Promising New, Innovative Non-Standard Traffic Signs, Pavement Markings and Traffic Signals

Requested by
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The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field. The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this publication are for clarity only.

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Executive Summary

Background

California Department of Transportation (Caltrans) uses traffic signs, pavement markings and traffic signals on roadways to help promote pedestrian and bicyclist safety and to reduce fatalities and serious injuries. In its efforts to achieve zero fatalities and serious injuries, Caltrans' Division of Safety Programs is exploring new, non-standard traffic control devices that other transportation agencies are using to enhance pedestrian and bicyclist safety. Non-standard devices are those that are currently not included in the Manual on Uniform Traffic Control Devices (MUTCD).

This investigation gathered information from other state departments of transportation (DOTs) and local agencies about their use of non-standard traffic signs, pavement markings and traffic signals on roadways, including at intersections and midblock locations. This effort also sought to identify the benefits of these non-standard traffic control devices in reducing vehicle speeds, improving compliance by pedestrians and bicyclists, reducing crashes or conflicts, and reducing fatalities or serious injuries, and any other information that supports their effectiveness.

Summary of Findings

An online survey about non-standard traffic control devices was distributed to 135 Caltrans functional managers and district signing, striping and traffic signal contacts; 453 members of the League of California Cities; 57 members of the County Engineers Association of California; and 50 state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Traffic Engineering. (Total distribution: 695.)

For the purposes of the survey and this Preliminary Investigation, non-standard traffic control devices are defined as follows:

- *Traffic signs* include regulatory, warning and guide signs, as well as barricades, gates, object markers and changeable message signs.
- *Pavement markings* include pavement and curb markings, delineators, colored pavements, channelizing devices and islands.
- *Traffic signals* include traffic control signals for general applications, one-lane/two-way facilities, freeway entrance ramps, movable bridges at toll plazas and lane-use control; pedestrian signals; hybrid beacons; emergency-vehicle signals; flashing beacons; and in-roadway lights.

Sixty-six respondents participated in the survey: representatives from 48 California cities; three California counties; six Caltrans districts (two responses from District 8; to distinguish the responses, comments are labeled District 8A and District 8B throughout this report); and eight state DOTs. Of this respondent group:

- Fifteen agencies have implemented non-standard traffic signs, pavement markings or traffic signals other than those included in the MUTCD to improve pedestrian and bicyclist safety.
- Nine agencies are considering using non-standard traffic control devices.
- Forty-one agencies are not using non-standard traffic control devices and are not considering them. The primary reasons for adopting this approach include potential

liability of using non-MUTCD signs, traffic control uniformity and sufficient guidance from MUTCD devices.

Survey results are summarized below in the following topic areas:

- Agencies using non-standard traffic control devices.
- Agencies considering implementing non-standard traffic control devices.
- Agencies not implementing non-standard traffic control devices.

Agencies Using Non-Standard Traffic Control Devices

Fifteen agencies have implemented non-standard traffic signs, pavement markings and traffic signals:

- City of American Canyon.
- City of Bell Gardens.
- City of Brisbane.
- City of Costa Mesa.
- City of Lawndale.
- City of Long Beach.
- City of Mountain View.
- City of Rocklin.
- Contra Costa County Public Works.
- Caltrans District 4.
- Colorado DOT.
- Delaware DOT.
- Minnesota DOT.
- New Hampshire DOT.
- Ohio DOT.

The City of Lawndale respondent noted that the city uses customized oversized MUTCD traffic signs near streets with high-volume traffic and unusually wide streets. Respondents from the remaining agencies provided information about at least one non-standard traffic control device that their agencies have implemented.

Below are highlights of these devices in three categories: traffic signs, pavement markings and traffic signals. More information about each device, including application, design criteria, benefits, and safety and operational issues, is available in the **Detailed Findings** section of this report. Following these highlights is a discussion of safety and operational issues and device effectiveness.

Traffic Signs

Flashing Stop Signs With Reflective Posts
(*see page 13*)
City of Bell Gardens
Flashing stop signs are rimmed with LED lights. Reflective posts are included in the installation.

Alternative Pedestrian Hybrid Beacon Sign
(*see page 13*)
Delaware DOT
Interim guidance has been developed for a sign with the message Crosswalk/Stop On Red/Proceed On Flashing Red When Clear in conjunction with a pedestrian hybrid beacon.

Delaware Authority for Regional Transit (DART) Bus Stop Signs
(*see page 14*)
Delaware DOT
The agency has developed interim guidance for an updated design of DART bus stop signs.

