuge islands for pedestrians. They create predictability of movement, making them comfortable and intuitive.

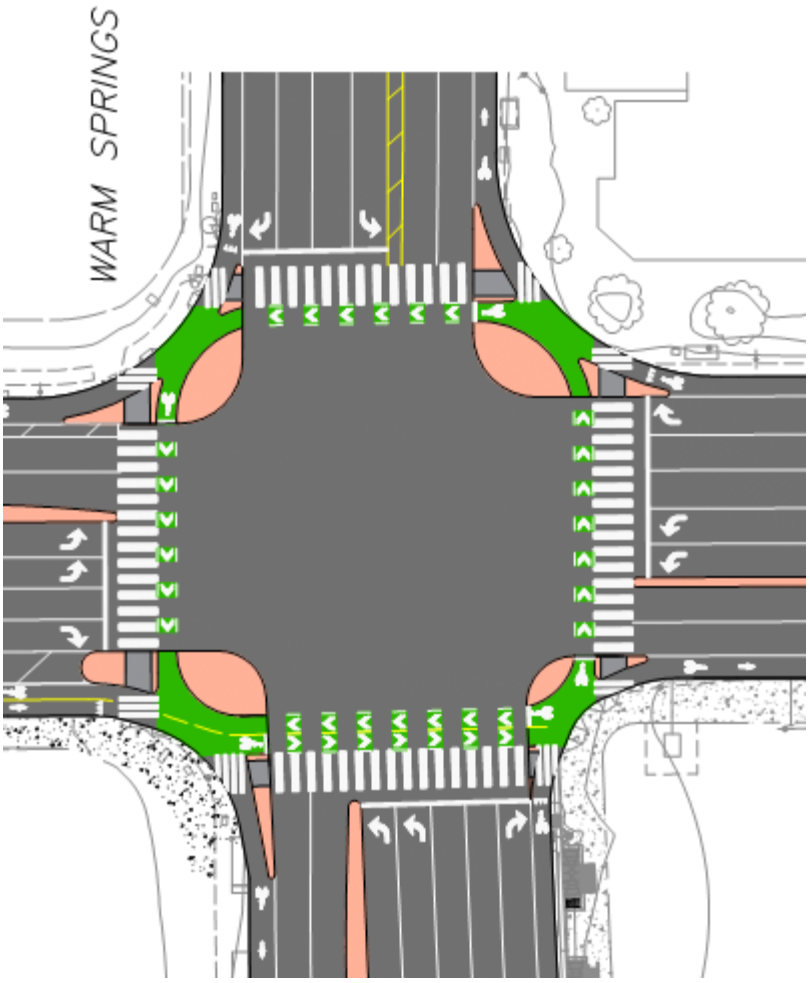


Example protected intersection showing how pedestrians, bicyclists, and drivers use the intersection. Source: MassDOT Separated Bikeway Guide

Protected intersections should generally be provided where two bikeways in the low stress network intersect. Protected intersections should also be considered:

- Where any dedicated bikeways in the network intersect
- At major intersections along separated bikeways where bicyclists need improved sightlines and additional protection from heavy traffic volumes
- Opportunistically at any intersection where bicyclists need assistance making turning movements

Where automobile right-turn volumes are heavy, protected intersections may need to be supplemented with bicycle signals and protected right-turns for autos. For more information, see the FHWA *Separated Bike Lane Planning and Design Guide* and MassDOT *Separated Bike Lane Planning and Design Guide*.



Example protected intersection from planned improvements on Warm Springs Boulevard at the future Wisdom Road. A two stage

Multi-Use Paths

The AASHTO *Guide for the Development of Bicycle Facilities*, 4th Edition should be consulted when planning for and designing trails in Contra Costa County. The following section provides general information and focuses on trail crossing design guidance.

Typical Design

Class I Paths or Multi-Use Paths provide a completely separate right of way for bicyclists and pedestrians. In most cases, paths provide the most comfortable option for people walking and bicycling as they are separated from the roadway and typically have few intersections with autos. Where paths intersect the roadway network, trail crossings are critical. Unsafe trail crossings have higher collision rates which diminish the value of the trail itself. For these reasons, minimizing vehicle and pedestrian cross-flow at crossings to improve the safety of path users is essential. Paths intersecting many driveways and roadways have a high collision potential for cyclists, because drivers exiting driveways or traveling on intersecting roads often do not look for cyclists approaching in the opposite direction of traffic. Thus, the local agencies should consider

warning signs and pavement markings wherever driveways and side streets must cross Class I Paths. The preferred dimension for multi-use paths is 10 to 14 feet wide. The minimum dimension for a path to be considered multi-use is eight feet wide with shoulders.

