Memorandum

Bicycle Boulevard Treatments

Emeryville Pedestrian and Bicycle Plan

March 30, 2011

Submitted by: Alta Planning + Design

Table of Contents

Table of Tables

Table of Figures

This page left blank intentionally.

1. Introduction and Background

Bicycle boulevards are generally defined as low-volume, low-speed streets that have been optimized for bicycle travel using treatments such as traffic calming and traffic reduction, signage and pavement markings, and intersection crossing treatments. These treatments allow through-movements for bicyclists while discouraging similar through-trips by nonlocal motorized traffic. Jurisdictions throughout the country use a wide variety of strategies to determine where specific treatments are applied.

The City of Emeryville considers Bicycle Boulevards as one of the basic street "typologies" of the city's circulation system as set forth in the Circulation Element of the General Plan. Under Section 3.2 Circulation System, Bicycle Boulevards are defined as follows:

> *These are through-routes for bicycles providing continuous access and connections to the local and regional bicycle route network. Through-motor vehicle traffic is discouraged. High volumes of motor vehicle traffic are also discouraged, but may be allowed in localized areas where necessary to accommodate adjacent land uses. Local automobile, truck, and transit traffic are accommodated in the roadway, but if there are conflicts, bicycles have priority. Traffic calming techniques to slow and discourage through-automobile and truck traffic may be appropriate. Pedestrians are accommodated with ample sidewalks on both sides of the road.*

Emeryville has a partially developed bicycle boulevard network, with the main existing north-south route following Horton Street / Overland Avenue between 40th Street and 65th Street. Other existing bicycle boulevard segments include 59th Street between Horton and Doyle, and Doyle Street north of 59th Street. Proposed segments recommended for inclusion in the *Pedestrian and Bicycle Master Plan* include Stanford Avenue, Doyle Street south of 59th Street, and 45th, 47th, and 53rd Streets.

In late 2009, the Bicycle and Pedestrian Advisory Subcommittee (BPAC) forwarded a recommendation to the Transportation Committee to adopt specific vehicle speed and volume "metrics" for Emeryville's bicycle boulevard network. These would serve as thresholds that, if exceeded, would trigger traffic calming improvements in order to reduce the vehicular speeds and /or volumes. The BPAC recommended 3,000 average daily trips (ADT) and 25 mph as metrics. The recommendations of the BPAC were considered at the November 2009 Transportation Committee meeting and at the December 15, 2009 City Council meeting. Neither the Transportation Committee nor the City Council chose to take any action to approve the metrics, but instead directed staff to conduct further study of the issue.

This memorandum is intended to provide guidance to the City regarding the adoption of metrics for bicycle boulevards. It provides a summary of current bicycle boulevard standards and best practices drawn from published guidelines and case studies of other communities. Based on this summary, the memorandum then presents recommended speed, volume, and intersection delay goals for Emeryville's bicycle boulevards. Finally, it describes how closely the City's existing and proposed bicycle boulevards meet these goals, and provides recommendations for improving the City's bicycle boulevards to meet these goals. After review by the BPAC and further discussion with the City, the resulting recommendations provided here will be incorporated into the City's Pedestrian and Bicycle Plan.

2. Bicycle Boulevard Standards and Best Practices

Bicycle boulevards have been implemented in several cities throughout the country, and while no federal guidelines exist, several best practices have emerged for their development. This section summarizes standards and best practices for the development of bicycle boulevards, drawn from published materials and interviews with agency staff working to implement bicycle boulevards in communities throughout North America.

People Contacted

The following city staff were interviewed about bicycle boulevard practices and policies. Case studies from these interviews are described in the following section.

- Nathan Wilkes, Engineer, City of Austin, Texas
- Eric Anderson, Associate Planner, City of Berkeley, California
- Rafael Rius, Transportation Engineer, City of Palo Alto, California
- Roger Geller, Bicycle Coordinator, City of Portland, Oregon
- Scott Batson, Engineer, City of Portland, Oregon
- Sam Woods, Manager of Traffic Calming, Pedestrian and Bicycle Program, City of Seattle, Washington
- Luke Korpi, Senior Civil Engineer, City of Seattle, Washington
- Mike Anderson, Civil Engineer, City of Vancouver, British Columbia

Key Published Materials

The following published materials were reviewed. An annotated bibliography is provided as an appendix.

- *Guide for the Development of Bicycle Facilities.* American Association of Highway Transportation Officials (AASHTO) National Cooperative Highway Research Program, Project #15-37 (2010 proposed update).
- *Bicycle Boulevard Planning and Design Handbook.* Alta Planning + Design and Initiative for Bicycle Pedestrian Innovation. (2009).
- *BikeSafe: Bicycle Countermeasure Selection System.* U.S. Department of Transportation Federal Highway Administration (FHWA). (No date).
- *Bicycle Boulevard Design Tools and Guidelines.* City of Berkeley. (2000).
- *Policy Guidelines: "Bicycle Boulevards".* City of Napa. (2005).
- *Portland Neighborhood Greenways-Goals.* City of Portland. (2010).
- *Traffic Calming: State of the Practice.* Ewing, Reid. (1999).
- *Responding to the Challenges of Bicycle Crossings at Offset Intersections. Third Urban Street Symposium.* Hendrix, Michael. (2007).
- *Neighborhood Traffic Calming: Seattle's Traffic Circle Program.* Road Management & Engineering Journal. (1998).
- *U.S. Traffic Calming Manual.* American Planners Association (APA). (2009).

2.1. Case Studies

This section summarizes information gathered through interviews with staff at cities that have implemented bicycle boulevards. Eight staff in six communities were interviewed, representing the majority of jurisdictions currently implementing bicycle boulevard treatments.

Albuquerque, New Mexico

In 2007, the City of Albuquerque adopted a resolution for the development of bicycle boulevards. The resolution establishes the conversion of local streets to create bicycle boulevards, stating that the City will use "a package of traffic tools that transform a residential street into a 'bike expressway' that also accommodates local motor traffic." Since 2007, the City has begun implementing three bicycle boulevards by adding distinctive pavement markings and signs (Figure 1).

Street Selection

The resolution formally designates three bicycle boulevards in the city and dedicates funding to the planning and development of the boulevards. These streets were selected in conjunction with bicycle advocates.

Intersection Treatments

Albuquerque's resolution specifies that removing stop signs from the boulevard (turning onto cross-streets) and stopping traffic approaching from intersecting streets are acceptable bicycle boulevard treatments. It also allows the installation of bicycle-actuated signals or mid-block crossings at intersections with major streets. None of these treatments have been implemented at this time. Phase II of implementation will likely include turning stop signs to control minor cross streets.

Figure 1. Bicycle boulevards in Albuquerque incorporate distinctive bicycle pavement markings.

Speed Control Measures

The resolution allows removal of barriers and detours to through-bicycling, as well as other speed/volume control measures. Albuquerque signs all bicycle boulevards at an 18 mph speed limit, a treatment unique to the city. The City has not monitored the extent to which motorists comply with the speed limit, nor whether the bicyclists perceive an improved environment.

Albuquerque has a Neighborhood Traffic Management Program, which establishes that speed humps can be used where a local residential street carries more than 500 vehicles per day (vpd) traveling more than five mph over the speed limit. This program can be used to manage vehicle speeds on bicycle boulevards.

Volume Control Measures

The City defines a local residential street as having a cut-through problem if it carries more than 1,500 vpd with more than 30 percent cutting through from one major street to another. The City's bicycle boulevard resolution allows installing bike permeable street closures and mandatory turns that admit bicycles through the closure. However, the diverters that were installed have since been removed due to engineering issues.

- Additional information: http://www.cabq.gov/bike/documents/fsr-07-268.doc

Austin, Texas

Austin is currently developing a bicycle boulevard on Rio Grande Street in the downtown area, which is scheduled for completion in spring 2011.

Street Selection

Rio Grande Street was selected as the bicycle boulevard based on public input, connections to schools, traffic impacts, motor vehicle safety, bicycle and pedestrian mobility and safety, first response routes, and motor-vehicle travel time. A comparable alternative alignment was not selected due to future plans for a streetcar, which may be hazardous for bicyclists.

Intersection Treatments

The Rio Grande bicycle boulevard project incorporates four "landscaped modern roundabouts," shown in Figure 2. This design would require bicyclists to take the lane to travel through the roundabout, which works best when traffic speeds are close to bicyclist speed. Most intersections along the corridor currently have four-way stops, and the proposal will remove two stop signs at each intersection. The stop signs will be "woven" so that every other pair faces the bicycle boulevard.

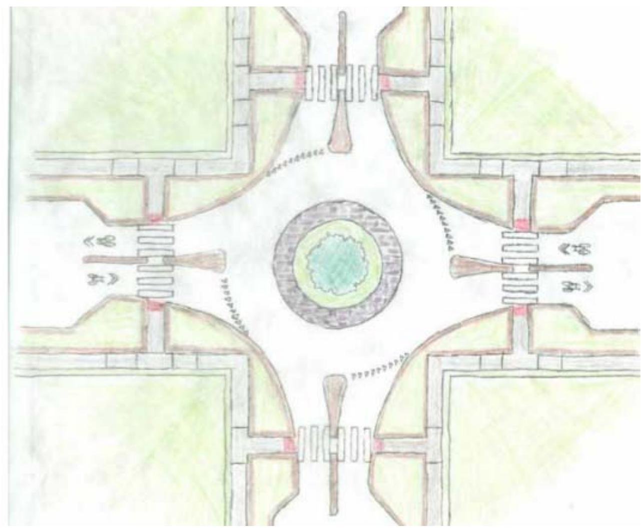


Figure 2. Landscaped modern roundabout design for downtown Austin bicycle boulevard
Source: http://www.ci.austin.tx.us/publicworks/downloads/bike_blvd_update_9_8_10.pdf

Speed Control Measures

The City plans to track before- and after- motor vehicle speeds, although no specific thresholds for implementing additional treatments have been set. The speed limit on Rio Grande will be reduced from 30 mph to 25 mph, and further reductions may be considered based on impacts of the traffic calming treatments. In general, traffic calming in Austin is a challenge, as the streets are not in a grid network except in the downtown area, and traffic calming treatments are limited on collector streets.

Volume Control Measures

Rio Grande Street currently has between 3,000 to 3,500 vpd and runs through a historic commercial district. No diversion is being considered at this time.

- Additional information:
    - http://www.ci.austin.tx.us/publicworks/downloads/bike_blvd_update_9_8_10.pdf
    - http://www.ci.austin.tx.us/publicworks/downloads/phase_2_downtown_bicycle_boulevard_recommendation_final_report.pdf
- Contact: Annick Beaudet, Bicycle Coordinator; Nathan Wilkes, Engineer

Berkeley, California

The City of Berkeley has been developing bicycle boulevards since the Bicycle Plan was adopted in 1999. Seven bicycle boulevards are currently designated. The City is using a phased approach for developing the bicycle boulevard network. After a trial, Phase I involved installing pavement markings and signs along all designated streets. Phase II will improve arterial street crossings. Berkeley's Bicycle Boulevard Design Tools and Guidelines (2000) provides an overview of strategies used to develop bicycle boulevards, including issues addressed, typical application, implementation guidelines, design suggestions, and cost.

Street Selection

Many of the treatments used on bicycle boulevards in Berkeley were implemented as part of the Traffic Calming Program in the 1970's; bicycle boulevard alignments were chosen in part due to the presence of traffic calming. Criteria used to select streets to implement bicycle boulevard treatments on include:

- Local street or low-volume collector
- Not a transit or truck route
- Very little commercial frontage
- Within a quarter-mile of a major street or a high-traffic collector street
- Spaced between three-quarters and 1.5 miles from another bicycle boulevard (approximately the traditional spacing of major streets)
- Reasonably continuous (i.e., extends over half of the cross-section of the city)
- Few jogs with main segments at least a half-mile long
- Traffic signals at major intersections, or traffic signals are potentially feasible
- Access to major destinations
- Connections to routes in neighboring cities

Intersection Treatments

Improving crossings of arterial streets is a secondary priority for the development of bicycle boulevards in Berkeley. A contraflow bicycle lane is provided in one location to facilitate continuous bicycle travel where the corridor turns onto a one-way street. Most arterial crossings do not have specific improvements to facilitate bicycle travel.

Speed Control

Berkeley does not have a pro-active program to control speeds on bicycle boulevards. The Berkeley Traffic Calming Program provides warrants for traffic calming treatments, but the process is request-based and does not apply to the development of bicycle boulevards. Bulb-outs and speed humps are the primary speed control treatments used on bicycle boulevards in Berkeley.

Figure 3. Chicanes narrow travel lanes to reduce motor vehicle speeds in Berkeley.

Volume Control

Berkeley's 1990 Bicycle Master Plan cited 3,000 vpd as a threshold for a Class III bicycle route, over which a street should be considered for Class II bicycle lanes. However, the City does not designate a threshold for automobile speeds or volumes on bicycle boulevards, as design and treatments should be sensitive to the context of the roadway. The highest volume of vehicles on a bicycle boulevard in Berkeley is approximately 1,600 vpd.[1] Volume control treatments used in Berkeley include diagonal diverters, right-turn diverters, and full diverters. As noted earlier, these treatments were installed prior to the bicycle boulevards development.

- Additional information: http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=6560
- Contact: Eric Anderson, Planner

Palo Alto, California

The bicycle boulevard constructed on Bryant Street in Palo Alto in 1982 is generally considered the first bicycle boulevard in the country.

Street Selection

Palo Alto has developed bicycle boulevards on streets with existing traffic calming, pedestrian bridges and full or partial closures. The City generally considers the following features when identifying a potential bicycle boulevard:

- Low traffic volumes
- Not attractive for non-local motor vehicle traffic
- Free flow travel for bikes or reasonable ability to create right-of-way for bicycle traffic at intersections (i.e. reversing or creating two-way stop control for the crossing streets)
- Traffic control at major streets to assist crossing bicycle traffic
- Continuous streets with few jogs, and segments of a half-mile or longer

The Palo Alto BIKESAFE case study indicated that the City's goals for Bryant Street included reducing motor vehicle volumes and car-bike conflicts. The existing pedestrian-only crossing was upgraded to accommodate the anticipated levels of bicyclists, and additional improvements included two bicycle-permeable street closures, turning of most stop signs to control cross-traffic. A 1982 study found that motor vehicle volumes remained consistently less than 1,000 vpd along the corridor, despite the turned stop signs facilitating through-traffic on the street.

Intersection Treatments

The City Bicycle Transportation Plan (2003) notes a desire to reduce the number of stop signs to minimize bicyclist delay on bicycle boulevards. On newly developed bicycle boulevards, Palo Alto is considering turning stop signs to control cross-traffic and potentially converting some four-way stop-controlled intersections to two-way (controlling cross-traffic).

Speed Control

The City intends to measure speeds to track whether they increase when stop signs are turned to favor the bicycle boulevard. If speeds increase over 32 mph, the City would consider installation of speed humps, as right-of-way is generally insufficient to accommodate traffic circles. Bulb-outs will be used at intersections where pedestrian activity is high, particularly where the bicycle boulevard travels through a business district.

[1] The only exception is on Milvia Street. A bike lane is provided through the higher-volume section to provide a continuous route.