Park/Bike Sign Along Parking-Protected Bikeways
(*see page 14*)
City of Long Beach
An 18-inch-wide by 12-inch-high, black-on-white sign along parking-protected bikeways indicates where vehicles should park or bike. One-half of sign reads “PARK HERE” with a black left arrow; the other half reads “[bike symbol] HERE” with a black right arrow.

Low-Stress Bicycle Network Signs
(*see page 15*)
Delaware DOT
Interim guidance identifies roads and paths that are appropriate for most cyclist skill levels.

Non-Standard Traffic Sign for Pedestrians and Bicyclists
(*see page 16*)
Colorado DOT
The agency has started implementing non-standard traffic signs on high-volume roads to address safety issues with drivers not allowing cyclists enough clearance.

Bike Lane Signs and Markings
(*see page 16*)
City of Brisbane
Non-standard signs and markings direct cyclists from the shoulder of a northbound one-lane road to the shoulder of a northbound two-lane road. These devices indicate that bicycles should yield to motorists.

Pavement Markings

Green Bicycle Boxes
(*see page 17*)
City of Costa Mesa
Using these markings has resulted in improved pedestrian and bicyclist compliance and reduced crashes and conflicts.

Green Bike Crossings
(*see page 18*)
City of Mountain View
Two successful implementations are provided. The agency followed National Association of City Transportation Officials (NACTO) guidelines for implementing these devices, which may not have been approved by California MUTCD (CA MUTCD) or covered under Federal Highway Administration’s (FHWA’s) Interim Approvals.

Sharrow Pavement Markings in Green Square
(*see page 18*)
Contra Costa County Public Works
This marking, which has been implemented on only one roadway, appears to be effective. Green backgrounds for sharrows are currently being tested and may be added to the MUTCD.

Green-Colored Pavement
(*see page 19*)
Minnesota DOT
Green-colored pavement has been used in accordance with MUTCD Interim Approval IA-14. Anecdotal evidence suggests it produces better right of way between drivers and cyclists.

Share the Path Marking
(*see page 19*)
City of American Canyon
A 3-foot round, preformed thermoplastic marking is used in areas where Share the Path signs are installed. Markings and signs inform users that a walkway was meant for bicycles and pedestrians.

Pavement Marking for Mixed-Use Paths
(*see page 20*)
City of Mountain View
Two-way pedestrian and bicyclist paths use red pavement for pedestrians and green for cyclists.

Symbol: State Law 3-Foot Minimum for Bicycles
(*see page 21*)
New Hampshire DOT
Markings are installed on high-volume roads and maintained by towns to indicate clearance for cyclists.

Longitudinal Bar Crosswalks (Double Zebra)
(*see page 21*)
Minnesota DOT
Markings were installed to address slip and fall concerns at continental block crosswalk locations. The agency would like to install markings at additional locations for further study.

Green K-71 Markers
(*see page 22*)
City of Costa Mesa
Markers are used in midblock locations to reduce vehicle speed, improve pedestrian and cyclist compliance, and increase visibility.

Traffic Signals

Rectangular Rapid Flashing Beacons (RRFBs)

City of Costa Mesa
(*see page 22*)
Signals are used in midblock locations to reduce vehicle speed, improve pedestrian and cyclist compliance, reduce crashes and conflicts, and reduce fatalities and serious injuries.

Caltrans District 4
(*see page 22*)
Implemented in midblock locations and on ramps, the signals have received positive feedback from the community.

Minnesota DOT
(*see page 23*)
RRFBs are installed in accordance with MUTCD Interim Approval IA-21 by a city or county via permit. The agency is developing criteria to provide better consistency for deploying these devices.

Ohio DOT
(*see page 23*)
The agency is tracking many implementations throughout the state. RRFBs allow for rapid implementation of low-cost improvements for pedestrian safety and mobility.

Pushbutton-Activated Pedestrian Blinker Sign
(*see page 24*)
City of Rocklin
Implementation of these solar-powered signs gives residents an "extra sense of security."

Pedestrian Pushbutton Signs
(*see page 25*)
Delaware DOT
The agency has developed interim guidance related to the pilot light to improve maintenance challenges with existing devices and technology. The guidance recommends that a pilot light or other means of indication installed with a pedestrian pushbutton should not be illuminated until actuation.

Accessible Pedestrian Signals
(*see page 25*)
Delaware DOT
Interim guidance provides a process to evaluate and prioritize requests for accessible pedestrian signal installations to ensure that all requests receive a fair and equal assessment and that funds are expended effectively.