Preferred Crossing Design

A consistent trail crossing design in Contra Costa will send a consistent message to drivers, pedestrians, and bicyclists alike. The preferred crossing design consists of high-visibility ladder striping or "triple-four" striping, which consists of three 4' segments, two dashed lines on the outside, with a clear space in the center to direct pedestrian traffic. Where the volume of trail users is high, the crosswalk should be widened. Bicyclist and pedestrian pavement legends with arrows may be placed within the triple-four striping to indicate to bicyclists and pedestrians they share the space, indicate the preferred directional path of travel, and reinforce the validity of bicyclists riding through the crossing. The preferred trail crossing design also includes wide curb ramps oriented parallel to the crosswalk, to orient those with mobility impairments as well as bicyclists directly into the marked crossing. Trail crossing enhancements, such as signals and lighted beacons, should be considered at uncontrolled locations.

Trail Crossing Signage

Modified triple-four striping with bicycle legends

Buffered and Standard Bicycle Lanes

The NACTO *Urban Bikeway Guide*, 2nd Edition should be consulted whenever designing bicycle lanes or buffered bicycle lanes in Contra Costa. The following section provides general guidance, definition of terms, and preferred dimensions and practices.

Typical Design

A Class II bicycle lane is typically a six-foot dedicated area for the use of bicyclists designated by striping, signage, and pavement markings. Bicycle lanes improve bicyclist safety by reducing interactions between cyclists and traffic, and by facilitating predictable behavior. Unlike Class IV Separated Bikeways, bicycle lanes have no physical barrier between bicyclists and motorized traffic. Bicycle lanes and buffered bicycle lanes are not necessarily All Ages and Abilities bikeways. They can be when speeds are 30MPH or less and on multi-lane roadways separated with a median. On wider and higher speed roadways, separated bikeways are needed to provide All Ages and Abilities bicycle facilities. When bicycle lanes are installed adjacent to a parking lane, the widths of the parking lane and bicycle lane should total 14 feet or greater (i.e., six-foot bicycle lane next to eight-foot parking lane). Dimensions narrower than 14 feet can be stressful for bicyclists relative to drivers getting into and out of vehicles and potential conflicts in the "door zone."

A striped buffer space separating the bicycle lane from the adjacent motor vehicle travel lane or parking lane distinguishes buffered bicycle lanes. Buffered bicycle lanes feature painted buffers of typically 2 feet or more in width, marked with two solid white lines and interior diagonal cross-hatching. The buffers do not include a raised separation, but that can be phased in with special consideration at intersections to provide separated bikeways. The recommended striped buffer width is 3 feet next to a 6-foot bicycle lane. The minimum striped buffer width is 1.5 feet next to a 5-foot bicycle lane.