Palo Alto has specific warrants for implementation of traffic calming:[2] a neighborhood group requests the treatment, and City engineers work with the community to determine if the location is appropriate, based on a checklist of factors. Traffic calming along a bicycle boulevard is justified if it is also a designated school route and has an 85th percentile speed exceeding 32 mph. Speed humps and traffic circles are the City's most commonly used traffic calming devices. The Traffic Calming Program states that an increase of up to 25 percent of existing volume on an adjacent local street is considered acceptable on most streets.[3] However, the resulting total traffic volume on an adjacent local street must not exceed 2,500 vpd. The City would remove traffic calming treatments if they cause unacceptable delays to emergency services or other unintended results as determined by City staff.

Figure 4. A partial closure on the Bryant bicycle boulevard requires drivers to turn right while allowing bicyclists to continue straight across the cross-street.

Volume Control

Both of the principal bicycle boulevards in Palo Alto include partial diverters (Figure 4). The City is currently developing a bicycle boulevard on a street with one full closure and one partial, with bicycle and pedestrian pass-throughs on both.

- Additional information: Neighborhood Traffic Calming Program http://www.cityofpaloalto.org/knowzone/city_projects/transportation/traffic_calming.asp
- Contact: Rafael Rius, Transportation Project Engineer

Portland, Oregon

In fall 2010, the City of Portland re-branded the bicycle boulevards as "neighborhood greenways" to emphasize the benefits for pedestrians, stormwater management, and neighborhood livability. The neighborhood greenway program reaches out to inexperienced bicyclists and people who prefer to ride on quiet, local streets. Portland has an extensive toolbox of treatments and designs for use along city bikeways.[4] Treatments are selected based on traffic flow, engineering judgment, and interest of the neighborhood in traffic calming or diversion.

In December 2010, the City of Portland developed a set of draft goals for neighborhood greenways agreed upon by the City's bicycle planning staff, traffic calming staff, and City engineers. The draft goals include maximizing safety for bicyclists and pedestrians, minimizing delay for bicyclists, and minimizing negative impacts of changes to bicyclists and neighbors.

---

[2] Available online at: http://www.cityofpaloalto.org/civica/filebank/blobdload.asp?BlobID=6666

[3] Based on the Traffic Infusion on Residential Environments (TIRE) index, which shows that most residents do not notice an increase of 25 percent.

[4] City of Portland. (2010). Bikeway Facility Design: Survey of Best Practices. ftp://ftp02.portlandoregon.gov/PBOT/Bicycle_Plan_for_2030/Plan_Documents/Supplemental_Documents/Supplement_Appendix_D.pdf

Street Selection

The bicycle boulevard draft goals document defines project goals and performance measures for development of individual bicycle boulevards, allowing the City to track whether the design is successful at accomplishing the identified goals. Fifteen neighborhood greenway projects are currently under development, and the City has defined specific goals and measures of success for each neighborhood greenway based on the existing conditions.

Intersection Treatments

Portland has used center left turn lanes, left turn pockets, short bike lanes, and a cycle track to aid offset crossings. While no specific warrant exists for treatment selection, the City considers the classification of the cross street, as well as treatments recommended by National Cooperative Highway Research Program (NCHRP) Report 562, *Improving Pedestrian Safely at Unsignalized Crossings.* In addition, the City has been moving toward treatments that focus the crossing on one location, such as a two-way cycle track (Figure 5).

Figure 5. A cycle track is provided to assist with an offset crossing of a higher-order street.

Portland has used a High-Intensity Activated Crosswalk (HAWK) signal at one intersection of a bicycle boulevard at a larger street. The City has been in regular communication with the Federal Highway Administration (FHWA) regarding the signal, as well as the Cities for Cycling effort to advance the design. The City also has several pedestrian signals, which are now disallowed by the *Manual on Uniform Traffic Control Devices* (MUTCD). In general, the City prefers pedestrian signals and HAWKS over a standard signal with a diverter because standard signals always require a bicyclist to wait for the signal phase. A bicyclist is not required to activate and wait for a pedestrian signal if gaps in traffic allow the bicyclist to cross without the aid of the signal.

Speed Control Measures

One of Portland's newly established goals for bicycle boulevards is to reduce 85^{th} percentile speeds below 25 mph (preferably 20 mph). Previously, the City required that any traffic calming be suggested and approved by residents. With the new bicycle boulevard goals, the City is the catalyst for traffic calming on bicycle boulevards, and residential approval is not required, though it is encouraged.

Figure 6. Portland has used pinch-points to narrow streets for automobiles. Source: Greg Raisman

Portland has implemented a pinchpoint design that was drawn from European designs (Figure 6). The treatment consists of two choker islands that narrow the travel lane to a point where only one vehicle can pass at a time. The chokers are designed to allow bicyclists to pass them on the outside. The City considers it a good concept, although the first implementation was too close to an intersection and not restrictive enough (it is 16-feet curb-to-curb, which allows automobiles to pass each other).

Volume Control Measures

For any given project, the goal is to maintain volumes under 1,000 vpd and to not increase vehicular traffic over the existing conditions. Prior to the newly-established goals, the only defined threshold was that over 3,000 vpd, a City bikeway should be striped with bike lanes, while lower volumes were acceptable as a shared street (based on the 1996 Bicycle Master Plan).

However, the 1,000 vpd goal is not always possible on bicycle boulevards. Southeast Clinton Street bicycle boulevard has volumes around 2,000 to 2,400 vpd. Traffic calming along the street keeps speeds relatively low and the City is implementing the Clinton Street Bike Boulevard Enhancement Project to add distinctive signs and pavement markings to improve the visibility of the boulevard (Figure 7). The City recognizes that not all bicyclists feel comfortable riding on that roadway and targets improvements to achieve the 1,000 vpd threshold on other projects.

The City will consider traffic diversion to meet vehicle volume goals if community support exists and if treatments would not affect bus traffic. Where diversion is not possible, the City looks to solutions that add friction or force vehicles to queue in order to pass. Along short segments where neither of these is an option, the City considers a separated facility, such as a cycle track, to provide bicycle access past the difficult area.

- Additional information: http://www.neighborhoodgreenway.com/
- http://www.portlandonline.com/Transportation/index.cfm?c=50518
- Contacts: Roger Geller, Bicycle Program; Scott Batson, PE

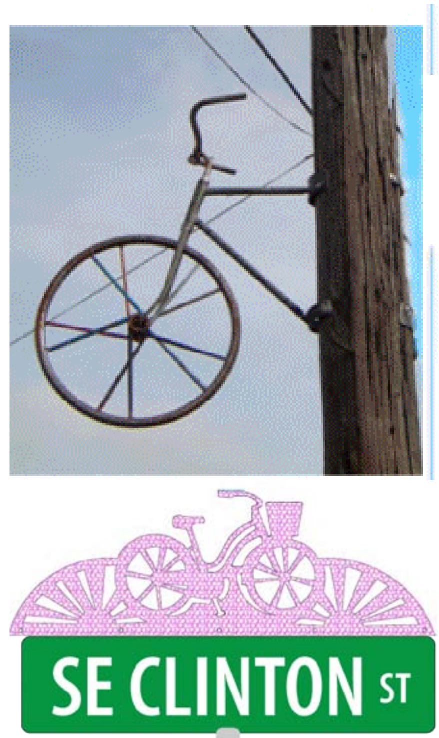


Figure 7. Design elements to improve the visibility of the Southeast Clinton Street bicycle boulevard.

Seattle, Washington

Seattle's Traffic Calming Program pioneered mini-traffic circle devices in the 1980's and has since developed specific metrics for implementation of traffic calming treatments. The City is considering using the neighborhood greenway terminology used in Portland, incorporating green elements, storm water treatments, and pedestrian treatments in order to emphasize the benefits to users in addition to bicyclists.

Street Selection

Seattle has only recently begun planning bicycle boulevards; the 2007 bicycle master plan identified several potential locations for bicycle boulevards, but did not recommend specific designs or treatments. The Wallingford Bicycle Boulevard project, a community-driven effort, is currently underway.

Most of the city's bicycle boulevards were selected in part because of the presence of existing traffic calming treatments. The City is now focusing efforts on improving crossings of arterials. Arterial crossing improvements will primarily use 'bicycle signals', which allow bicyclist through-movements but require that drivers turn onto the arterial street. The treatment uses signs and pavement markings rather than physical barriers and City staff reports that compliance varies. The City's planned approach for developing a specific bicycle boulevard depends on the project and community.

Intersection Treatments

Many intersections of local streets in Seattle are uncontrolled, particularly where traffic circles are installed. There is not much public support for installation of stop signs, and the City has no plan to add unwarranted stops to control intersections with local streets along a bicycle boulevard.

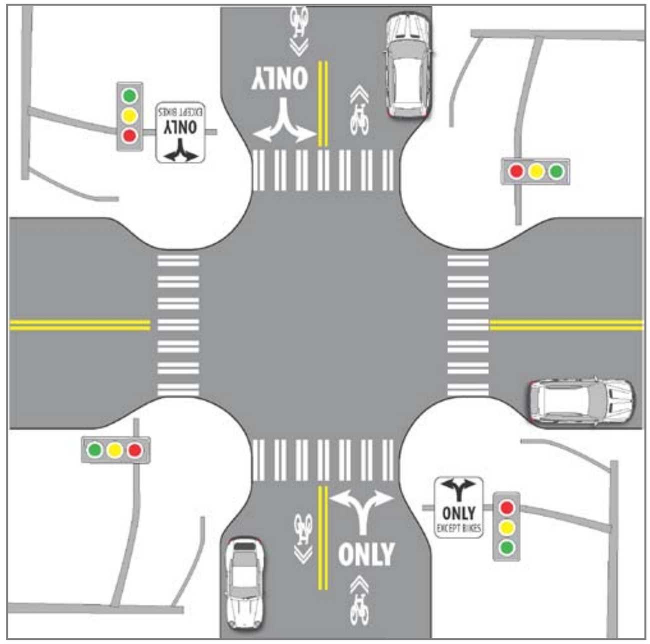


Figure 8. Example of a partial diverter signal in Seattle.

Seattle has a long history of providing traffic circles at intersections of local streets; over 600 traffic circles were constructed in Seattle between 1973 and 1998. Studies have indicated substantial crash and injury reductions, and the City will consider a traffic circle at any non-arterial intersection as a bicycle boulevard improvement.

At crossings of arterial streets, Seattle has frequently used half-signals (also known as crosswalk signals), which are bicycle- and pedestrian-actuated signals that control a larger street where a lower-order street crosses it. The City found that crash rates at half-signals are consistently equal to or lower than crash rates at full signals, and recommends installing a half-signal when traffic volumes on the cross-street are less than half of MUTCD-recommended benchmarks for a full traffic signal and when installation of a full signal might deter a substantial amount of motor vehicle traffic to the lower volume residential street (i.e. where the street grid is well-established with an arterial street every four to six blocks).

Seattle also uses signals that act as partial diverters by allowing bicyclists to travel straight through the intersection, while forcing motorists to turn either direction (Figure 8). With no physical barrier to the lower-order street, the City feels that motorist compliance with these diverters is low.

Speed Control

Seattle has not systematically looked at operational characteristics for bicycle boulevards, although the prototypical local street in Seattle carries 500 to 1,000 vpd with an average speed of 28 mph. The City considers vehicular speeds to be a greater issue for the cycling environment than volumes. Designated bicycle boulevards where the 85th percentile speed is five mph over the speed limit are prioritized for traffic calming, particularly chicanes, chokers, and speed humps. Speed cushions (lumps) are also used on emergency vehicle routes, and bicyclists are directed to pass between the lumps via pavement markings.

Most local streets in Seattle are 25 feet wide with parking, requiring vehicles to queue to pass each other. Bicycle boulevards implemented on wider streets may include corridor narrowing treatments such as chokers, or chicanes, potentially in partnership with drainage improvements such as rain gardens.

Volume Control

The City is not considering many diverters (other than the bike signal) or closures at this time, due to the difficulty of determining impacts to adjacent streets.

- Additional information at: Seattle Bike Blog, Bike boulevard coming to Wallingford
  http://seattlebikeblog.com/2011/01/03/bike-boulevard-coming-to-wallingford/

- Contact: Sam Woods, Manager of Traffic Calming, Pedestrian and Bicycle Program; Luke Korpi, Senior Civil Engineer

Vancouver, British Columbia

The City of Vancouver designates local street bikeways and neighborhood greenways, both of which use similar treatments to bicycle boulevards. Local street bikeways are traffic calmed to discourage through-movement of vehicles, while greenways provide bicycle, pedestrian, and green space connections within and to neighborhoods.

Street Selection

The City chooses streets to implement as local street bikeways based on streets identified in the Bike Master Plan (1999), as well as in discussions between the engineering and planning departments and the community.

Intersection Treatments

The City implemented a Stop Sign Infill Program in 2006 to assign right-of-way or traffic control to one or more approaches of all intersections to clarify user behavior.

Vancouver frequently signalizes arterial streets where they cross local street bikeways. Signal warrants for these crossings consider a five-year time horizon of pedestrian volumes. The City assumes that, within the five-year horizon, any local street bikeway will have the necessary levels of use to warrant signalization. Where intersections with larger streets are not signalized, the City limits some motor vehicle movements with median islands or with right-in/right-out splitters.

Speed Control Measures

Typical traffic calming used in Vancouver includes traffic circles and speed humps, both of which are commonly used on local street bikeways. Residents can request traffic calming through the City's Livable Neighborhood Program.

Volume Control Measures

Treatments for local street bikeways are selected to discourage movement of motor vehicles depending on existing volumes; if the existing conditions have low volumes, the City would use non-diversionary traffic calming and aim to not increase motor vehicle traffic. The City is conducting an ongoing monitoring program (using both automatic and manual counts) to anticipate motor vehicle and bicycle volumes on local street bikeways in the future.

Figure 9. Partial closure in Vancouver, B.C.

On some of the older local street bikeways, complaints spurred the City to conduct counts that found over 3,000 vpd. The City responded by blocking some intersections, reducing average daily traffic to 1,000 vpd (Figure 9).

- Additional information: http://vancouver.ca/engsvcs/streets/greenways/neighbourhood/
- Contact: Mike Anderson, City Engineer

2.2. Summary of Best Practices Review

As demonstrated through the range of experiences and techniques used to develop bicycle boulevards in different jurisdictions, there are no strict standards or warrants for use of bicycle boulevard treatments. Commonalities that emerge among the jurisdictions include:

- Bicycle boulevards are low-speed, low-volume streets that encourage use by bicyclists.
- Distinctive signs and pavement markings are essential components of designating a bicycle boulevard.
- Most municipalities are looking into improving crossings of arterial streets and applying traffic calming and diversion techniques to improve the bicycling environment.
- Public input is a key component of identifying streets and treatments for bicycle boulevards.

However, the jurisdictions differed in terms of street selection, intersection treatments, speed control measures, and volume control measures.