Safety and Operational Issues

Respondents provided limited information about safety criteria and safety, operational and other issues. Only three agencies have established safety criteria for using non-standard traffic control devices: City of Mountain View, which follows NACTO guidance for its non-standard pavement markings; Delaware DOT, which has established interim guidance for its devices; and Ohio DOT, which plans to include RRFBs and raised crosswalks in its forthcoming Multimodal Design Guide.

Safety issues were reported by five agencies, including drivers not allowing sufficient clearance for cyclists (Colorado DOT) and occasional low compliance with RRFBs (Ohio DOT). Other agencies described operational issues, primarily related to increased maintenance (City of Bell Gardens, City of Long Beach, Minnesota DOT and City of Rocklin).

Assessment

None of the agencies have measured the effectiveness (safety or operational) of using these treatments.

General recommendations were provided by two respondents: The City of Brisbane respondent noted that if signs, markings and other traffic control devices are straightforward and clear, they are an asset for all users. The City of Rocklin respondent commented that while new and non-standard devices are eye-catching initially, "issues might be better resolved through educational campaigns at as many levels as possible for anyone using the roadway systems," in addition to enforcement with monetary and other penalties.

Agencies Considering Implementing Non-Standard Traffic Control Devices

Nine agencies are considering using non-standard traffic control devices:

- City of Belmont.
- City of Carlsbad.
- City of Montague.
- City of Oakdale.
- City of Pismo Beach.
- City of Redding.
- City of West Sacramento.
- City of Windsor.
- Ventura County.

Six respondents described potential implementations:

Traffic Signs

- Bicycle symbol instead of a pedestrian symbol on an R10-15 sign (City of Carlsbad).
- Stop and yield signs specifically for pedestrians and bicyclists (City of Redding).
- Modifying an SW4-1 sign (size and logo) to enhance bicycle safety (Ventura County).

Pavement Markings

- Greenback sharrows (City of Belmont).
- Buffered bike lane delineators, specifically, wave delineators (City of Windsor).

Traffic Signals

- Lighted crossings for pedestrians and bicyclists (City of West Sacramento).

The City of Carlsbad respondent added that to reduce liability and increase message consistency, the city avoids devices that are not compliant with the CA MUTCD. It does consider minor modifications to existing devices as long as they do not conflict with CA MUTCD. In the City of Oakdale, the discussion of non-standard signs has been “very preliminary and very infrequent.” The respondent noted that the city is “trying to move beyond the white noise of standard street signs.”

Potential Applications

Agencies in this group are mostly likely to locate non-standard traffic control devices in bicycle facilities, midblock locations and intersections. Locations that are least likely to see an implementation are school zones, railroad or light rail transit crossings, and driveways. None of these respondents have plans to implement a device in a work zone. Other possible locations are trail crossings (City of Redding), steep two-lane rural roads (Ventura County) and areas with pedestrian movements (City of Oakdale).

Design Criteria

Traffic volume, traffic speed and crash data are the primary design factors driving implementations along with road width and classification. Of least significance are traffic delay and traffic type. Other design criteria used are bicycle volumes and the potential for conflicts between vehicles and bicycles (City of Carlsbad). The City of Oakdale has not yet determined design criteria.

Benefits of Non-Standard Implementations

Eight of nine respondents noted improved pedestrian and bicyclist compliance as a key benefit of these implementations. Other benefits include reduced crashes or conflicts, and improved or equitable access. Only three respondents noted reduced speed as a benefit. Additional advantages of these implementations include the opportunity to personalize signs (City of Oakdale) and address concerns received from the public (City of Carlsbad).

Agencies Not implementing Non-Standard Traffic Control Devices

Forty-one agencies do not use non-standard traffic signs, pavement markings or traffic signals to improve pedestrian and bicyclist safety:

California Cities

- City of Apple Valley.
- City of Bell.
- City of Buellton.
- City of Buena Park.
- City of Calexico.
- City of Carson.
- City of Claremont.
- City of Del Rey Oaks.
- City of Duarte.
- City of El Cajon.
- City of El Segundo.
- City of Eureka.
- City of Exeter.
- City of Fullerton.
- City of Garden Grove.
- City of Hemet.
- City of Indian Wells.
- City of Indio.
- City of Irwindale.
- City of Laguna Beach.
- City of Laguna Hills.
- City of Lomita.
- City of Maywood Public Works.
- City of Menifee.
- City of Poway.
- City of San Bernardino.
- City of San Juan Capistrano.
- City of San Ramon.
- City of Simi Valley.
- City of Tustin.
- City of Winters.
- City of Yorba Linda.

California County

- Sutter County.

Caltrans

- Headquarters/Maintenance.
- District 7.
- District 8 (two responses).
- District 10.
- District 12.