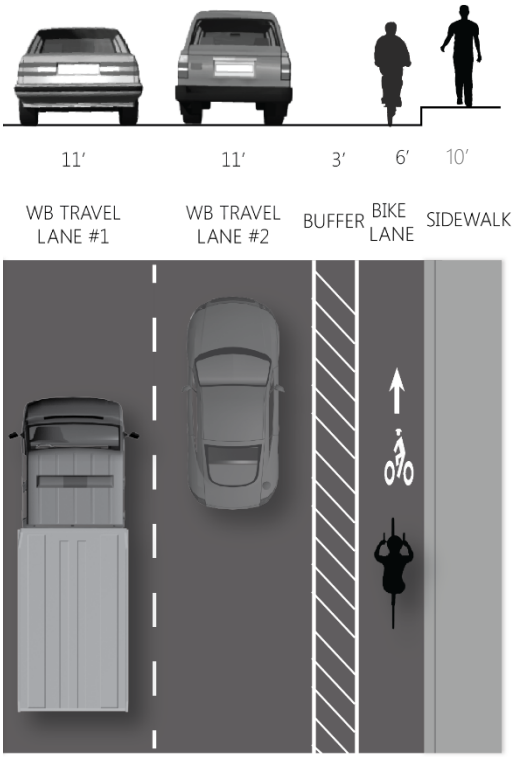


Figure D-8 Buffered Bicycle Lanes Preferred Width

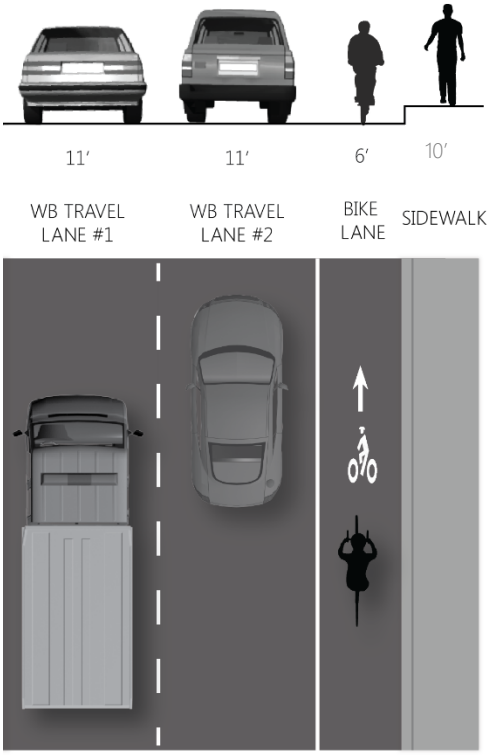


Figure D-9 Bicycle Lanes Preferred Width

Typical Design Elements

In addition to those described above, green "skip" striping should be applied at conflict zones and major driveways where cars will frequently turn or merge across the bicycle lane. This includes slip lanes, right-turn pockets, and large commercial driveways with heavy turnover. Where right-turn lanes or pockets are added, such as at signalized intersections or at freeway ramps, the bicycle lane should remain adjacent to the curb until approximately 200 feet or less before the intersection, at which point the bicycle lane should transition with colorized green markings between the through and right travel lanes. Bicycle lanes should always be striped up to the stop bar/crosswalk and should not drop to allow for turn pockets to be added.

Buffered bicycle lane with wayfinding signage

Green skip-striping at intersection where cars may merge across or into the bicycle lane

Design Issues to Consider

The minimum width of a bicycle lane should be five feet against a curb or adjacent to a parking lane, with six feet as the preferred standard with. A minimum of four feet of rideable surface must be clear of gutter pans. Poor pavement quality and inconsistent striping or disappearing lanes are also design issues of concern for bicycle lanes and other on-street facilities.

Bicycle lane painted over gutter pan

Poor pavement quality in a bicycle lane

Neighborhood Bikeways

The NACTO *Urban Bikeway Guide*, 2nd Edition should be consulted whenever planning for or designing neighborhood bikeways in Contra Costa. This section provides general guidance on neighborhood bikeways.

Typical Design

Neighborhood bikeways are low-volume, low-speed streets shared by bicyclists and autos. These are comfortable for bicyclists due to the low number of interactions with automobile traffic. Typically, these are located as alternative routes to higher speed collector and arterial roadways. Neighborhood bikeways have sharrows, wayfinding signage, enhanced facilities at crossings of major arterials, and traffic calming measures where appropriate. Neighborhood bikeways are intended for local/residential streets with low speeds and volumes. Maintaining low volumes and speeds on these streets is critical, as many of these routes serve children – who have less experience riding – as bicycle routes to school.

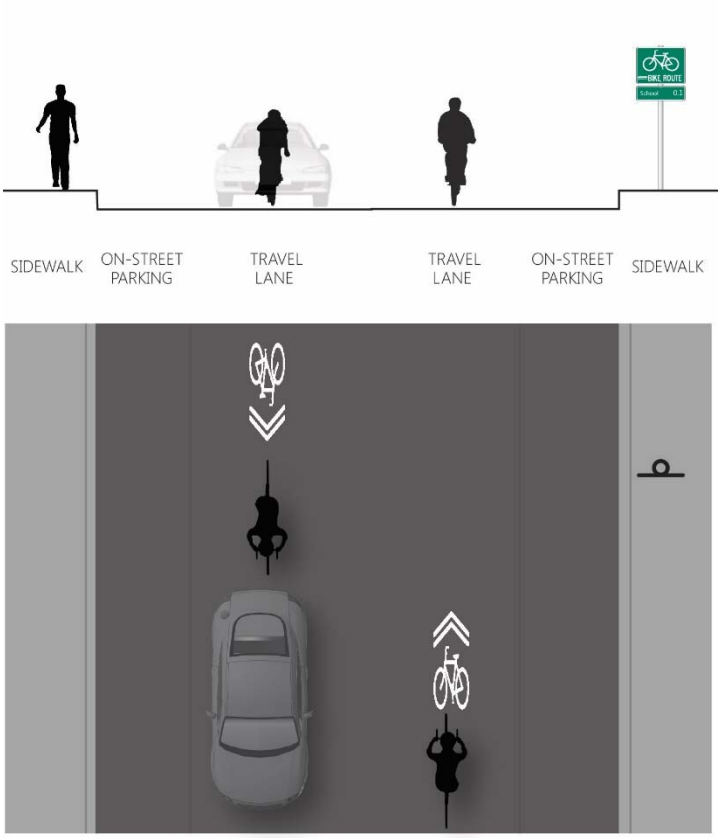


Figure A-10 Neighborhood bikeway Preferred Widths

Standard Neighborhood Bikeway Elements

In addition to the elements described above, wayfinding is an important element of neighborhood bikeways. This is because in taking advantage of quieter streets, neighborhood bikeways often involve some turns. Wayfinding confirms bicyclists are on the preferred path and provides information about how to get to nearby destinations. Wayfinding signs also help brand the local bicycle networks, and inform cyclists by identifying intersecting bikeways and travel times to nearby destinations.