Street Selection

Most municipalities identified bicycle boulevards through the City's bicycle master plan process. All municipalities considered local streets with existing traffic calming, closures, or signalized crossings of major streets. Streets that improve connectivity to key destinations, provide a direct route for bicyclists, or where residents have expressed a desire for traffic calming are also good candidates. Austin's bicycle boulevard was selected in part by connectivity to downtown and into the bicycle network, important due to the City's limited number of local through-streets. Seattle and Vancouver considered bicycle boulevard treatments in neighborhoods where residents requested traffic calming.

Most bicycle boulevards are located on residential streets, although Austin, Berkeley, and Portland all have boulevards along commercial streets.

The City of Emeryville's 2010 General Plan includes bicycle boulevards as a street typology, and identifies bicycle boulevards along Horton/Overland, Doyle Street, 66th Street, 65th Street, 59th Street, 53rd Street, and 47th Street. During the development of the Pedestrian and Bicycle Master Plan, these routes were evaluated and refined.

Intersection Treatments

Major Street Crossings

Quality of treatments at major street crossings can significantly affect a bicyclist's choice to use a bicycle boulevard or not. If the delay for a bicyclist to cross a major street is considerably longer than the delay for crossing at an adjacent street, bicyclists are unlikely to use the bicycle boulevard.

Seattle and Austin have prioritized improving bicycle boulevard crossings of arterial streets when establishing a bicycle boulevard, while other jurisdictions such as Portland and Berkeley began with signs and pavement markings, and are more recently focusing on improving major street intersections. Common treatments include curb extensions, crosswalks, median islands, and signals. Treatment selection is based on engineering judgment as well as manuals, primarily the MUTCD and NCHRP Report #562 (2006). Several jurisdictions use pedestrian half-signals, which are not allowed under the MUTCD. Others use or are considering implementing HAWK signals.

Minor Street Crossings

Municipalities differ significantly on use of stop control on bicycle boulevard intersections with other local streets. CAMUTCD Section 2B.05 Stop Application specifies the places where a stop sign can be used where two streets with relatively equal traffic volumes and/or characteristics intersect. Some municipalities, including Portland and Vancouver, stop control one direction of every intersection with a minor street. Most of Seattle's minor street intersections are not stop-controlled, and if a traffic circle is installed at an intersection with stop signs, they are removed.

Many municipalities turn stop signs or remove four-way stop-controlled intersections to give right-of-way to the bicycle boulevard, reducing the delay for bicyclists on the bicycle boulevard.

Speed Control Measures

Speeds are critical to the bicycling environment because of the likelihood of injury resulting from a crash, as well as turning, passing, and other potential conflicts between motor vehicles and bicyclists.

Automobile speed has a significant impact on the likelihood a fatality will result from a crash (see Figure 10).

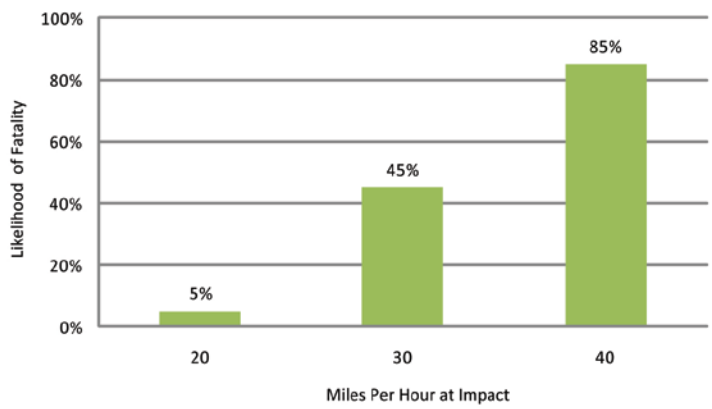


Figure 10. Likelihood of pedestrian fatality resulting from crash based on automobile speed.
Source: U.K. Department of Transport

Roads selected for bicycle boulevards tend to have maximum motor vehicle speeds of 25 mph, although some communities such as Albuquerque are reducing speeds through traffic calming or posting reduced speed limits. Table 1 summarizes guidance for speeds on bicycle boulevards from the communities interviewed and key resources.

In general, a speed differential between motor vehicles and bicyclists of 15 mph or less is desirable to reduce turning conflicts and the number of passing events; the San Francisco Bicycle Plan recommends re-designing a street for maximum speed of 15 mph unless volumes are low.

Table 1. Posted Speeds and Speed Thresholds

Source	Posted Speed	Speed Threshold/Goal
Albuquerque, New Mexico	18	None specified
Austin, Texas	25	85th percentile 25 mph or less
Berkeley, California	25	None specified
Palo Alto, California	25	85th percentile 32 mph or less
Portland, Oregon	25	85th percentile25 mph or less; 15-20 mph preferred
Seattle, Washington	25	85th % speeds <5mph over posted
Vancouver, British Columbia	25	None specified
AASHTO *Guide for the Development of Bicycle Facilities*	25	None specified

Volume Control Measures

Motor vehicle traffic volumes affect the comfort of a bicyclist, particularly for roadways with shared travel lanes, such as bicycle boulevards. Higher vehicle volumes are less comfortable and mean more potential conflicts. To illustrate, on a 25 mph street with 1,000 vpd, during peak hour a cyclist traveling at 12 mph would be passed by a car traveling in the same direction about every two minutes.[5] By comparison, at 3,000 vpd, a bicyclist would be passed by a car every 46 seconds, and at 5,000 vpd, a bicyclist would be passed by a car every 28 seconds.

Table 2. Traffic Volume Guidelines

Source	Volume Threshold
Albuquerque, New Mexico	500+ vpd threshold for speed humps; 1,500 for diversion
Austin, Texas	None
Berkeley, California	None
Palo Alto, California	None
Portland, Oregon	1,000 vpd goal, depends on street
Seattle, Washington	None
Vancouver, British Columbia	< 3,000 vpd
AASHTO *Guide for the Development of Bicycle Facilities*	generally < 3,000 vpd

There is a wide variation in vehicle volume goals for bicycle boulevards considered by different jurisdictions, shown in Table 3. Goals range from 1,000 to 3,000, with the majority of jurisdictions lacking a volume goal. No jurisdiction has a specific set threshold that triggers implementation of volume control treatments. Instead, the decision to implement volume control treatments is based on the context of the bicycle boulevard, and engineering judgment plays heavily in the decision.

The majority of cities interviewed have a traffic calming program that is separate from bicycle boulevard implementation programs. Portland has modified the traffic calming program to permit traffic calming to be installed on a bicycle boulevard at the City's discretion, rather than just as a response to community request.

Impacts to Neighboring Streets

Some cities consider how traffic calming and/or diversion can affect traffic on adjacent streets; in Palo Alto, an increase of up to 25 percent of existing volume (under 2,500 vpd) is generally considered acceptable.[6] The Traffic Calming Program manual estimates that traffic calming treatments such as a series of speed humps can be expected to divert 10 to 20 percent of traffic onto other routes, while full and partial street closures result in a 50 to 90 percent reduction.

Portland's Neighborhood Traffic Management Program's has defined an impact threshold curve to evaluate impacts to neighboring streets. The standard impact curve is expressed in terms of total traffic volume. The parameters allow for an increase of up to 150 vpd on any street, while an increase of over 400 vpd on a local street is unacceptable, and the the resulting traffic volume on any local street should not exceed 3,000 vpd.[7]

[5] At peak hour, assuming peak hour is 10 percent of vpd, the street is two-way with traffic volumes split evenly between each direction, and cars are evenly spaced along the street .
[6] Based on the Traffic Infusion on Residential Environments (TIRE) index, which shows that most residents do not notice an increase of 25 percent.
[7] http://www.portlandonline.com/transportation/index.cfm?&a=85375&c=35934

Impacts to Emergency Response Vehicles

Jurisdictions consider traffic calming impacts to emergency vehicle routes in one or more of the following ways:

- Emergency response routes are ineligible for traffic calming. (Minneapolis)
- Treatments on emergency response routes must be approved by emergency response officials. (Seattle)
- A limited set of emergency-vehicle-friendly traffic calming techniques are allowed. (Portland, Vancouver)

Examples of emergency-vehicle-friendly traffic calming techniques include 22-foot speed tables in lieu of speed humps, offset speed tables (also called split humps), and other treatments.

The Palo Alto Traffic Calming Program Manual notes that emergency "vehicles are particularly susceptible to the vertical displacement of speed humps because of the weight and length of fire trucks, and the delicate instruments and patients in paramedic vans and ambulances." Emergency vehicles must reduce speeds more than a passenger car would to travel over a speed hump. The manual also states that intersection treatments have less of an impact on emergency vehicles than corridor treatments, as the vehicles already slow for intersections. Emeryville's emergency vehicle response time goals are an average of five minutes or less.[8]

It is estimated that a ladder truck may be delayed up to ten seconds at a speed hump and an ambulance may be delayed up to five seconds.[9]

Other Lessons Learned

Experience in several communities indicates that it is important to record where automobile speed measurements are taken in relation to the traffic calming or diversion treatment and replicate for before and after trials. In addition, traffic calming and diversion measures can be implemented on a trial basis to gauge residents' support prior to finalizing the design. Temporary speed humps, tables, and lumps are available, and temporary closures can be created with construction barrels or planters. However, the temporary measures can diminish residents' opinions due to unappealing design.

[8] City of Emeryville Website. Accessed March 15, 2011. http://www.ci.emeryville.ca.us/index.aspx?NID=359
[9] Ewing, Reid. (1999). p.142 Traffic Calming: State of the Practice. http://www.ite.org/traffic/tcsop/Chapter7.pdf

3. Recommended Bicycle Boulevard Policies and Treatments for Emeryville

This section recommends policies for bicycle boulevard development in Emeryville. None of the case study cities have strict policies that require specific action if bicycle boulevard goals are not met. Similarly, because of the variety of conditions and importance of context-sensitive design, Emeryville's policies are meant to serve as guidelines, rather than standards. If a bicycle boulevard goal is not met, the City should consider treatments that will allow the bicycle boulevard to meet goals, or if goals cannot be met, should consider a different type of bicycle facility.

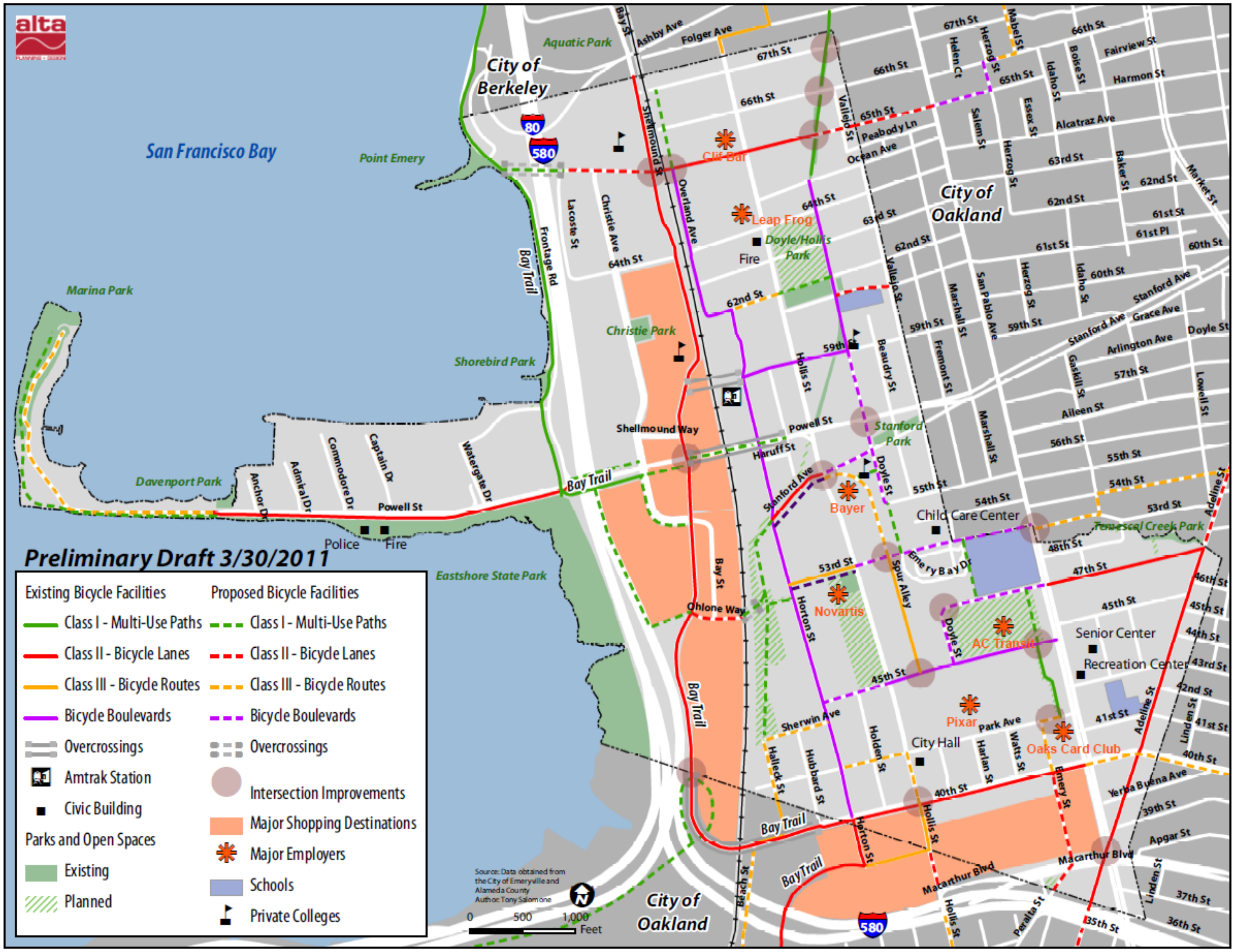
This section first identifies Emeryville's existing and proposed bicycle boulevards. It then presents three goals for bicycle boulevards addressing speeds, volumes, and intersection delay.

3.1. Street Selection

Emeryville's General Plan and the 1999 Pedestrian and Bicycle Plan identify bicycle boulevards based on existing traffic conditions and proximity to key destinations, including schools and parks. *Memorandum #4. Recommended Pedestrian and Bicycle Infrastructure Projects* further refined this list. Table 3 lists the bicycle boulevards recommended in the memorandum. Note that bicycle boulevards on 66th Street and 59th Street are not recommended for inclusion in the Pedestrian and Bicycle Master Plan. See also Map 1.

Table 3. Emeryville's Bicycle Boulevards

Street	Extents	Notes
45th Street	Horton Street to Doyle Street	Modified from General Plan. Changed eastern extent from AC Transit Pixar Path to Doyle Street.
47th Street/Doyle Street	45th Street to San Pablo Avenue	New bicycle boulevard. Designated as Class II/III in General Plan.
53rd Street	Horton Street to San Pablo Avenue	Included in General Plan.
Doyle Street	Ocean Avenue to 55th Street	Included in General Plan.
Horton Street/Overland Avenue	66th Street to 40th Street	Included in General Plan.
Stanford Avenue	Horton Street to Doyle Street	Included in General Plan.
66th Street	Shellmound Street to City Limits.	Modified from General Plan. Not recommended as a bikeway in the Pedestrian and Bicycle Master Plan.
59th Street	Horton Street to Doyle Street	Modified from General Plan. Changed eastern extent from City Limits to Doyle Street.
55th Street	Doyle Street to City Limits.	Modified from General Plan. Not recommended as a bikeway in the Pedestrian and Bicycle Master Plan.