State DOTs

- Connecticut DOT.
- Utah DOT.
- Wisconsin DOT.

The primary reasons for adopting this approach include potential liability of using non-MUTCD signs, traffic control uniformity and sufficient guidance from MUTCD devices. Several respondents noted that traffic signs should conform with MUTCD standards. Others like the City of Buellton rely on and follow Caltrans guidance. The respondent from Caltrans District 12 noted that the CA MUTCD is “comprehensive,” and non-standard devices must have experimental approval from the California Traffic Control Devices Committee (CTCDC).

Possible Modifications to Existing Traffic Control Devices

Of this group of respondents, six would consider modifying an existing traffic control device application to improve pedestrian and bicyclist safety, including the City of San Ramon, which

would “if the need arises.” The District 7 respondent noted that design flexibility may help with improving pedestrian and bicyclist safety. Other efforts are described below:

- *City of Buena Park*: Adding bicycle detection to various intersections to improve active transportation infrastructure.
- *City of Fullerton*: After completing its Local Road Safety Plan, will investigate specific locations that “may warrant more aggressive traffic control due to collision history.”
- *City of Irwindale*: Using orange color (construction) for permanent delineators to improve visibility. (Drivers often hit white delineators.)
- *City of Laguna Beach*: If recommended by professional traffic engineers, will consider new technologies and innovative ideas.
- *District 8A*: Sometimes considers using roadway stencils that are not in the MUTCD to provide direction to drivers.
- *Caltrans HQ*: Adopting Complete Streets policies.

Related Research and Resources

A literature search of recent publicly available resources identified publications that are organized into the following topic areas:

- General design guidance.
- Traffic signs.
- Pavement markings.
- Traffic signals.

General Design Guidance

National research underway includes National Cooperative Highway Research Program (NCHRP) 15-74, Safety Evaluation of On-Street Bicycle Facility Design Features, a project aimed at providing state DOTs and other transportation agencies with data-driven guidelines for selecting context-appropriate design features to improve safety in existing separated and nonseparated on-street bicycle facilities and to plan new facilities. The guidelines will be based on a quantitative analysis of crash patterns and an evaluation of the roadway characteristics, land use patterns and human factors that increase conflicts and the risk and severity of midblock crashes involving cyclists. A Transportation Pooled Fund study seeks to foster innovative facility design, planning and implementation that will improve safety and mobility for pedestrians and bicyclists. An additional goal of this study is to conduct research about innovative traffic control devices to accelerate their incorporation into the MUTCD.

Completed research includes numerous resources from FHWA, including the Pedestrian and Bicycle Information Center web site, which “develops and shares resources vital to advancing mobility, access, equity and safety for pedestrians and bicyclists.” A December 2021 FHWA webinar shares strategies for accelerated delivery of safety countermeasures for pedestrians and bicyclists, and a June 2021 webinar examines how transportation professionals can use traffic signals to make intersections safer for bicycling and walking. Additional resources include a 2018 toolbox of countermeasures to pedestrian crashes, a 2018 guide for improving pedestrian safety at uncontrolled crossings and a 2018 literature review of resources for separating bicyclists from traffic.

State resources include research in progress in Oregon that is examining the impacts of intersection treatments and traffic characteristics on bicyclist safety. Completed research

includes a 2018 analysis of the safety effectiveness of pedestrian crossing enhancements in Oregon. A 2021 Minnesota DOT project developed best practices for pedestrian and bicycle safety and a 2020 report provides guidelines for pedestrian crosswalk policy development.

Traffic Signs

The University Transportation Centers Program is conducting a research study to identify optimal locations for signage at unsignalized pedestrian crossing locations and optimal signage configurations. The project will generate innovations in multimodal planning and modeling for high-growth regions, and innovations to improve multimodal connections, system integration and security.

Pavement Markings

Research underway in Texas is analyzing the impact on safety of green-colored pavement at intersections. A 2021 University Transportation Center study measured the durability, retroreflectivity, color changes and friction of three pavement markings used in bike lanes: green waterborne paint, green liquid methacrylate paint and white thermoplastic paint. A 2019 study in Virginia evaluated the effects of two bike boxes and two turn boxes on facilitating safe bicycle travel. Other state research includes a project underway in North Carolina that is evaluating yielding compliance at high-visibility crosswalks.

Traffic Signals

An NCHRP project has been tentatively selected that will develop guidance for selecting appropriate pedestrian crossing treatments, including the characteristics of each treatment and how they might be beneficial for a given location.