Bicycle route wayfinding with destinations and distances

Enhanced crossing of arterial via median refuge traffic diverter

Potential Traffic Calming Enhancements

Enhancements to neighborhood bikeway streets should consider both roadway volumes and speeds. To be an All Ages and Abilities bikeway, speeds and volumes should be low. The NACTO *Urban Bikeway Guide* establishes volume and speed thresholds for neighborhood bikeways. These treatments benefit bicyclists while also helping to create "quiet" streets for residents and other road users.

Speed lump

Chicane

Traffic circle on neighborhood bikeway

Bikeway Crossing Treatments

Where bikeways intersect major roadways, additional support is needed to assist bicyclists in crossing these roadways. While many of these locations in Contra Costa are signalized, which is helpful, additional enhancements can be provided. These enhancements may be put into one of two general categories: signals and detection and intersection design.

Signals and Detection

Bicycle signals help bicyclists cross busy streets by clarifying when they should enter the intersection and by restricting conflicting vehicle movements. The type of signals will depend on the type of crossing streets, the number and speed of vehicles on both crossing streets, and the design of the intersection itself. There are three main types of signals:

- **Active warning beacons** are user-actuated amber flashing lights that supplement warning signs at unsignalized intersections or mid-block crosswalks. Beacons can be actuated either manually by a push-button or passively through detection. These can significantly increase the number of vehicles that yield to bicyclists and are much lower cost than fully signalizing an intersection.

Example of an uncontrolled bicycle and pedestrian crossing with pedestrian activated warning device

- **Bicycle signals** are typically used to improve identified safety or operational problems involving bicycle facilities or to provide guidance for bicyclists at intersections where they may have different needs from other road users (e.g., bicycle only movements, leading bicycle intervals). They should only be used in combination with an existing conventional traffic signal or hybrid beacon. Bicycle signals accommodate of bicycle-only movements within signalized intersections, helps to simplify bicycle movements, and separate bicycle movements from conflicting motor vehicle, streetcar, light rail, or pedestrian movements. Especially where children or seniors are expected, crossing times should be set to reflect the time needed by pedestrians and bicyclists.

- A **hybrid beacon**, also known as a High-intensity Activated CrosswalK (HAWK), consists of a signal-head with two red lenses above a single yellow lens on the major street, and pedestrian and/or bicycle signal heads for the minor street. While they were developed specifically to enhance pedestrian crossings of major streets, several cities have installed modified hybrid beacons specifically for bicycle movements. The hybrid beacon can significantly improve the operations of a bicycle route, particularly along bicycle boulevards. Because of the low traffic volumes on these facilities, intersections with major roadways are often unsignalized, creating difficult and potentially unsafe crossing conditions for bicyclists.

Bicycle detection is used at actuated signals to alert the signal controller of bicycle crossing demand on a particular approach. Bicycle detection occurs either through the use of push-buttons or by automated means (e.g., in-pavement loops, video, microwave, etc.). To work well, bicycle detection must meet two criteria: it accurately detects bicyclists, and it provides clear guidance to bicyclists on how to actuate detection (e.g., what button to push, where to stand). There are four primary types of bicycle signal detection:

- **Loop** – Induction loop embedded in the pavement
- **Video** – Video detection aimed at bicyclist approaches and calibrated to detect bicyclists
- **Push-button** – User-activated button mounted on a pole facing the street
- **Microwave** – Miniature microwave radar that picks up non-background targets

Induction loop detectors are the most common technology for detecting bicyclists at signalized intersections. They are coils of wire set into the pavement that, by sensing changes in their surrounding electromagnetic field caused by a bicycle, alert traffic lights to change to permit a bicyclist to cross. To detect a bicycle, however, it needs to be directly above the loops and the electromagnetic field they generate. To ensure this, markings need to clearly inform bicyclists where to place their bikes and staff must calibrate the loops to ensure that the loops are able to detect them.

In **video detection**, images from cameras pointed at the intersection use special algorithms to identify bicyclists and change traffic signals to allow them to cross the roadway. To work effectively, the intersection must be well-lit, which may be an issue in inclement weather. Agencies in the Bay Area have had issues where fog is common.

Push-buttons, which are frequently used for pedestrians at intersections, may also be used to change signals so that bicyclists may cross the roadway. The push-buttons work well when bicyclists share the sidewalk with pedestrians (though sharing the sidewalk raises its own issues) but are inconvenient for bicyclists who must dismount to push the button.