Map 1. Recommended Bikeway Network

Going forward, this list should be revisited in conjunction with future updates to the Pedestrian Bicycle Master Plan or as community feedback requires to determine whether conditions on the selected streets are still appropriate for bicycle boulevards, and to verify whether the treatment level for the street is still appropriate.

3.2. Bicycle Boulevard Goals and Metrics

This section outlines recommended bicycle boulevard goals and metrics for Emeryville based on the best practices resources surveyed. The bicycle boulevard goals address metrics for motor vehicle speeds, motor vehicle volumes, and major intersection delay, described below.

Speed Goals

Streets developed as bicycle boulevards should have posted speeds of 20 mph or less, with 85th percentile speeds at 22 mph or less. If the street has relatively high volumes (over 3,000 vpd) 85th percentile speeds should be further reduced below 22 mph where feasible.

Rationale

Higher vehicular speeds increase the frequency of automobiles passing bicyclists and increase the severity of crashes that occur. Cyclists generally travel at approximately 12 mph, and maintaining vehicular speeds at a speed closer to bicyclists' speeds greatly improves bicyclists' comfort on a street. Slower vehicular speeds also improve drivers' ability to see and react to bicyclists and minimize conflicts at driveways and other turning locations.

Motor Vehicle Volume Goals

Traffic volumes on bicycle boulevards east of Hollis Street should be below 1,500 vpd. West of Hollis Street, traffic volumes should be below 3,000. Higher volumes can be permitted for short segments with additional treatments.

Rationale

Volumes of motor vehicles determine the frequency of passing events; at 1,000 vpd cars pass a bicyclist approximately every two minutes, while at 3,000 vpd passing events occur every 46 seconds. The rate of automobiles passing a cyclist indicates the number of potential conflicts and affects the comfort of the bicycling environment.

Bicycle boulevards with volumes higher than 3,000 vpd are not recommended, although a segment of a bicycle boulevard may accommodate more traffic for a short distance if necessary to complete the corridor. Providing additional separation with a bike lane, raised bike lane, cycle track, or other treatment is recommended where traffic calming or diversion cannot reduce volumes below this threshold.

Major Intersection Goals

Minimize bicyclist delay and maximize safety at intersections and major crossings.

Rationale

Collisions and delay are the two major considerations of bicycle boulevard crossings of major streets (transit streets and connector streets). Bicycle boulevards intersect the following major streets: Hollis Street, San

Pablo Avenue, 65th Street, Powell Street, Park Avenue, 40th Street. Emeryville should develop a warrant for facilitating bicyclist crossings at major streets based on bicyclist delay, rather than bicyclist volumes.

Where there is a history of bicycle-related crashes along a bicycle boulevard, the City should determine the causes of the crashes and consider treatments to mitigate the problem. The National Cooperative Highway Research Program (NCHRP) Report # 562 *Improving Pedestrian Safety at Unsignalized Crossings* (2006) the MUTCD, and FHWA-RD-04-100 *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations* can be used to determine which treatments are appropriate to aid bicyclists crossing the major street. Treatments may include but are not limited to bicycle detection, warning signage, flashing beacons, in-pavement lights, median refuges, curb extensions, or signalization.

3.3. Monitoring

The metrics used to monitor these goals (motor vehicle speeds and volumes and bicyclist delay) should be measured regularly to determine whether additional treatments are necessary to bring the street to the target goal. For example, fifteen years of data at 45th Street and Horton Street show that traffic volumes are slowly rising. Emeryville should collect this data and evaluate each bicycle boulevard in the case of any of the following:

- Development occurs that is projected to increase motor vehicle volumes on the bicycle boulevard
- The Bicycle and Pedestrian Plan is updated
- Substantial community concern is brought to the City

3.4. Bicycle Boulevard Treatment Selection

This section identifies five levels of treatment for bicycle boulevards. The appropriate treatment level is dependent on how well the bicycle boulevard meets the above speed, volume and delay goals. If one treatment does not address out-of-compliance bicycle boulevards, the next treatment level should be used. Table 4 shows the hierarchy of application levels.

The minimum standard to designate a street as a bicycle boulevard, Level 1 treatments consist of "Bicycle Boulevard" or other identification signs and pavement markings. The second level includes these items, plus wayfinding signage and treatments to major street crossings. All bicycle boulevards in Emeryville should meet Level 2 treatments at a minimum.

Traffic calming and diversion treatments (Levels 3, 4, and 5) should be implemented on bicycle boulevards as necessary when the street exceeds the target vehicular speed and volume thresholds. If an analysis shows that the bicycle boulevard does not meet the thresholds, the City should consider applications for the next treatment level.

Note that while traffic calming treatments primarily affect motor vehicle speeds, they also reduce volumes, as drivers avoid slower streets. Speed humps can lead to a 20 percent reduction in vehicular speeds, while chicanes, traffic circles, and other narrowing can reduce vehicle volumes by 10 percent.[10]

[10] Berkeley Bicycle Boulevard Design Tools and Guidelines.

Table 4 : Application of bicycle boulevard treatment levels

	Signs	Pavement Markings	Intersection Treatments	Traffic Calming	Traffic Diversion
Level 1 Basic Bicycle Boulevard	• identification	• shared lane markings			
Level 2 Enhanced Bicycle Boulevard	• identification • wayfinding	• shared lane markings • directional markings for bicyclists	• crossing improvements at major streets (high-visibility crosswalks, median islands, HAWK and standard signals)		
Level 3 Limited Traffic Calming	• identification • wayfinding	• shared lane markings • directional markings for bicyclists	• crossing improvements at major streets (high-visibility crosswalks, median islands, HAWK and standard signals) • improve visibility of bicyclists (forward stop bars, bicycle crosswalks)	• vertical speed control (speed humps/ cushions/ tables) • horizontal speed control (chicanes, traffic circles, curb extensions)	
Level 4 Significant Traffic Calming	• identification • wayfinding	• shared lane markings • directional markings for bicyclists	• crossing improvements at major streets (high-visibility crosswalks, median islands, HAWK and standard signals) • improve visibility of bicyclists (forward stop bars, bicycle crosswalks)	• vertical speed control (speed humps/ cushions/ tables) • horizontal speed control (chicanes, traffic circles, curb extensions) • narrowings (chokers, neckdowns, pinchpoints, center island narrowing)	
Level 5 Traffic Diversion	• identification • wayfinding	• shared lane markings • directional markings for bicyclists	• crossing improvements at major streets (high-visibility crosswalks, median islands, HAWK and standard signals) • improve visibility of bicyclists (forward stop bars, bicycle crosswalks)	• vertical speed control (speed humps/ cushions/ tables) • horizontal speed control (chicanes, traffic circles, curb extensions) • narrowings (chokers, neckdowns, pinchpoints, center island narrowing)	• full and partial closures, diagonal diverters

Level 1. Basic Bicycle Boulevard

Signs and pavement markings represent the least physically intensive treatments and should be included in all bicycle boulevard treatments. Emeryville's pavement stencils and purple bicycle boulevard signs provide a strong visual identity for the street and designate the corridor as a bicycle route. This is the minimum treatment for a street to be considered a bicycle boulevard.

Level 2. Enhanced Bicycle Boulevards

Wayfinding signs and directional pavement markings improve the experience of a bicycle boulevard and passively market the facility. Intersection treatments that reduce delay can be a major determinant of whether a bicyclist uses the bicycle boulevard rather than a parallel street. Emeryville should build all bicycle boulevards to a Level 2 minimum standard.

Level 3. Limited Traffic Calming

If speeds and volumes on a bicycle boulevard rise above the City's goals, Level 3 treatments should be implemented. Traffic calming should be considered on bicycle boulevards that have 85th percentile speeds greater than 22 mph. Limited traffic calming can also reduce volumes 10 to 20 percent.

Specific treatments depend on public input, whether the street is a transit street, vehicular speeds, and lane widths. Where on-street parking is important, minimize loss of parking by using vertical speed control where appropriate.

Level 4. Significant Traffic Calming

If treatments indicated in Level 3 do not reduce speeds and volumes below the City's goals, Level 4 treatments should be implemented. On bicycle boulevards east of Hollis Street where automobile speeds and volumes are identified issues, neck-downs can reduce speeds significantly, as drivers must slow and wait for one car to pass the treatment at a time. This treatment is not recommended on bicycle boulevards west of Hollis.

Treatments should not significantly hinder emergency vehicle access or bus routes and the Emeryville Fire Department, AC Transit, or Emery Go-Round should be consulted in the design, as appropriate. Neck-downs should be designed to permit a 20 foot clear access for emergency vehicles.

Level 5. Traffic Diversion

If treatments indicated in Level 4 do not reduce speeds and volumes below the City's goals, Level 5 treatments should be implemented. Where a bicycle boulevard has high traffic volumes, particularly cut-through traffic, diversion should be considered to substantially reduce volumes on the road. Diversion should only be implemented after a thorough traffic analysis and public outreach process, and traffic conditions should be evaluated after six months to determine whether neighboring streets were negatively impacted.

Alternatively, a treatment can be implemented based on engineering judgment and monitored to determine impacts to neighboring streets. Based on the *Traffic Infusion on Residential Environments* (TIRE) index, an increase of up to 25 percent of existing volume on an adjacent local street is generally acceptable.

4. Recommended Design Treatments for Emeryville's Bicycle Boulevards

This section provides existing conditions and general recommendations for Emeryville's existing and proposed bicycle boulevards, based on automobile speeds and volumes, number and location of crashes, and other factors. Table 4 summarizes existing conditions and proposed treatments for all bicycle boulevards.

All bicycle boulevards in the City need some level of treatment to be brought up to Level 2: Enhanced Bicycle Boulevard Design treatments. Sections of several bicycle boulevards are also designated as transit streets in the City's General Plan. Treatments on these streets should allow for wider travel lanes, limit horizontal traffic calming treatments, and depending on bus volumes, should consider separation of bicyclists and motor vehicles.

At this time, all of Emeryville's bicycle boulevards with vehicle volume data except Horton/Overland meet vehicle volume goals. Vehicle volumes at 45th Street, 47th Street, and Stanford Avenue, and vehicle speeds and intersection delay on all bicycle boulevards should be measured to determine if additional treatments are necessary.

More extensive treatments are required along Horton/Overland to meet the proposed bicycle boulevard goals. Section 4.1 provides detailed recommendations for Horton/Overland. Prior to installation of any diverters a traffic study will be needed to determine the effects.

Table 4. Existing Conditions of Existing and Proposed Bicycle Boulevards

Bicycle Boulevard	Existing Conditions	Recommended Treatments
45th Street Horton Street to Doyle Street	VPD: n/a Speed: n/a Major Intersections: Hollis Street (4-way stop) San Pablo Avenue (signal) Crash History: None, but San Pablo Avenue & 45th Street has 7 collisions Two-lane road with parallel parking on both sides. No bicycle facilities signed or striped. Identified as Green Street in General Plan.	• Measure speeds and traffic volumes. • Install bicycle boulevard signage and pavement markings to bring up to Level 2 Treatments. • Consider speed cushions or traffic circles if measured speeds are higher than 20 mph. • If Spur Alley bicycle route is implemented, improve crossing with high visibility crosswalks and consider raised intersection.
47th Street/Doyle Street 45th Street to San Pablo Avenue	VPD: n/a Speed: n/a Major Intersections: San Pablo Avenue (signal) Crash History: none Two-lane road with diagonal parking. No bicycle facilities signed or striped. Poorly defined roadway and access point at 47th and Doyle intersection. Identified as Green Street in General Plan.	• Measure speeds and traffic volumes. • Define 47th/Doyle Intersection by articulating corner with curb, gutter and sidewalk. Replace off-street parking with on-street parking. • Improvements on Doyle Street must consider parking needs for planned Emeryville Center for Community Life.
53rd Street Horton Street to San Pablo Avenue	VPD: Hollis Street: 1,009 Adeline Street: 515 San Pablo Ave: 880 Speed: n/a Major Intersections: Horton Street (signal) Hollis Street (signal) San Pablo Avenue (signal) Crash History: none Signed as bicycle route between Horton Street and Hollis Street. Speed bumps between Boyer Street and San Pablo Avenue. 53rd Street/ San Pablo Avenue intersection is skewed. Identified as Green Street in General Plan. Connects to planned bicycle route in Oakland.	• Measure speeds. • Install bicycle boulevard signage and pavement markings to bring up to Level 2 Treatments. • Consider green street treatments such as narrowing street and removing parking to provide bioswales or to daylight Temescal creek. • At Spur Alley intersection, install high-visibility crosswalks and consider raised intersection. • At San Pablo Avenue, add bicycle pocket or narrow 53rd Street to two lanes in either direction with shared lane marking. Adjust signal timing to provide enough time for bicyclists to cross San Pablo Avenue.

Table 4. Existing Conditions of Existing and Proposed Bicycle Boulevards

Bicycle Boulevard	Existing Conditions	Recommended Treatments
Doyle Street Ocean Avenue to 55th Street	VPD: 59th Street: 665 Powell Street: 504 Speed: n/a Major Intersections: Powell Street (uncontrolled) Stanford Avenue (4-way stop) Crash History: none **Between Ocean Avenue and 59th Street:** Bicycle boulevard signage and stencils installed. Traffic calming includes curb extensions and roadway narrowing. Stop signs turned to favor bicycle boulevard traffic. **Between 59th Street and 55th Street:** No signage, pavement stencils or traffic calming. Powell Street intersection difficult to cross.	• Measure speeds. • Install wayfinding signage. • Add HAWK signal or full signal at Powell Street. • Install bicycle boulevard signage and pavement markings south of 59th Street to bring up to Level 2 Treatments.
Horton Street/Overland Avenue 66th Street to 40th Street	VPD: Between the following streets: Park Ave & 40th Street: 3,177 Stanford Ave & 53rd St: 4,859 59th St & Powell St: 3,742 64th St and 65th St: 1,808 Speed: n/a Major Intersections: 65th Street (signal) 40th Street (signal) Crash History: At 59th Street: 2-3 crashes At Powell Street: 1 crash At 40th Street: 2 crashes High collision location Entire route signed as bicycle boulevard. Bicycle boulevard pavement markings north of 62nd Street and south of 53rd Street. Bike lanes striped on Horton Street from 62nd to 53rd Street. Section from 59th Street to Stanford Avenue identified as Green Street and Transit Street in General Plan.	• Measure speeds • Consider diversion at 62nd Street, Stanford Avenue, 45th Street, and 40th Street. Diversion to be installed on a temporary trial basis first, with final decision after evaluation. • Reconfigure roadway between 62nd Street and Stanford Avenue to prevent loading/parking in bicycle lanes. Alternative 1: buffered bike lanes. Alternative 2: Remove bike lanes and create shared roadway with chicanes to reduce traffic speeds and allow for vehicle loading. Alternative 3: Remove bike lanes and provide shared roadway with parking/loading on one side. • North of 62nd Street and south of Stanford Avenue, consider speed bumps or cushions and permanent speed feedback signs to reduce vehicle speeds. • Improve bicycle detection at 40th Street and 65th Street. • See Section 4.1 for details
Stanford Avenue Horton Street to Doyle Street	VPD: n/a Speed: n/a Major Intersections: Hollis Street (signal) Crash History: none Bike lanes striped between Hollis Street and Horton Street. No bicycle boulevard signage. Bicyclists are not detected in bike lanes at Hollis Street. Section between Horton Street and Hollis Street identified as a Transit Street in General Plan.	• Measure speeds and volumes • Install bicycle boulevard signage to bring up to Level 2 Treatments. • Extend bicycle lanes to Doyle Street. Will likely require removal of on-street parking. • Install bicycle detection in bicycle lane at Hollis Street.