Gaps in Findings

Despite distributing the survey to a wide pool of respondents, participation in the survey was very limited. (Sixty-six of 695 respondents participated in the survey.) Additional non-standard traffic control devices and other useful information from other agencies could potentially increase the findings of this effort and provide additional devices.

Next Steps

Moving forward, Caltrans could consider:

- Reviewing the non-standard traffic control devices implemented by other agencies for possible addition to existing devices by incorporating them into the CA MUTCD to enhance pedestrian and bicyclist safety.
- Following up with agencies that are considering non-standard implementations to monitor their progress and for potential application to Caltrans' efforts.
- Reaching out to local and state agencies that did not respond to the survey for additional information about non-standard traffic control devices.
- Reviewing the findings of the literature search for additional information about non-standard traffic control devices and their applications.

Detailed Findings

Background

California Department of Transportation (Caltrans) uses traffic signs, pavement markings and traffic signals on roadways to help promote pedestrian and bicyclist safety and to reduce fatalities and serious injuries at intersections, midblock sites and other locations. In its efforts to achieve zero fatalities and serious injuries, Caltrans' Division of Safety Programs is exploring new, non-standard traffic control devices that are being used by other transportation agencies to enhance pedestrian and bicyclist safety.

Non-standard devices are those that are currently not included in the Manual on Uniform Traffic Control Devices (MUTCD). This investigation gathered information from local agencies and other state departments of transportation (DOTs) about their use of non-standard traffic signs, pavement markings and traffic signals on roadways, including at intersections and midblock locations. This effort also identified design criteria for these devices, safety benefits and other information that supports their effectiveness, and recommendations for implementation.

Survey of Practice

An online survey was distributed to 135 Caltrans functional managers and district signing, striping and traffic signal contacts; 453 members of the League of California Cities; 57 members of the County Engineers Association of California; and 50 state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Traffic Engineering. (Total distribution: 695.) Survey questions are provided in Appendix A. The full text of survey responses is presented in a supplement to this report.

For the purposes of the survey and this Preliminary Investigation, non-standard traffic control devices are defined as follows:

- *Traffic signs* include regulatory, warning and guide signs, as well as barricades, gates, object markers and changeable message signs.
- *Pavement markings* include pavement and curb markings, delineators, colored pavements, channelizing devices and islands.
- *Traffic signals* include traffic control signals for general applications, one-lane/two-way facilities, freeway entrance ramps, movable bridges at toll plazas and lane-use control; pedestrian signals; hybrid beacons; emergency-vehicle signals; flashing beacons; and in-roadway lights.

Sixty-six respondents participated in the survey: representatives from 48 California cities, three California counties, six Caltrans districts (two responses from District 8) and eight state DOTs. Of this respondent group:

- Fifteen agencies have implemented non-standard traffic signs, pavement markings or traffic signals other than those included in the MUTCD to improve pedestrian and bicyclist safety. Survey responses from these agencies begin on page 12.
- Nine agencies are considering using non-standard traffic control devices. Respondents provided information about these potential implementations, including location, design criteria and the benefits of the device. Survey responses begin on page 26.
- Nearly two-thirds of the responding agencies (41) are not using non-standard traffic control devices and are not considering them. The primary reasons for adopting this

approach include potential liability of using non-MUTCD signs, traffic control uniformity and sufficient guidance from MUTCD devices. Survey responses begin on page 29.

Agencies Using Non-Standard Traffic Control Devices

Fifteen agencies have implemented non-standard traffic signs, pavement markings and traffic signals:

- City of American Canyon.
- City of Bell Gardens.
- City of Brisbane.
- City of Costa Mesa.
- City of Lawndale.
- City of Long Beach.
- City of Mountain View.
- City of Rocklin.
- Contra Costa County Public Works.
- Caltrans District 4.
- Colorado DOT.
- Delaware DOT.
- Minnesota DOT.
- New Hampshire DOT.
- Ohio DOT.

All but one respondent (City of Lawndale) in this group provided information about at least one non-standard traffic control device that their agencies have implemented. (The respondent from the City of Lawndale noted that the city uses customized oversized MUTCD traffic signs near streets with high-volume traffic and unusually wide streets.) Descriptions include where the device has been implemented, the design criteria that were considered and the benefits of the device, when available.

Respondents provided limited information about safety criteria; safety, operational and other issues; and device effectiveness. Only three agencies have established safety criteria for using non-standard traffic control devices: City of Mountain View, which follows National Association of City Transportation Officials (NACTO) guidance for its non-standard pavement markings; Delaware DOT, which has established interim guidance for its devices; and Ohio DOT, which plans to include Rectangular Rapid Flashing Beacons (RRFBs) and raised crosswalks in its forthcoming Multimodal Design Guide.