Microwave detection uses microwave technology to monitor intersections and determine whether objects moving in the roadway are vehicles or bicyclists, without the need for them to be directly over sensors. Microwave detection can be used to extend green lights for bicyclists to pass through the intersection.

The following table outlines the advantages and disadvantages of these four main types of detection technologies.

Method	Description	Advantage	Disadvantage
Induction loop detectors	Inductive loops embedded in the pavement to detect the presence or passage of a bicycle. Induction loops are the most common detector used.	• Induction loops can be positioned anywhere which enables options for advance and stop line detection. • Induction loops can be used to detect once a bicycle has travelled through an intersection. • Sensitivity can be adjusted to enable detection of bicycles rather than vehicles when used in shared lanes. • Performs well in all weather.	• Different layout arrangements have different areas of detection sensitivity which could be missed if not highlighted to riders. • Must be recut when carriageway resurfaced. • Alternative materials such as carbon fiber rims can reduce detection reliability. • Rider is not informed that their demand has been recorded.
Video detectors	Processes images from camera.		• Sensitive to light. • Have been expensive, but costs are dropping. • Rider is not informed that their demand has been recorded.
Push button	User activated button mounted onto a pole facing the street.	• Unquestionable demand. • Rider is aware that their demand has been recorded. • An LED light on the push button can be displayed to show demand placed.	• No option for advanced detection. Requires riders to wait for bicycle phase. • Requires grab rails or bicycle boxes.
Microwave detection	Mounted on a structure above the roadway.	• Performs well in all weather. • Sensitivity can be adjusted to enable detection of bicycles rather than vehicles.	• Only registers a moving bicycle. • Has a limited range of view for detection • Rider is not informed that their demand has been recorded.

Source: *Traffic Signal Features for Bicycles*, Australian Bicycle Council, 2017

For more information, see the NACTO Urban Bikeway Guide on bicycle signals: https://nacto.org/publication/urban-bikeway-design-guide/bicycle-signals/.

Intersection Design

A number of treatments can be used at intersections to make crossing for people on bikes easier. They include bicycle boxes, two-stage turn boxes, traffic diverters, and intersection crossing markings.

Two-stage turn boxes facilitate bicyclist left turns, allowing them to cross the intersection in two stages, making an "L" through the intersection. First, the bicyclist proceeds straight with traffic and a green box provides them a space to queue ahead of opposing traffic that has a red signal. When the cross street receives a green signal, the bicyclists proceeds straight with traffic.

Bike boxes, similar to advanced stop bars, provide a designated space for bicyclists to queue ahead of traffic. This discourages right-hook collisions between drivers and bicyclists, and can provide a space for bicyclists to make two stage turns. Both should be implemented with no right turn on red restrictions to avoid motorists encroaching into the bike space.

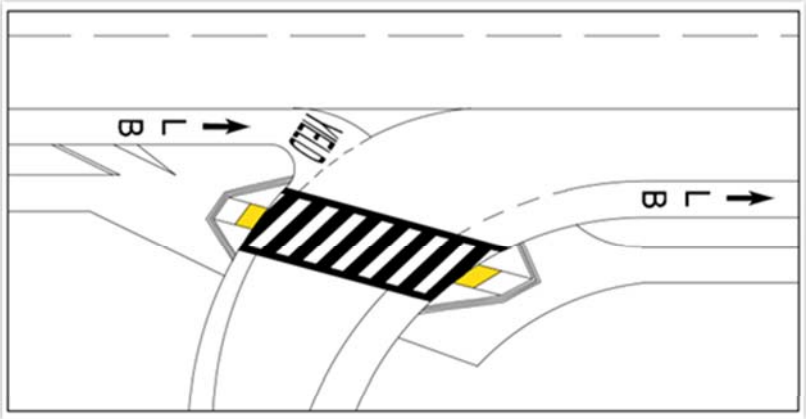
Bicycle Box

Traffic diverters, where feasible, can be used at the entrance to streets or as median refuges to allow bicyclists to cross the major roadway in two stages. They provide a protected space that both bicyclists and pedestrians can use to cross only one direction of traffic at a time on a major arterial. Bicyclists can thus take advantage of gaps in one direction of traffic at a time and reduces the overall crossing length and exposure to vehicle traffic for both people who walk and bicycle.

Intersection crossing markings such as green conflict zone striping and extending the bike lane through the intersection indicate the intended path of bicyclists through the intersection. These markings can reduce conflicts between bicyclists and motorists by raising awareness for both to potential conflict areas; guiding bicyclists through the intersection and making bicycle movements more predictable; and reinforcing that through bicyclists have priority over turning vehicles or vehicles entering the roadway. This type of treatment is typically used along roadways with bike lanes or separated bikeways across signalized intersections, especially wide or complete intersections, as well as across driveways and Stop or Yield-controlled cross streets.