Table 4. Existing Conditions of Existing and Proposed Bicycle Boulevards

Bicycle Boulevard	Existing Conditions	Recommended Treatments
59th Street Horton Street to Doyle Street	VPD: Horton Street: 467 Hollis Street: 1,374 Doyle Street: 370 Speed: n/a Major Intersections: Hollis Street (signal) Crash History: At Horton Street: 2 crashes Bicycle boulevard pavement stencils east of Hollis Street. Bicycle lanes west of Hollis Street. Diagonal parking between Hollis Street and Doyle Street. Identified as Green Street in General Plan. Section between Horton Street and Hollis Street identified as a Transit Street in General Plan.	• Measure speeds. • Install bicycle detection at Hollis Street. • Install bicycle boulevard signage to bring up to Level 2 Treatments.

4.1. Horton/Overland Treatments

The Horton/Overland bicycle boulevard provides a continuous north-south connection through most of Emeryville, and is a very important bicycle connection, providing access to the Transit Center, the future South Bayfront Bridge, and to Mandela Parkway in Oakland. The entire bicycle boulevard is currently signed. Bicyclists share the road with motorists north of 62nd Street and south of 53rd Street. Bike lanes are striped between 62nd Street and 53rd Street.

Twenty-four hour traffic counts conducted in fall 2010 show that sections of the bicycle boulevard exceed the 3,000 vehicles per day goal. Within a 24-hour weekday period 3,177 motorists were counted between Park Avenue and 40th Street, 4,859 motorists were counted between Stanford Avenue and 53rd Street, and 3,742 motorists were counted between 59th Street and Powell Street. Volumes along the bicycle boulevard are expected to increase with the construction of Emery Station West. The entrance for the transit center will be located on Horton Street at 59th Street, and the entrance to the garage that will serve the facility will be located along Horton Street just south of 62nd Street.

Delivery drivers and other motorists commonly park on the bicycle lanes on Horton Street between 62nd Street and Powell Street. Bicyclists have noted that it is difficult to merge with traffic to travel around parked vehicles.

Recommended Treatments

The following treatments are recommended along the Horton/Overland bicycle boulevard. Figure 11 summarizes these treatments.

- **Consider new diverters at 62nd Street, Stanford Avenue, and 45th Street. Enhance the existing signed diversion at 40th Street.** Diverters should be implemented on a trial basis first, with final decision after evaluation. Diverters at these streets may reduce traffic volumes along much of Horton/Overland. However, these diverters are not likely to mitigate traffic volumes associated with the development of Emery Station West. See Figures 12 through 14 for illustrations of the diverters at 62nd Street, Stanford Avenue and 45th Street. The 40th Street diversion would be enhanced by installing bollards on the north leg, preventing motorists from traveling north across 40th. The left turn lane for eastbound traffic on 40th would be replaced with a raised median with pedestrian refuge. Signs currently prohibit vehicle through traffic northbound on Horton Street.

- **Reconfigure roadway between 62nd Street and Stanford Avenue to prevent loading/parking in bicycle lanes**. Four alternatives are presented.
    - **Alternative 1** would buffer the existing bicycle lanes with a one-foot striped buffer. The vehicle travel lanes would be reduced to 22 feet, and the centerline would be removed. This treatment is low cost. See Figure 15.
    - **Alternativ**e 2: Remove bike lanes and create shared roadway with chicanes to reduce traffic speeds and allow for vehicle loading. Raised chicanes would serve to reduce vehicle speeds, and provide a location for official vehicle loading. Bicyclists would ride in the travel lane with motorists. Due to the volumes of motorists on Horton Street, this alternative may not provide a comfortable bicycling environment. See Figure 16.
    - **Alternative 3**: Remove bike lanes and create shared roadway with parking/loading zone on one side. The vehicle travel lanes would be reduced to 23 feet, and the centerline would be removed. Due to the volumes of motorists on Horton Street, this alternative may not provide a comfortable bicycling environment. See Figure 17.
- **North of 62nd Street and south of Stanford Avenue, reduce vehicle speeds**, if a speed survey indicates the need. Treatments such as speed bumps or cushions and permanent speed feedback signs can reduce vehicle speeds and are relatively low-cost.
- **At Horton and 40th Street, install video detection and stripe a bicycle lane between right and left turn lanes** to allow bicyclists to continue through. This should be installed in conjunction with the bollards at 40th Street.
- **At Overland and65th Street, adjust signal phasing and install bicycle detection.** Move signage directing bicyclists to Overland Avenue further east to provide advance notice of the turn. Stencil shared lane markings in the right turn lane to indicate to motorists that bicyclists may be using the lane.

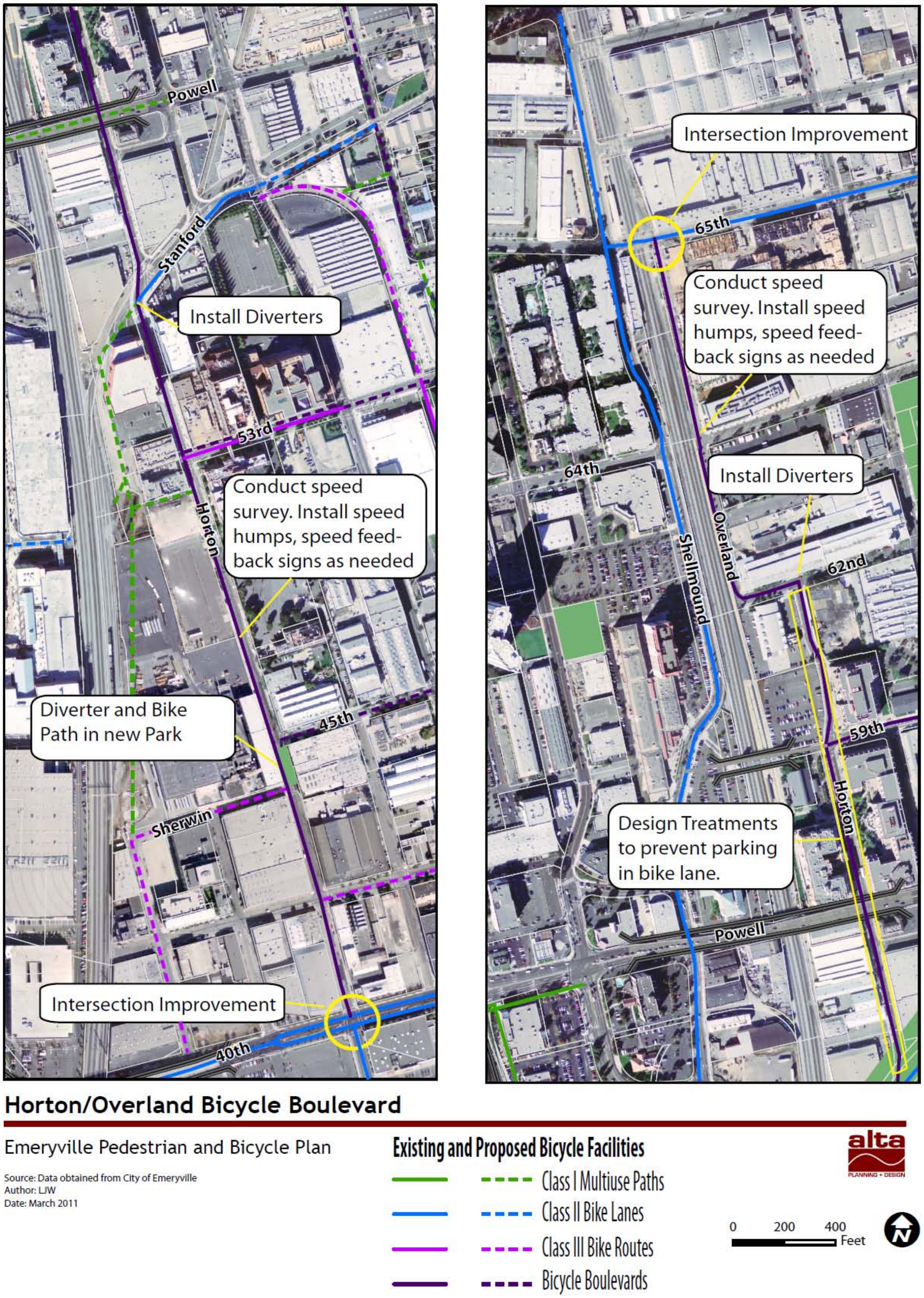


Figure 11: Recommended Treatments for Horton/Overland Bicycle Boulevard

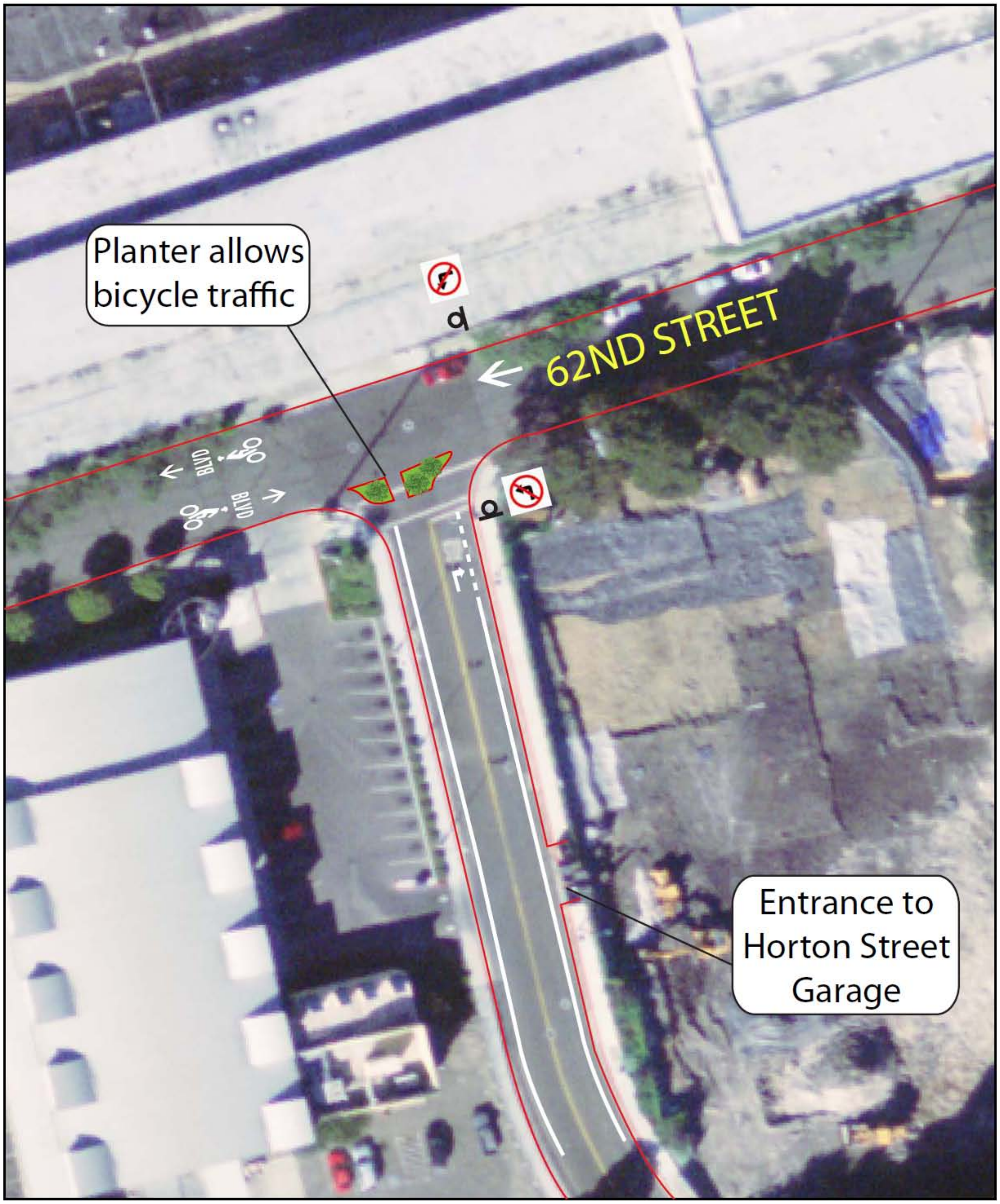


Figure 12: Diverter at Horton Street and 62nd Street

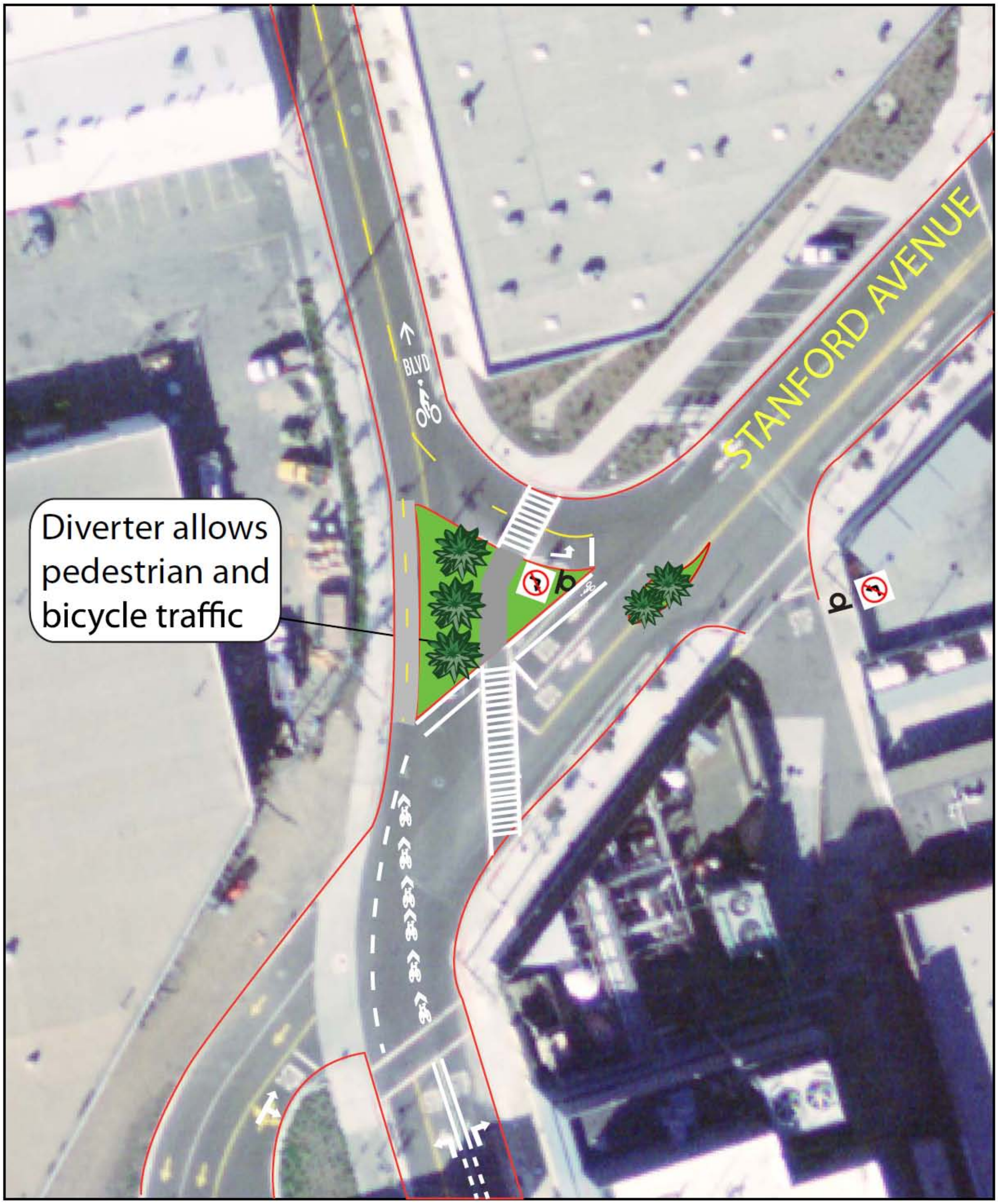


Figure 13: Diverter at Horton Street and Stanford Avenue

Figure 14: Diverter and Park at Horton Street between 45th Street and Sherwin Avenue