Safety issues were reported by five agencies, including drivers not allowing sufficient clearance for bicyclists (Colorado DOT) and occasional low compliance with RRFBs (Ohio DOT). Other agencies described operational issues, primarily related to increased maintenance (City of Bell Gardens, City of Long Beach, Minnesota DOT and City of Rocklin).

None of the agencies have measured the effectiveness (safety or operational) of using these treatments.

Two respondents provided overall recommendations: The City of Brisbane respondent noted that if signs, markings and other traffic control devices are straightforward and clear, they are an asset for all users. The City of Rocklin respondent commented that while new and non-standard devices are eye-catching initially, “issues might be better resolved through educational campaigns at as many levels as possible for anyone using the roadway systems,” in addition to enforcement with monetary and time penalties.

Below are brief case studies of the non-standard traffic control devices in three categories: traffic signs, pavement markings (beginning on page 17) and traffic signals (beginning on page 22).

Traffic Signs

Non-standard traffic sign implementations were described by 10 respondents, including the respondent from the City of Lawndale, who noted that the city uses customized oversized MUTCD traffic signs near streets with high-volume traffic and unusually wide streets. Below are descriptions of the non-standard traffic signs provided by the remaining respondents:

- Flashing stop signs with reflective posts (City of Bell Gardens).
- Alternative pedestrian hybrid beacon sign (Delaware DOT).
- Delaware Authority for Regional Transit (DART) bus stop signs (Delaware DOT).
- Park/bike sign along parking-protected bikeways (City of Long Beach).
- Low-stress bicycle network signs (Delaware DOT).
- Non-standard traffic sign for pedestrians and bicyclists (Colorado DOT).
- Bike lane signs and markings (City of Brisbane).

Flashing Stop Signs With Reflective Posts

City of Bell Gardens

- Flashing stop signs rimmed with LED lights.
- Reflective posts included in installation.

Topic	Description
Application	Intersection
Design Criteria	• Roadway classification • Traffic volume • Traffic speed • Crash data
Benefits	• Reduced vehicle speed • Reduced crashes/conflicts • Increased visibility for drivers
Operational Issues	Increased maintenance costs from the LED sign and reflectors.

Alternative Pedestrian Hybrid Beacon Sign

Delaware Department of Transportation

- Interim guidance for a Crosswalk/Stop On Red/Proceed On Flashing Red When Clear (R10-23a) word message sign that may be used instead of the required R10-23 sign in conjunction with a pedestrian hybrid beacon.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Bicycle facilities

Topic	Description
Design Criteria	• Roadway classification • Traffic volume • Traffic speed • Crash data
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Criteria Established	Interim guidance developed for the device.

DART Bus Stop Signs

Delaware Department of Transportation

- Interim guidance for an updated design of DART bus stop signs.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Bicycle facilities
Design Criteria	• Roadway classification • Traffic volume • Traffic speed • Crash data
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Criteria Established	Interim guidance developed for the sign.

Park/Bike Sign Along Parking-Protected Bikeways

City of Long Beach

- 18-inch-wide by 12-inch-high, black-on-white sign designating where vehicles should park or bike along parking-protected bikeways.
- One-half of sign reads “PARK HERE” with a black left arrow; the other half reads “[bike symbol] HERE” with a black right arrow.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Bicycle facilities
Successful Implementations	• Artesia Boulevard between Atlantic Avenue and Orange Avenue • Broadway between Alamitos Avenue and Redondo Avenue • Atlantic Avenue between San Antonio Drive and Roosevelt Road • Bellflower Boulevard between Colorado Street and Atherton Street
Design Criteria	• Used only within buffers of parking-protected bikeways. • Placed in the space between the parking stalls and bike lane at the beginning of each block and repeating approximately every 200 feet.
Benefits	• Reduced crashes/conflicts. • Faster adjustment to new parking requirements. Previous projects with parking-protected bikeways took months for motorists to adapt to parking in the newly marked parking lanes instead of against the curb. With the signs, the adjustment was nearly immediate.
Safety Issues	Proper parking practices.
Operational Issues	• Signs typically mounted temporarily on delineators or A-frame barricades after completion of a new project. • Temporary elements require regular inspection (often knocked over or tampered with).
Successes	Anecdotal improvement in adoption of new parking practices.
Challenges	Vandalism. Temporary traffic control devices often knocked over and must be inspected/restored regularly.
Implementation Recommendations	Since this is a non-standard sign that is unfamiliar to users, the agency adds “CVC Section 22502(a)” and “LONG BEACH PUBLIC WORKS” at the bottom of the sign in small type to convey authority.