For more information, see the *NACTO Urban Bikeway Guide* on neighborhood bikeway crossing treatments: http://nacto.org/publication/urban-bikeway-design-guide/bicycle-boulevards/major-street-crossing/.

Bicyclists at Interchanges



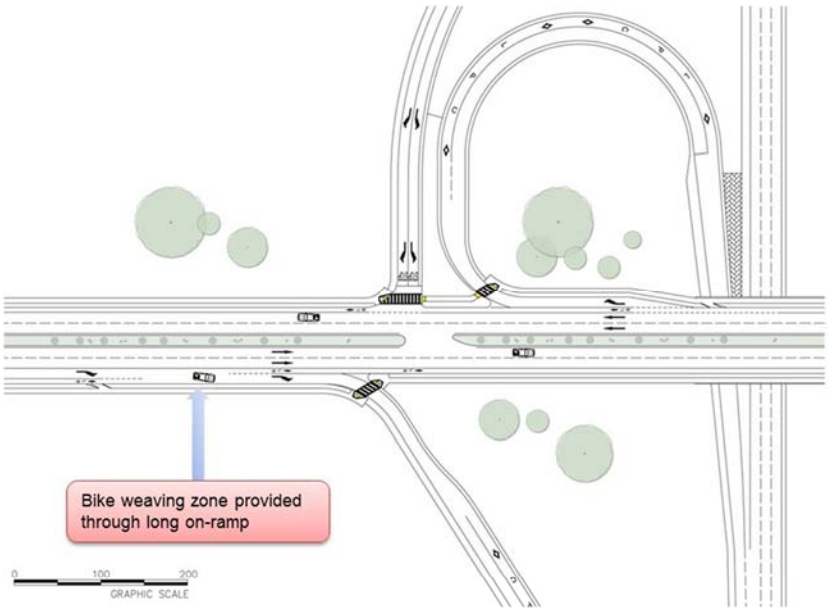
Bike Lane Crossing Detail at Highway Interchanges

Interchanges are difficult to navigate and stressful for pedestrians and bicyclists due to the high speeds and volume of vehicles. New techniques have been developed for improved interchange design to better accommodate both pedestrians and bicyclists with respect to safety and accessibility while effectively moving auto traffic. ITE's *Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges* presents preferred concepts for providing safe, comfortable connections for bicyclists and pedestrians through a variety of highway ramp geometries that are fully compliant with national design standards. The report should be consulted when considering enhancements at interchanges. The following should always be considered when pedestrian facilities and bikeways are considered near and/or through interchanges:

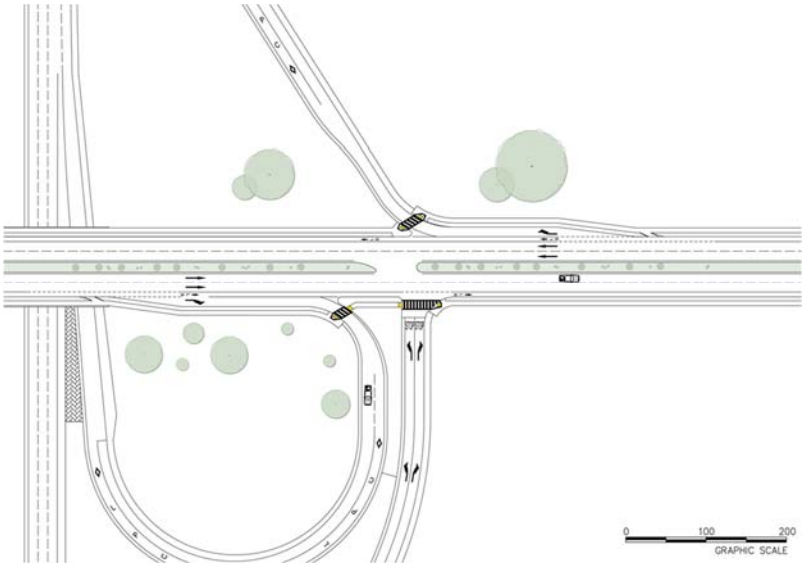
- "Square up" all ramps to improve multi-modal safety and reduce curb radii to reduce vehicle speeds for vehicles entering/exiting on/off ramps (see inset image)
- Provide single lane approaches at on-ramps, where possible, to minimize the number of conflict points between pedestrians, bicyclists, and vehicles (e.g. start HOV lanes downstream of the crosswalk),
- Site crosswalk to "split the difference" between the shortest crossing distance and slowest vehicle speed through the turn, where speed is lowest and visibility is highest (see inset image)
- Use the X-Walk+ ASAP-branded Tool[8] (or other current best practice resource) to select appropriate crossing treatments, which can range from advance yield or stop lines, raised crosswalks, to a pedestrian hybrid beacon or a pedestrian traffic signal

[8] Fehr & Peers (2017). Xwalk+ ASAP Tool. See http://asap.fehrandpeers.com/complete-streetslayered-networks/xwalk/ for more information.