Alternative 1:

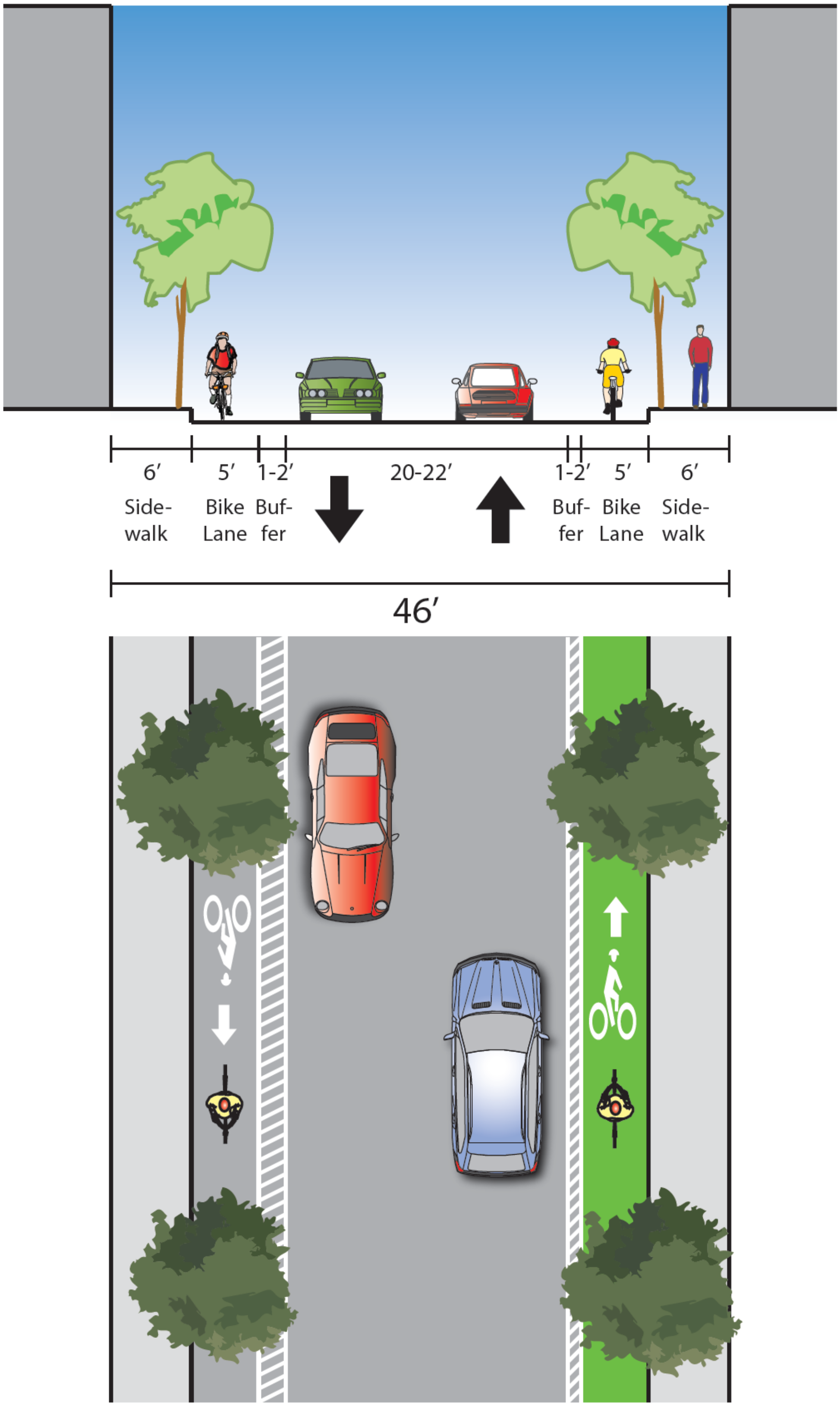


Figure 15: 62nd Street to Stanford Avenue, Alternative 1, Buffered Bicycle Lanes

Note: graphic shows options for more visible separation by widening the buffer (left) or applying coloration (right)

Alternative 2:

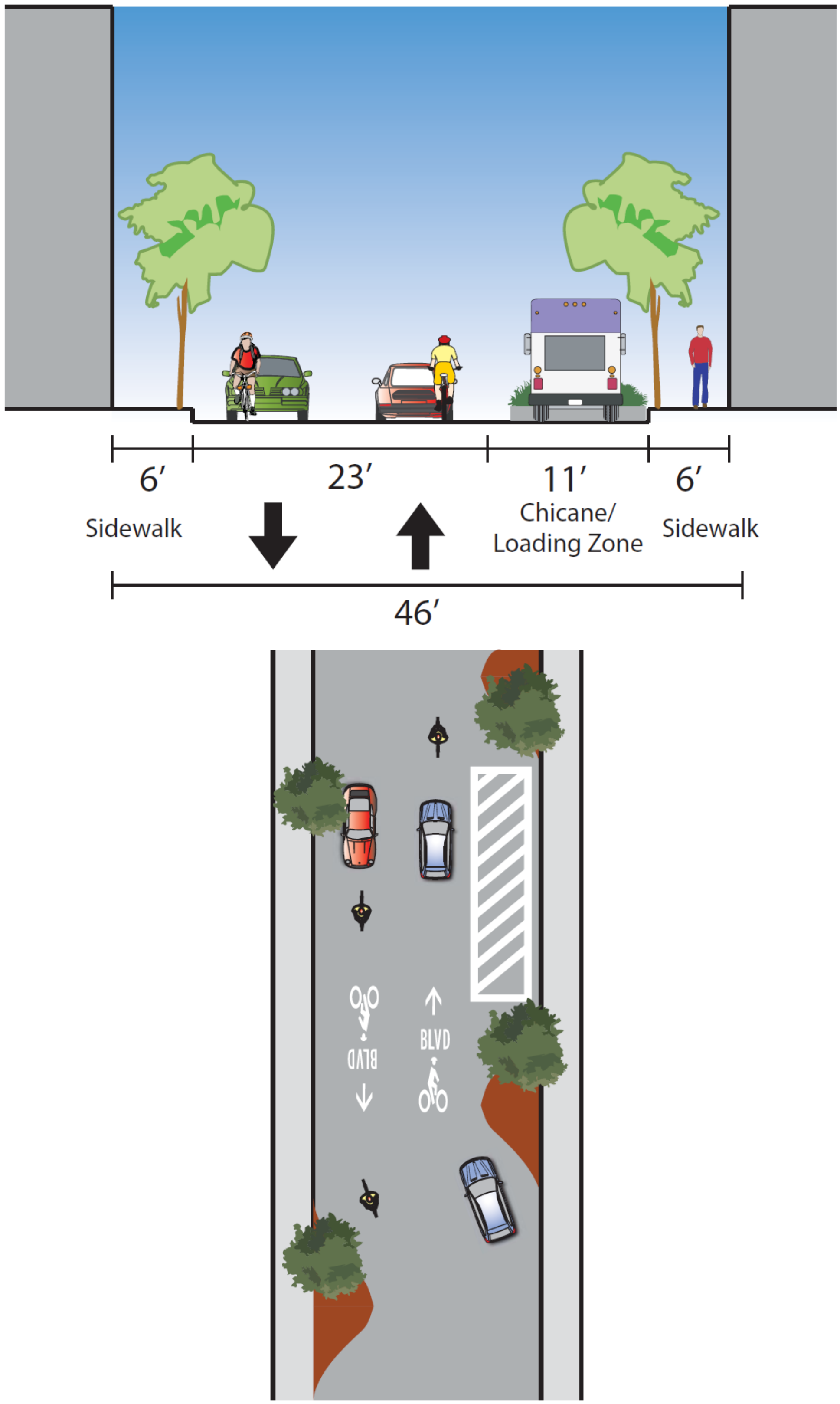


Figure 16: 62nd Street to Stanford Avenue, Alternative 2, Shared Roadway with Chicanes

Alternative 3:

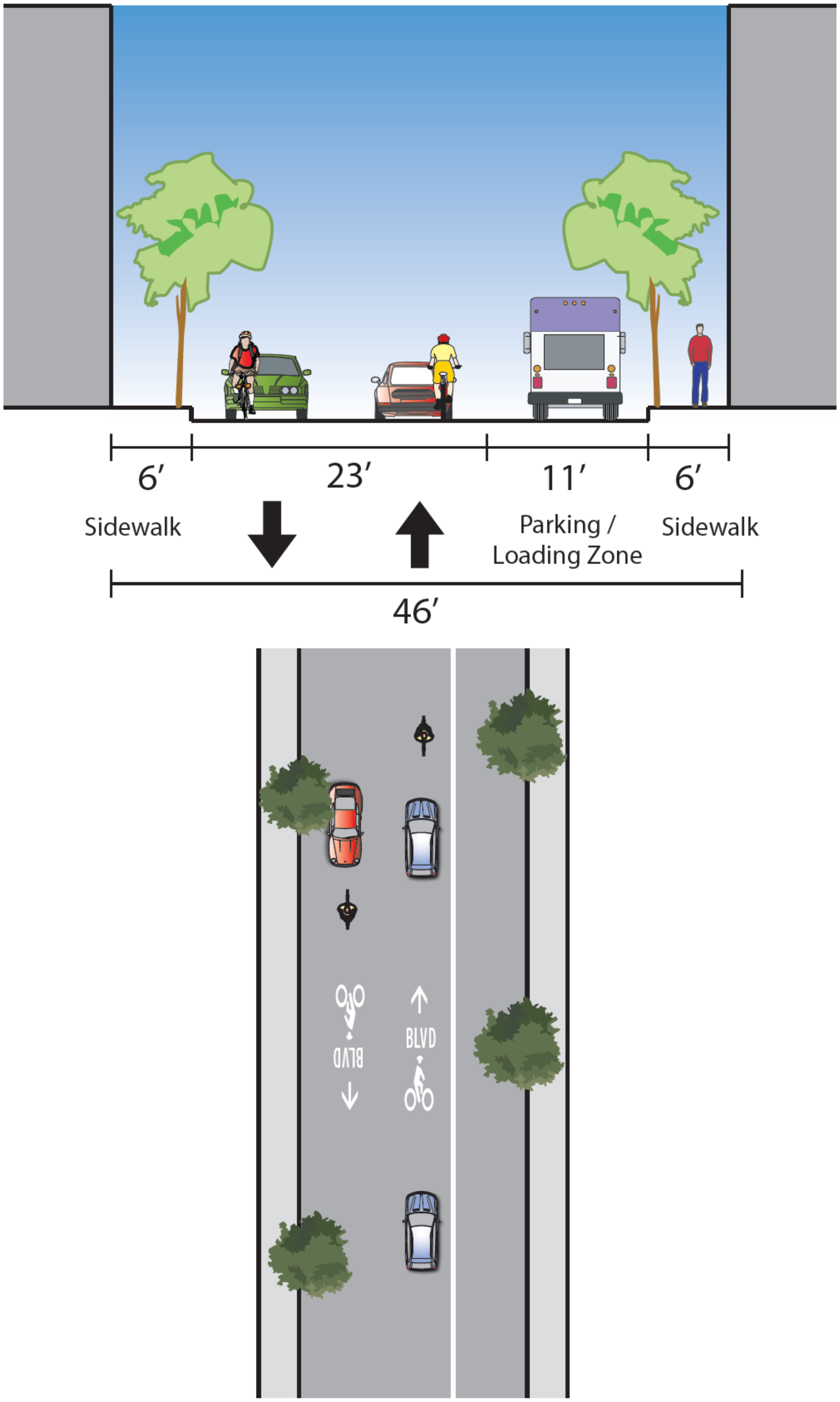


Figure 17: 62nd Street to Stanford Avenue, Alternative 3, Shared Roadway with Parking/Loading Zone

This page left blank intentionally.

5. Appendix A. Glossary

85th percentile speed	The speed which 85 percent of traffic travels below and 15 percent travels above; this higher-than-average speed is often used to set speed limits.
Average daily traffic (ADT)	The number of vehicles per day on a roadway during a typical 24-hour period.
Bicycle boulevard	A street segment, or series of contiguous street segments, that have been modified to accommodate through bicycle traffic but discourage through motor vehicle traffic.
Cut-through traffic	Traffic using minor roadways, usually residential streets, as shortcuts to avoid congestion on major streets.
Speed control measures	Traffic calming measures that use deflection of vehicle travel paths to moderate speeds. Examples include speed humps and tables, raised intersections, traffic circles, chicanes, chokers, and others.
Traffic calming	Traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes. (Institute of Transportation Engineers).
Vehicles per day (vpd)	The measure of average daily traffic on a roadway during a 24-hour period.
Volume control measures:	Traffic calming measures that use barriers to preclude one or more movements along a street or at an intersection. Examples include full, half, and diagonal street closures, median barriers, and right-in, right-out islands.

6. Appendix B: Annotated Bibliography

This section briefly summarizes the key published materials that provide specific guidance for development of bicycle boulevards.

American Association of Highway Transportation Officials (AASHTO) Guide for the Development of Bicycle Facilities

The proposed update to the 1999 *Guide to the Development of Bicycle Facilities* (expected 2011) includes the bicycle boulevard as a recognized bicycle facility. The Guide defines a bicycle boulevard as, "a local street or series of contiguous street segments that have been modified to function as a through street for bicyclists while discouraging through automobile travel." It recommends bicycle boulevards where the speed differential between motorists and bicyclists is typically 15 mph or less, generally with posted speed of 25 mph or less. The Guide also states that bicycle boulevards should generally have an ADT of less than 3,000 vehicles per day.