Low-Stress Bicycle Network Signs

Delaware Department of Transportation

- Interim guidance developed to identify roads and paths that are appropriate for most skill levels.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Bicycle facilities

Topic	Description
Design Criteria	• Roadway classification • Traffic volume • Traffic speed • Crash data
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Criteria Established	Interim guidance developed for the sign.

Non-Standard Traffic Sign for Pedestrians and Bicyclists

Colorado Department of Transportation

- The agency has only started to implement non-standard traffic signs.

Topic	Description
Location	High-volume road
Design Criteria	• Road width • Traffic volume • Traffic speed
Benefits	• Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Issues	Drivers not allowing cyclists enough clearance.
Successes	Too soon to determine
Challenges	Budget
Additional Information	The agency's online signing and pavement markings resource includes its supplement to the MUTCD.

Bike Lane Signs and Markings

City of Brisbane

- One lane of a northbound arterial becomes two when the highway exit joins the arterial.
- Non-standard signs and markings used to place a bike lane between two lanes and indicate that bikes should yield to motorists.
- Signs and markings direct bicyclists from the shoulder of the northbound one-lane road to the shoulder of the northbound two-lane road.

Topic	Description
Application	• High-volume road • Highway exit that adds a second traffic lane to an arterial roadway
Successful Implementation	Bayshore Boulevard at Highway 101, Exit 426A

Topic	Description
Design Criteria	• Road width • Roadway classification • Number of lanes • Traffic volume • Traffic speed • Traffic type
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries
Safety Issues	• None. Only experienced cyclists use route (as intended). • Experienced cyclists express concern for novice cyclists.
Successes	Agency identified where cyclists should be located in travel lanes and where they can necessarily and safely cross one traffic lane without losing speed or momentum on an uphill slope.
Challenges	Although novice cyclists do not use this route, experienced cyclists express concern for novices.
Implementation Recommendations	Keep signs, markings and other traffic control devices straightforward and clear.

Pavement Markings

Below are descriptions for the following non-standard pavement markings provided by respondents:

- Green bicycle boxes (City of Costa Mesa).
- Green bike crossings (City of Mountain View).
- Sharrow pavement markings in green square (Contra Costa County Public Works).
- Green-colored pavement (Minnesota DOT).
- Share the Path marking (City of American Canyon).
- Pavement marking for mixed-use paths (City of Mountain View).
- Symbol: State law 3-foot minimum for bicycles (New Hampshire DOT).
- Longitudinal bar crosswalks (double zebra) (Minnesota DOT).
- Green K-71 markers (City of Costa Mesa).

Note: See page 16 for information from the City of Brisbane about its use of markings with signs.

Green Bicycle Boxes

City of Costa Mesa

Topic	Description
Application	Intersection
Design Criteria	• Traffic volume • Traffic speed

Topic	Description
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts

Green Bike Crossings

City of Mountain View

Topic	Description
Application	• Intersection • Driveway
Successful Implementations	• Shoreline Boulevard and Charleston Road (bike crossings) • Calderon Avenue (driveways)
Design Criteria	• Road width • Roadway classification • Number of lanes • Traffic speed • Traffic delay
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries
Safety Criteria Established	Agency follows NACTO guidelines for these devices, which may not have been approved by California MUTCD (CA MUTCD) or in interim approval.
Installation Issues	• Inconsistent installations at different locations (as with most pavement treatments). • Stipulating specific products to meet standards.
Successes	Consistent treatment throughout the Charleston Road corridor
Implementation Recommendations	• Be consistent. • Use the same treatment through the entire project or corridor.

Sharrow Pavement Markings in Green Square

Contra Costa County Public Works

- Using green backgrounds for sharrows is in the testing phase and may be added to the MUTCD in the near future.

Topic	Description
Application	• Intersection • Midblock • Bicycle facilities
Design Criteria	• Roadway classification • Traffic volume

Topic	Description
Successful Implementation	Blackhawk Road in unincorporated Danville
Benefits	• Difficult to quantify benefits. • Anecdotal evidence suggests improved visibility for all road users.
Implementation Recommendations	Based on limited experience (only used on one roadway), these measures appear to be effective with no negative feedback.

Green-Colored Pavement

Minnesota Department of Transportation

- Green-colored pavement as discussed in MUTCD Interim Approval IA-14.

Topic	Description
Application	• Intersection • Midblock • Bicycle facilities • Local roadways within Minnesota DOT right of way
Design Criteria	• Road width • Number of lanes • Traffic volume • Traffic speed • System continuity • Intersection complexity
Benefits	• Reduced crashes/conflicts. • A formal review has not yet been completed. Anecdotal evidence suggests it results in better right of way between drivers and bicyclists.