- Provide multiple options for bicyclists to navigate through interchanges, including separated bikeways on the street and enhanced crosswalks and bicycle ramps to allow bicyclists to use the sidewalk through the ramps
- Add bike weaving zone at long on-ramps (see inset figure below), placing the bicycle lane between two lanes of auto traffic for no longer than 150'
- Keep bicycle lanes curbside until 150' before the ramp intersection to minimize the distance bicyclist have to ride between two auto travel lanes



Recommended Bicycle and Pedestrian Improvements at On Ramp Entered from Long, Single Right Lane



Recommended Bicycle and Pedestrian Improvements at Arterial Entered from Stop/Merge Off Ramp (Combined Ramps)

Bicycle Parking

Bicycle parking facilities are necessary to provide safe, convenient, and secure places to park bicycles at trip ends while people are working, going to school, accessing transit, shopping or doing other activities. Lack of adequate, secure bicycle parking can be a major deterrent to riding a bicycle. Bicycle parking facilities are typically classified either as long-term (also known as Class I) or short-term (Class II). Class I parking is meant to be used for more than two hours and is typically used by employees at work, students at school, commuters at transit stations and residents at home. Class I facilities are secure and weather-protected: examples include bicycle lockers and "bicycle corrals" (fenced-in areas usually secured by lock and opened by keys provided to users). Class I facilities are typically located in civic centers, office buildings and multi-family residential buildings. Class II, or short-term parking, is meant for visitors, customers at stores and other users who normally park for less than two hours. The most common example of Class II parking is bicycle racks. All bicycle parking facilities should be purchased, installed, and sited per the design guidelines in the APBP *Bicycle Parking Guidelines*, 2nd Edition.

Recommended Enhancements

Agencies should consider the following recommended enhancements to the bicycle-parking requirements:

1. Update local agency Municipal Codes to provide bicycle parking and end-of-trip facilities (e.g. shower and lockers) requirements with all new development, using the parking generation factors from the Association of Bicycle and Pedestrian Professional's (APBP's) *Bicycle Parking Guideline,* 2nd edition.

2. Select, site, and install bicycle parking fixtures and facilities per the APBP *Bicycle Parking Guidelines*, 2nd edition.

3. Require new developments to provide the location and amount of bicycle parking to the local agency's Traffic Engineering Division to allow for easy tracking and mapping. Also, record the location of new bicycle racks installed by transit agencies.