Recommendations for bicycle boulevard design elements include:

- Traffic diverters
- Priority assignment of two-way stop-controlled intersections that favors the bicycle boulevard
- Neighborhood traffic circles and mini-roundabouts at minor intersections
- Other traffic-calming features where deemed appropriate
- Wayfinding signs to guide bicyclists
- Shared lane markings to alert drivers to the path bicyclists need to take on a shared roadway
- Crossing improvements where the boulevard crosses major streets, including traffic signals/crossing beacons with bicycle-sensitive loop detectors or push-buttons, median refuges, and curb extensions

The Guide does not provide any specific metrics for applying these treatments, although the section on bicycles and traffic calming provides an overview of the range of traffic calming treatments that are beneficial to the bicycling environment.

Alta Planning + Design and IBPI Fundamentals of Bicycle Boulevard Planning and Design

Published in July 2009, this collaboration between Alta Planning + Design and Portland State University's Initiative for Bicycle and Pedestrian Innovation (IBPI) is an overview of bicycle boulevard planning and design elements. The resource provides guidance for bicycle boulevard implementation, including corridor selection, public process, and other considerations. The design elements were grouped into: signage, prioritizing travel on bicycle boulevards, intersection treatments, traffic calming, and traffic reduction, and the document provides general guidance and cost estimates for each treatment.

- Resource available at: http://www.altaplanning.com/bike+blvd+guidebook.aspx

Bicycle Countermeasure Selection System (BIKESAFE)

Sponsored by the U.S. Department of Transportation Federal Highway Administration (FHWA), the BIKESAFE website is a compendium of measures used to improve safety and mobility for bicycling. The website provides a description and analysis of factors contributing to bicycle crashes and a description of treatments and countermeasures to address these crashes. The website also includes case studies.

- Resource available at: http://www.bicyclinginfo.org/bikesafe/

City of Berkeley Bicycle Boulevard Design Tools and Guidelines

Published in April 2000, the City of Berkeley's Bicycle Boulevard Design Tools and Guidelines reports on the Early Design Phase of implementing bicycle boulevard improvements defined in the 1999 Berkeley Bicycle Plan. The document defines the purpose, goals and objectives of developing bicycle boulevards in Berkeley. It provides a summary of the process used to identify streets for bicycle boulevard treatments. The document outlines existing conditions on streets designated as bicycle boulevards, as well as concerns and solutions suggested by the public.

The document also provides an overview of strategies used to develop bicycle boulevards, including issues addressed, typical application, implementation guidelines, design suggestions, and cost. The document also reviews the impacts of traffic calming devices, discussing ITE's *Traffic Calming: State of the Practice* (1999) report, although it does not specifically state thresholds or metrics such as average daily traffic for implementing traffic calming or diversion measures.

- Resource available at: http://www.ci.berkeley.ca.us/contentdisplay.aspx?id=6652

City of Napa Policy Guidelines: "Bicycle Boulevards"

The City of Napa, California adopted policy guidelines for implementation of bicycle boulevards in 2005. The goal was to, "to develop and maintain a safe integrated bicycle route network for residents and visitors, connecting key destinations to neighborhoods, neighborhoods to each other, and the City of Napa to the county." The guidelines outline characteristics of roads where bicycle boulevards could be implemented, including the requirement that, "Potential candidate streets include local streets or low-volume collector streets with less than 5,000 vpd." Lane widths should be Napa's typical 12-foot width, but narrowing lanes is appropriate for low volume streets (approximately 2,500 vpd or less) that are not designated emergency response routes. On-street parking can only be removed if a safety enhancement is required. Traffic calming is allowable, based on Public Work's *Citywide Guidelines for Traffic Calming and Neighborhood Traffic Management* manual.

- Resource available at: http://www.cityofnapa.org/images/publicworks/Traffic/TACpolicies/tac_10.pdf

Traffic Calming: State of the Practice

This widely used manual on traffic calming was published in 1999 by the Institute of Transportation Engineers (ITE). While this manual does not address bicycle boulevards, many of the treatments discussed can be applied to bicycle boulevards. The manual includes a brief history of traffic calming, a toolbox of measures, consideration of engineering and aesthetic issues, impacts, legal authority and liability, warrants, and effectiveness of various traffic calming treatments. The manual defines traffic calming measures, including: speed humps/tables, raised intersections, traffic circles, chicanes, chokers, and lateral shifts (all speed control measures); and street closures, diverters, median barriers, and other elements that restrict motor vehicle movements (all volume control measures).

The report analyzes impacts of traffic calming treatments using the following measures:

- 85th percentile speeds
- Daily traffic volumes
- Number of crashes
- Ease of street crossings for bicyclists/pedestrians
- Safer bicycle operation

The manual summarizes impacts to average speeds, volumes, and numbers of crashes for typical traffic calming measures. The manual found that volume control measures lead to significant reductions in annual collision frequency, although this was primarily attributed to reducing the vehicular volumes.

Table 4 provides a summary of the impacts of traffic calming and diversion techniques as well as considerations for emergency vehicle response routes.

Table 4. Recommended Treatment Matrix

	Average Speed After Installation	Impacts to Motor Vehicle Volumes	Allowed on Emergency Response Routes
Speed Hump	27.3 mph (12' humps) 25.6 mph (14' humps)	20 percent reduction	No
Speed Table/ Raised Crosswalk (22')	29.2 mph	12 percent reduction	Yes
Speed Lump	27.0 mph	12 percent reduction	Yes
Raised Intersection	34.3 mph	12 percent reduction	Yes
Chicane	32.3 mph	10 percent reduction	Yes
Mini Traffic Circle	30.3 mph	5 percent reduction	No
Curb Extension	32.3 mph	10 percent reduction	Yes
Neckdown	32.3 mph	10 percent reduction	Yes
Pinchpoint	28.6 mph	10 percent reduction	Yes
Center Island Narrowing	32.3 mph	10 percent reduction	Yes
Full Closure	N/A mph	44 percent reduction	No
Partial Closure/ Choker Entrance	26.3 mph	42 percent reduction	Yes, with mountable curb or removable bollards
Diagonal Diverter	27.9 mph	35 percent reduction	Yes
Median Island/Diverter	32.3	10 percent reduction	Yes

Source: Ewing, *Traffic Calming: State of the Practice*

- Resource available at: http://www.ite.org/traffic/tcstate.asp#tcsop

Responding to the Challenges of Bicycle Crossings at Offset Intersections.

This resource was written by an engineer at the Seattle Department of Transportation for the Third Urban Street Symposium in 2007. The report identifies solutions to offset bikeway crossings, which are a typical challenge for bicycle boulevard design. The report evaluates three existing facilities, finding high compliance with a side path and signalized crossing treatment in Tucson, AZ and a striped left turn in Portland, OR (91 percent compliance). By contrast, a left turn pocket in Seattle, WA had only 60 percent compliance.

The report also makes recommendations for additional treatments, including: a median left turn lane (allows two-way protected left turns); a right bicycle lane and refuge area (bicycle lane on the main street with a 'jug handle' waiting area for bicyclists to cross); and a median bicycle path (full median island with two-way bicycle path).

The report notes the lack of federal guidelines or warrants for providing bicycle crossings at offset intersections. It recommends considering volume of traffic including turning volumes, the speed limit or 85th percentile speed of the main street, and the make-up of the bicyclists using the crossing.

- Resource available at: http://www.urbanstreet.info/3rd_symp_proceedings/Responding%20to%20the%20Challenges.pdf

Neighborhood Traffic Calming: Seattle's Traffic Circle Program

Published in 1998 in the Road Management & Engineering Journal, this article outlines the Neighborhood Traffic Control Program (NTCP), in particular the use of traffic circles for traffic calming. Over 600 traffic circles were constructed in Seattle between 1973 and 1998. The article summarizes the process for determining a location for a traffic circle. Traffic circles are designed to allow a single unit fire truck (45-foot turning radius) to pass, and they include a two-foot mountable curb to facilitate emergency vehicle access. An analysis of crashes between 1991 and 1994 found a 94 percent reduction in crashes (11 crashes after construction, compared to 187 prior), as well as a substantial reduction in injuries. The analysis concludes that, "The significant reduction in accidents attributable to traffic circles demonstrates that they pay for themselves many times over in reduced accident costs in just the first year." They did not find that traffic circles reduce traffic volumes.

- Resource available at: http://www.usroads.com/journals/rmej/9801/rm980102.htm

U.S. Traffic Calming Manual, APA (2009)

Written by Reid Ewing and Steven J. Brow, this recently published manual updates the material developed in Ewing's 1999 *Traffic Calming: State of the Practice.* The Manual defines traffic calming as:

> Traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes.

The manual contains updated information from a survey of 20 jurisdictions considered leaders in traffic calming practices as well as relevant literature and online resources. It provides an overview of a model traffic calming process, including recommendations for selecting treatments using different methodologies. The toolbox section describes key design features, considerations, and impacts of traffic calming and diversion devices. Each section includes a brief description of impacts to bicycle and pedestrian traffic, as well as recommendations for mitigating potential safety concerns.

References

- American Association of Highway Transportation Officials (AASHTO). (2010 proposed update). *Guide for the Development of Bicycle Facilities.* NCHRP Project #15-37
- Alta Planning + Design and IBPI. (2009). *Bicycle Boulevard Planning and Design Handbook.* www.ibpi.usp.pdx.edu/guidebook.php
- BikeSafe. (No Date). *Bicycle countermeasure selection system.* http://www.bicyclinginfo.org/bikesafe/downloads.cfm
- City of Berkeley. (2000). *Bicycle Boulevard Design Tools and Guidelines.* http://www.ci.berkeley.ca.us/contentdisplay.aspx?id=6652
- City of London Transport for London. *Advanced stop lines (ASLS) background and research studies.* London, United Kingdom: Transport for London. http://www.tfl.gov.uk/assets/downloads/businessandpartners/asl.pdf
- City of Napa. (2005). *Policy Guidelines: "Bicycle Boulevards".* http://www.cityofnapa.org/images/publicworks/Traffic/TACpolicies/tac_10.pdf
- City of Oakland (2009). *Design Guidelines for Bicycle Wayfinding Signage.* http://www.oaklandrecycles.com/AssetFactory.aspx?did=3672
- City of Portland. (2010). *Bikeway Facility Design: Survey of Best Practices.* ftp://ftp02.portlandoregon.gov/PBOT/Bicycle_Plan_for_2030/Plan_Documents/Supplemental_Documents/Supplement_Appendix_D.pdf
- Dill, Jennifer, Gliebe, John. (2008). *Understanding and Measuring Bicycling Behavior: a Focus on Travel Time and Route Choice.* OTREC-RR-08-03. http://www.ibpi.usp.pdx.edu/media/OTREC_Dill_BikeGPS_Report.pdf
- Ewing, Reid. (1999). *Traffic Calming: State of the Practice.*
- Hendrix, Michael. (2007). *Responding to the Challenges of Bicycle Crossings at Offset Intersections.* Third Urban Street Symposium. http://www.urbanstreet.info/3rd_symp_proceedings/Responding%20to%20the%20Challenges.pdf
- Knoblauch & Raymond. (2000). *The effect of crosswalk markings on vehicle speeds in Maryland, Virginia, and Arizona.* FHWA Report FHWA-RD-00-101. http://www.fhwa.dot.gov/publications/research/safety/00101/00101.pdf
- Oregon Department of Transportation. (1998). *Right-In Right-Out Channelization.* http://www.oregon.gov/ODOT/HWY/ACCESSMGT/docs/RtInRtOut.pdf?ga=t
- Road Management & Engineering Journal. (1998). *Neighborhood Traffic Calming: Seattle's Traffic Circle Program.* http://www.usroads.com/journals/rmej/9801/rm980102.htm
- Road Safety Bureau, New South Wales (1994). *Evaluation of pedestrian road safety facilities.*
- Transportation Research Board. (2006). *Improving Pedestrian Safety at Unsignalized Crossings.* NCHRP Report # 562.
- United State Department of Transportation Federal Highway Administration. (2006). *HAWK Pedestrian Signals: A Survey of National Guidance, State Practice and Related Research* http://on.dot.wi.gov/wisdotresearch/database/tsrs/tsrhawksignals.pdf

7. Appendix C. Bicycle Boulevard Treatments

Bicycle Boulevard Signs

Design Summary

- Signs identify routes to both bicyclists and motorists, provide destination and distance information, and warn users about changes in road conditions as needed.
- Signs should be consistent in content, design, and intent throughout the region; colors reserved by the Manual on Uniform Traffic Devices (MUTCD) for regulatory and warning road signs (red, yellow, orange, etc.) are not recommended. Green and purple are commonly used.
- Signs "brand" the bicycle boulevard network, fostering familiarity among bicyclists and motorists with traffic conditions expected on these facilities. Unlike other marketing efforts, signs passively advertise the bicycle boulevard 24 hours a day.

Identification signs indicate that a street is a bicycle boulevard.

Treatments

<u>Identification Signs</u>

Also known as 'confirmation' signs, identification signs remind bicyclists and motorists that they are on a bicycle boulevard. Identification signs typically include a bicycle logo or bicycle boulevard branding. The use of modified street signs such as in Berkeley, CA and Vancouver, B.C. is an effective way to provide identification of the route without introducing a new sign.

Street signs can be modified to indicate that the street is a bicycle boulevard.

<u>Wayfinding Signs</u>

Wayfinding signs provide direction, distance and/or estimated travel time to destinations including commercial districts, transit hubs, schools and universities, and other bikeways. Wayfinding signs are placed where multiple routes intersect and at key bicyclist decision points. Wayfinding signs displaying destinations, distances and "riding time" can dispel common misperceptions about time and distance while increasing users' comfort and accessibility to the boulevard network.

Oakland's wayfinding signs provide distance.

<u>Warning signs</u>

Warning signs advise motorists to "share the road" and "watch for bicyclists" as well as warning about pedestrian crossings, and traffic calming. Warning signs should also be placed on major streets approaching bicycle boulevards to alert motorists of bicyclist crossings. See Manual on Uniform Traffic Control Devices (MUTCD) for guidance on use of warning signs.

Warning signs inform motorists to expect bicyclists.

Bicycle Boulevard Pavement Markings

Design Summary

- Pavement markings identify the roadway as a bicycle boulevard for bicyclists and drivers and provide wayfinding and traffic guidance.
- Markings encourage proper positioning in the roadway.

Treatments

Shared lane markings can also provide directional support for bicyclists.

Directional Pavement Markings

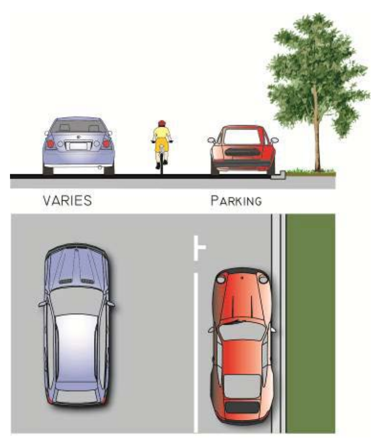
Directional pavement markings (also known as "breadcrumbs") lead bicyclists along a bicycle boulevard and reinforce the notion that they are on a designated route. Markings can take a variety of forms, such as small (12-24 inches) bicycle symbols placed every 600-800 feet along a linear corridor or large (6-foot by 30-foot) markings.

When a bicycle boulevard follows several streets (with multiple turns at intersections), additional markings accompanied by directional arrows may be provided to guide bicyclists through turns. On streets with narrow lanes where an automobile cannot pass a bicyclist within one lane of traffic, place stencils in the center of the travel lane.

Bicycle boulevard marking in Berkeley, CA.

On-Street Parking Delineation

Delineating on-street parking spaces with paint or other materials clearly indicates where a vehicle should be parked, and can discourage motorists from parking their vehicles too far into the adjacent travel lane. This helps bicyclists by maintaining a wide enough space to safely share a travel lane with moving vehicles.



Example of on-street parking delineation.

Centerline Striping Removal

Motorists have an easier time passing bicyclists on roads without centerline stripes for the majority of the block length. If there is too much oncoming traffic for a motorist to cross the centerline to pass a bicyclist, is likely that there is too much traffic for the subject street to be a successful bicycle boulevard. In addition, not striping the centerline reduces maintenance costs. This treatment may increase speeds, and additional treatments such as traffic circles should be used in conjunction with this treatment.

Minor Unsignalized Intersections

Design Summary

- To encourage use of the bikeways and improve bicyclists' safety, reduce bicycle travel time by eliminating unnecessary stops and improving intersection crossings.

Treatments

<u>Stop Sign on Cross-Street</u>

Ideally, the majority of intersections along a bicycle boulevard should have cross traffic stop-controlled or signalized. Where stop signs are facing every other block, turning signs along the bikeway to stop the cross traffic should be considered to maximize through-bicycle connectivity and momentum. Stop signs increase bicycling time and energy expenditure due to frequent starting and stopping, leading to non-compliance by bicyclists and motorists, and/or use of other routes. If several stop signs are turned along a corridor, speeds should be monitored, and traffic-calming treatments used to reduce excessive vehicle speeds on the bicycle boulevard. Bicycle boulevards should have fewer stops or delays than local streets; a typical bicycle trip of 30 minutes is increased to 40 minutes if there is a STOP sign at every block.[11]

<u>High-Visibility Crosswalks</u>

Crosswalks may be marked to improve visibility, particularly near activity centers with large amounts of pedestrian activity such as schools or commercial areas. Crosswalks are often combined with curb extensions, allowing bicyclists to move further into the road before making the crossing.

<u>Bicycle Forward Stop Bar</u>

A second stop bar for bicyclists placed closer to the centerline of the cross street than the drivers' stop bar increases the visibility of bicyclists waiting to cross a street. This treatment is typically used with other crossing treatments (i.e. curb extension) to encourage bicyclists to take full advantage of crossing design. They are appropriate at unsignalized crossings where fewer than 25 percent of motorists make a right turn movement.

Stop signs effectively minimize conflicts along bicycle boulevards.

High-visibility crosswalks increase visibility of bicyclists crossing a street on a bicycle boulevard.

Bicycle forward stop bars encourage bicyclists to wait where they are more visible.

---

[11] *Berkeley Bicycle Boulevard Design Tools and Guidelines*

Minor Unsignalized Intersections

Contraflow Bike Lanes

Allowing bicyclists to travel against the flow of traffic on a one-way street can improve connectivity on the bicycle boulevard network. Contraflow bike lanes are installed on left side of the street facing one-way traffic. The contraflow lane is generally separated from the motor vehicle lane with a double-yellow line, although a physical barrier or colored pavement can be used.

Intersection treatments such as signs and pavement markings should warn drivers to expect bicyclists in the reverse direction. This treatment may require modifications to existing traffic signals to allow bicyclists to activate signal from “wrong” direction.

This contraflow lane in Portland, OR provides a short cut-through for bicyclists following a bicycle boulevard.

Offset Intersections

Design Summary

- Provide turning lanes or pockets at offset intersection, providing bicyclists with a refuge to make a two-step turn.
- Bike turn pockets: five feet wide, with a total of 11-feet required for both turn pockets and center striping.

Treatments

Offset intersections can be challenging for bicyclists, who need to briefly travel along the busier cross street in order to continue along the boulevard.

Bicycle Left-Turn Lane

A bicycle left-turn lane can be painted where a bicycle boulevard crosses a street that has sufficient gaps in traffic to allow a bicyclist to cross one direction without a long wait. The bicyclist crosses one lane into the center of the cross street, and has a protected space to wait for a gap in the other direction.

The bike turn pockets should be at least four feet wide, with a total of 11 feet for both turn pockets and center striping.

Bike Lanes on the Cross Street

To assist with a bicycle boulevard jog to the left, a short segment of bike lane can be provided along the cross street. Crossing treatments appropriate to the level of street should be provided on both sides, so that bicyclists heading either direction on the bicycle boulevard can cross and ride in the lane on the appropriate side of the street; otherwise, wrong-way riding is likely to occur.

Bicycle Sidepath/Cycle Track

On particularly busy streets, a two-way or two one-way separated path can be provided on one side of the roadway. Bicyclists enter the sidepath from the bicycle boulevard and ride to a signalized intersection, where they cross, then continue along the bicycle boulevard. While more comfortable for users, this treatment is expensive and requires sufficient right-of-way.

Example of a bicycle left-turn lane.

Short bike lanes protect a left-turn jog.

Bicycle side path in Tucson, AZ.

Photo: Tom Thivener

A two-way cycle track on one side of the street provides a short connection.

Major Unsignalized Intersections

Design Summary

- Bicycle signals may be appropriate for use where high levels of bicycle traffic on a minor street cross a major street. Instructional and regulatory signage should be included with installation.

Treatments

<u>Crossbikes</u>

Crossbikes can be provided adjacent to the standard crosswalk marking or independently. Painted markings such as bicycle stencils or color treatment (including pattered surfacing) can accompany crossbikes to indicate to all users that bicyclists may use the crossing.

<u>Medians/Refuge Islands</u>

At uncontrolled intersections of bicycle boulevards and major streets, an island can be provided to allow bicyclists to cross one direction of traffic at a time when gaps in traffic allow. The bicycle crossing island should be at least 8’ wide (measured perpendicular to the centerline of the major road) to be used as the bike refuge area.

Narrower medians can accommodate bikes if the holding area is at an angle to the major roadway, which allows stopped bicyclists to face oncoming motorists. Railings can also be provided so bicyclists do not have to put their feet down, thus making it quicker to start again. Crossing islands can be placed in the middle of the intersection, prohibiting left and thru vehicle movements.

<u>Pedestrian Hybrid Beacon</u>

Also known as HAWK signals, pedestrian hybrid beacons can be used where a full traffic signal is otherwise unwarranted by volumes or gaps. Pedestrian hybrid beacons are installed to aid crossings where drivers do not tend to stop. The beacon signal consists of a traffic signal head with a red-yellow-red lens. The unit is off until activated, then:

- The signal flashes yellow to warn approaching drivers.
- A solid yellow advises drivers to prepare to stop.
- The signal changes to a solid red, and a WALK indicator is shown.

Bicycle signals can be actuated with bicycle sensitive loop detectors, video detection, or push buttons. HAWKS have not been approved for use in California, but are incorporated into the 2010 Federal MUTCD.

Crossbike in Berkeley, California.

Medians on bicycle boulevards should provide space for a bicyclist to wait.

Pedestrian hybrid signals for bicyclists should be clearly marked to minimize confusion.

Traffic Calming: Vertical Speed Control Measures

Design Summary

- Slopes should not exceed 1:10 or be less steep than 1:25. The *U.S. Traffic Calming Manual* recommends side slopes on tapers to be no greater than 1:6 to reduce the risk of bicyclists losing their balance. The vertical lip should be no more than a quarter-inch high.

Treatments

<u>Speed Humps</u>

Speed humps are rounded raised areas requiring approaching vehicles (automobiles and bicyclists) to reduce speed. Emergency vehicle response times should be considered where speed humps are used. Some bicyclists find speed humps uncomfortable or challenging, and speed humps can be designed to leave gaps in the center or three to four feet by the curb for bicyclists and drainage. Ewing (1999) found that that speeds increase about 0.5 to 1.0 mph for every 100 feet of separation for hump spacing up to 1,000 feet.

<u>Speed Tables/Raised Crosswalk</u>

Speed tables are longer than speed humps and flat-topped. The 22-foot table with a vertical rise of three inches high and 10-foot plateau is the most common. Because a speed table cannot be straddled by a truck, it decreases the risk of bottoming out. A raised crosswalk is a speed table that is marked and signed for pedestrian crossing. It extends fully across the street and can be loner and higher than a typical speed table.

<u>Speed Lumps/Speed Cushions</u>

Speed lumps are rounded or flat-topped raised areas across the road that include wheel cutouts to allow large vehicles to pass unaffected while acting as speed humps to passenger cars. They are increasingly used along emergency vehicle routes and recommended in the *U.S. Traffic Calming Manual*. Experience in La Habra, CA recommends a configuration of three lumps with a six-foot-wide center lump to minimize emergency vehicle delay. Wheel gaps should be one or two feet wide,

<u>Raised Intersection</u>

A speed table across the entire intersection, a raised intersection is generally three inches shorter than a standard curb height. ADA standards for curb ramps and tactile warnings should be used to accommodate pedestrians. Raised intersections are expensive, and drainage issues can arise.

Speed humps are a common traffic calming treatment.

Raised crosswalks calm traffic while improving the pedestrian environment.

Speed lumps or cushions are divided to allow emergency vehicles to pass unaffected.

Raised intersections are expensive but attractive features.

Traffic Calming: Horizontal Speed Control Measures

Design Summary

- Traffic calming treatments reduce vehicle speeds to the point where they generally match bicyclists' operating speeds, enabling motorists and bicyclists to safely co-exist on the same facility.
- Typical designs end bike lanes 70 to 100 feet in advance of slow points, allowing bicyclists to merge with motor vehicle traffic.
- In locations with high bicycle and/or motor vehicle volumes, provide five- to six-foot bypass lanes that are separated from motor vehicle lanes.

Chicanes require all vehicles to reduce their speeds to maneuver around the obstacle.

Treatments

<u>Chicanes</u>

Chicanes are a series of raised or delineated curb extensions, edge islands, or parking bays on alternating sides of a street forming an S-shaped curb, which reduce vehicle speeds by requiring drivers to shift laterally through narrowed travel lanes. (Edge islands leave a gap by the curb to improve drainage). European designs recommend shifts of least one lane width, deflection angles of at least 45 degrees, and islands to prevent drivers from traveling straight.[12]

Traffic circles require both drivers and bicyclists to reduce speeds.

<u>Mini Traffic Circles</u>

Mini traffic circles are raised or delineated islands placed at intersections that reduce vehicle speeds by narrowing turning radii and narrowing the travel lane. They can be used to replace four-way stops with yield controls, although they are typically not signed as such. Mini traffic circles can also include a paved apron to accommodate the turning radii of larger vehicles like fire trucks or school buses. Larger circles should include splitter islands at the approaches. Left turns in front of the islands may be allowed to accommodate larger trucks at small intersections.

Curb bulb-outs can be a good location for pedestrian amenities, including street trees.

<u>Curb Bulb-Outs/Curb Extensions</u>

Curb bulbouts extend the sidewalk or curb face into the parking lane at an intersection, visually narrowing the roadway. The curb extensions should only extend across the parking lane and should not obstruct bicyclists' path of travel or the travel lane. Curb extensions can increase the amount of space available for street furniture and trees or act as stormwater management features.

---

[12] Ewing, Reid. (1999). Traffic Calming: State of the Practice.

Traffic Calming: Narrowings

Design Summary

- Narrowings reduce the travel lane such that drivers must stop to allow one vehicle to pass from a single direction at a time.

Treatments

<u>Choker</u>

Similarly, to chicanes, chokers are curb extensions or edge islands placed midblock requiring drivers to reduce speeds to pass each other. This treatment narrows the travel lane to a maximum of 20 feet, with a constricted length of 20 feet in the direction of travel. European versions of this treatment often narrow the lane to considerably less than 20 feet clear width.

<u>Neckdown</u>

Neckdowns are narrowings at an intersection created by curb extensions on either side of the intersection. They are often combined with parking bays on side streets off commercial main streets. Curb radii should allow trucks to pass without having to pass the centerline, or incorporate mountable curbs if an alternate truck route is not available.

<u>Pinchpoint</u>

In a pinchpoint, bicyclists travel on the outside of the islands, reducing potential conflicts with motor vehicles. Pinchpoints encourage bicyclists to ride on the side of the road, then merge back into traffic, potentially reducing bicyclists comfort levels.

<u>Center Island Narrowing</u>

A short median island causes a small amount of deflection without blocking driveway access. Standard size is six feet wide and 20 feet long. A diverging taper can be used to deflect traffic to the right.

**Pinchpoints allow bicyclists to avoid conflicts with motor vehicles in the narrow passageway.
Source: Greg Raisman
Utrecht, The Netherlands**

Alternative pinchpoint design with speed hump in Skandinavia.

A neckdown in Eugene, OR narrows the travel lane at an intersection.

Traffic Diversion

Design Summary

- Traffic diversion treatments maintain through-bicycle and pedestrian travel on a street while physically restricting through-vehicle traffic.
- Traffic diversion is most effective when higher-order streets can sufficiently accommodate the diverted traffic.
- Bike lanes through diverters should be five or six feet in width, to allow trailers to pass while discouraging passenger car use.

Treatments

Full Closure

Raised features turn vehicle traffic while permitting through-bicycle travel. The treatment creates a "T" that does not affect vehicular traffic on the cross street but prevents driving along the bicycle boulevard. Full closures can be permeable to emergency vehicles with the use of removable bollards or mountable curbs (maximum of six inches high).

Partial Closure/Choker Entrance

Partial closures are intersection bulbouts or islands that allow full bicycle passage while restricting vehicle access to one side only. Motorists on the bicycle boulevard must turn onto the cross street while bicyclists may continue forward along a short contra-flow bike lane past the closure. These devices can permit some vehicle turning movements from a cross street onto the bicycle boulevard while restricting other movements.

Diagonal Diverter

Diverters can be placed diagonally across a four-way intersection, requiring all motor vehicle traffic to turn.

Median Island/Diverter

A median island can block automobiles from crossing a road while allowing bicyclists to pass through short gaps. Median island diverters can be narrow extruded curbs or wider islands with landscaping. The median can also provide a bike-only left-turn pocket permitting bicyclists to make left turns while restricting vehicle left turns.

Supplemental Treatment: Bike Boxes

Right-turn conflicts between bicyclists and motorists may occur at intersections at signals where traffic is diverted and forced to turn, while bicyclists continue through the intersections. Bike boxes increase bicyclist visibility to drivers by providing a space for bicyclists to wait at signalized intersections.

Choker entrances prevent vehicular traffic from turning from a main street.

Non-motorized only diverters deter motorists from driving on the street.

Median diverters include pass-throughs for bicyclists.

This bike-only left-turn pocket prevents motor vehicles from turning.