4. Develop and implement a campaign to educate users on how to securely park bicycle and prevent theft.

5. Consider working with local artists and across the region to create decorative branded racks for major destinations.

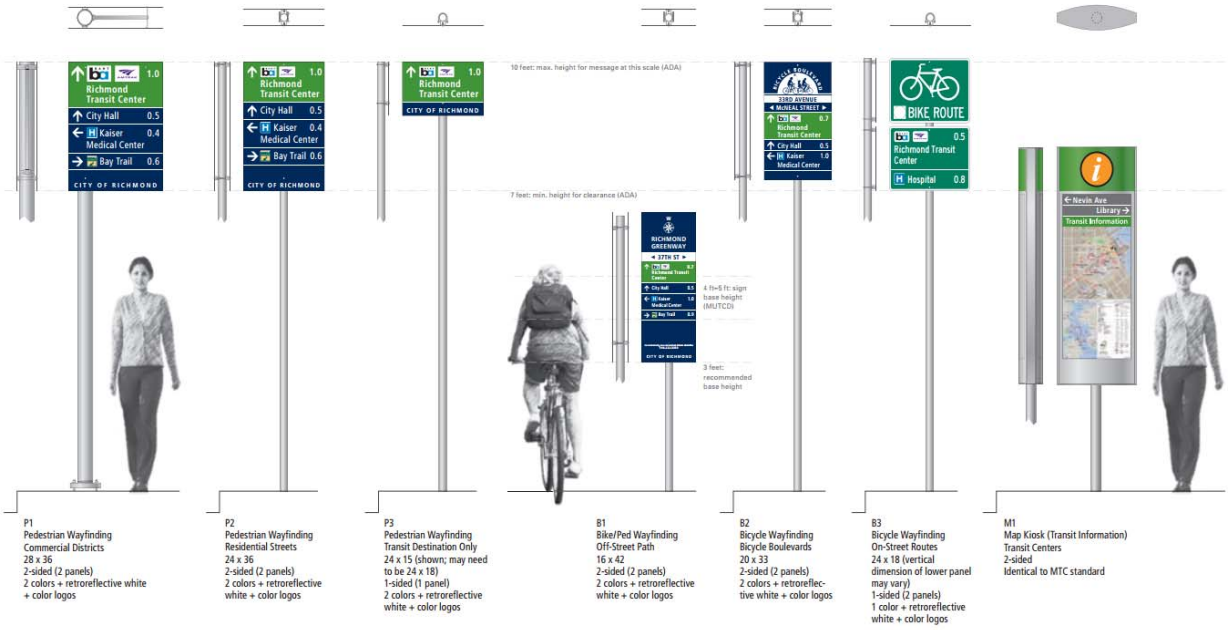
Green Infrastructure

Green infrastructure and sustainable stormwater management treatments such as bioswales, flow-through planters, pervious strips, and pervious pavement should be used whenever possible with bikeway and complete streets design.

For more information, see the *NACTO Urban Street Design Guide* on stormwater management: http://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/. The City of San Francisco also has developed *Stormwater Design Guidelines* as well as construction level detail for stormwater design treatments in their *Green Stormwater Infrastructure Typical Details* document: http://sfwater.org/index.aspx?page=446.

Wayfinding

A high quality bicycle network also includes wayfinding to assist residents and visitors in navigating Contra Costa and accessing key destinations by bicycle. Wayfinding is important on trails and along on-street facilities, particularly neighborhood bikeways meandering through residential communities. Bicycle wayfinding should be placed at an appropriate height for bicyclists. Signs confirm directions to nearby destinations and typically include estimated time or distance to those destinations. Wayfinding signs should be CA MUTCD-compliant, installed at key decision points in the bicycle network, and include confirmation signs that display destinations and mileage. Local agencies and small communities should consider a branded wayfinding program for neighborhood bikeways, bicycle routes, trails, and other destinations.



Local agencies and communities could establish a branded wayfinding program similar to that developed by the West Contra Costa Transportation Advisory Committee (WCCTAC) Transit Enhancement Plan and Wayfinding Guide, shown above.

F. Pedestrian and Bicycle Demand Forecasting

CCTA has developed simple Excel-based tools to calculate future bicycling and walking demand based on updated research regarding facility investment and associated mode shifts. These tools are meant to provide a quick and consistent way for local agencies to forecast future use of new facilities. Using these tools, local agencies will be able to be able to pursue grant opportunities without having to estimate ridership themselves, thus reducing barriers to obtaining grant funding.

These models are available by contacting Authority staff.

F.1 Walk Mode Share Model

The walk mode share model is a linear regression model developed by the Alameda County Transportation Commission as part of the Bicycle and Pedestrian Master Plan Demand Forecast Tool.[9] In this case, walk mode share for each TAZ is predicted from its population density, retail and service employment density, the percentage of households owning zero vehicles, and whether the TAZ has transit service within ¼ mile. The model was developed from data from the 2012 California Household Travel Survey and EPA's Smart Location Database. Here it is applied to Traffic Analysis Zones from the Contra Costa (CCTA) travel demand model. The data dictionary provides a list of required variables from model inputs (land use variables) and intermediate outputs (auto ownership model).

The Zonal Mode Share Forecast tab contains the calculations required to produce estimated 2010 and 2040 walk mode shares for each zone. The Mode Share Summary tab aggregates the zonal estimates to a single estimate of walk mode share, and provides a simple tabular summary of population in zones with walk mode shares in certain ranges (e.g. under 8 percent walk mode share or over 20 percent walk mode share).

F.2 Bike Mode Share Model

The bike mode share model is based on the miles of bicycle facilities (bike paths or bike lanes) in the county as compared to the number of bicycle commuters in the county. It applies a simple elasticity — in this case, how much the number of bicycle commuters increases based on the change in miles of bicycle facilities — from the research literature ("Cycling to work in 90 large American cities: new evidence on the role of bike

[9] A linear regression model is a linear equation of the form $y = a + b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_nx_n$ which predicts the value of one variable y from the values of one or more other variables x_1, x_2, x_3, etc. The coefficients b_1, b_2, b_3, and the constant a are selected to minimize the aggregate prediction error, measured as the sum of squared differences between predicted and actual values.

paths and lanes" by Ralph Buelher and John Pucher, 2012). Although the paper of Buehler and Pucher separates bike paths and bike lanes into two classes of facilities with separate elasticities, they note that the difference between the calculated elasticities is not statistically significant. For this reason, and because the separate elasticities do not provide intuitively reasonable results, the two elasticities are used to provide a range of plausible bicycle mode share estimates.