Share the Path Marking

City of American Canyon

- Yellow and black, 3-foot round, preformed thermoplastic medallion marking. (A vendor drawing of this marking has been provided to Caltrans separately.)
- Share the Path signs installed in the same locations. The signs have more details about the path.

Topic	Description
Application	• Walking path also designated for bicycles. • School zone (placed in front of a new school that intersects with the walking path). • Bicycle facilities.
Successful Implementation	Wetlands Edge Road

Topic	Description
Design Criteria	• Approximately 12-foot-wide walkway for pedestrians and bicycles. • Added markings and upgraded signs to educate users that walkway was meant for bicycles and pedestrians.
Benefits	Has only been implemented for a few months. Limited feedback from residents has been positive.
Additional Information	• Vendor: Ennis Flint. • Initially observed in another city (possibly Berkeley or Emeryville.)

Pavement Marking for Mixed-Use Paths

City of Mountain View

- Red pavement for pedestrians, green for cyclists.
- Two-way pedestrian and bicyclist paths.

Topic	Description
Application	Bicycle facilities
Design Criteria	Pedestrian and bicycle circulation and volumes around development.
Successful Implementations	• Shoreline/Shorebird up to Alta Avenue • Charleston and Shoreline Boulevard (bike crossings) • Calderon Avenue (bike driveway conflict striping)
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Improved/equitable access
Safety Criteria Established	Agency follows NACTO guidelines for these devices, which may not have been approved by CA MUTCD or in interim approval.
Installation Issues	• Inconsistent installations at different locations (as with most pavement treatments). • Stipulating specific products (green/red high-friction surface treatment) to meet standards.
Successes	Consistent treatment throughout the Charleston Road corridor. (The agency follows NACTO guidelines for these treatments.)
Implementation Recommendations	• Be consistent. • Use the same treatment throughout the entire project or corridor.

Symbol: State Law 3-Foot Minimum for Bicycles

New Hampshire Department of Transportation

- Installed and maintained by towns; subject to approval by New Hampshire DOT.

Topic	Description
Application	High-volume road
Successful Implementations	• Claremont • Newport • Newfound Lake
Design Criteria	• Road width • Roadway classification • Traffic volume • Traffic speed • Subject to local advocates.
Benefits	Public awareness
Successes	Good response from requesting towns, cities and bicycle advocacy groups.
Challenges	Initially, the agency was allowing signs that more accurately depicted New Hampshire's graduated “move over” statute (3-foot minimum and an additional 1 foot for each 10 mph over 30 mph).

Longitudinal Bar Crosswalks (Double Zebra)

Minnesota Department of Transportation

- Installation part of the Federal Highway Administration (FHWA) Request to Experiment 3(09)-22(E).
- Goal: To address slip and fall concerns at continental block crosswalk locations.
- Minnesota DOT would like to install these markings at additional locations for further study.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Local street
Design Criteria	A high-visibility crosswalk marking that provides pedestrians and cyclists with a higher probability of being in direct contact with the pavement (not pavement marking).
Benefits	• Improved driver compliance • Provide a crosswalk marking without creating slip and fall hazards for pedestrians and bicyclists
Additional Information	The final report from the study is available. (A copy of this report, 3(09-22E Lined Longitudinal Bar Crosswalk: An Experimental Study Report, has been provided to Caltrans separately.)

Green K-71 Markers

City of Costa Mesa

Topic	Description
Application	Midblock
Design Criteria	Traffic volume
Benefits	• Reduced vehicle speed • Improved pedestrian/bicyclist compliance • Increased visibility

Traffic Signals

Below are descriptions for the following non-standard traffic signals provided by respondents:

- RRFBs (City of Costa Mesa, Caltrans District 4, Minnesota DOT and Ohio DOT).
- Pushbutton-activated pedestrian blinker sign (City of Rocklin).
- Pedestrian pushbutton signs (Delaware DOT).
- Accessible pedestrian signals (Delaware DOT).

Rectangular Rapid Flashing Beacons

City of Costa Mesa

Topic	Description
Application	Midblock
Design Criteria	• Road width • Traffic volume • Traffic speed
Benefits	• Reduced vehicle speed • Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries

Caltrans District 4

Topic	Description
Application	• Midblock • Ramps
Design Criteria	• Road width • Number of lanes • Traffic speed • Crash data
Benefits	Not yet determined
Successes	Positive community feedback

Minnesota Department of Transportation

- RRFBs as discussed in MUTCD Interim Approval IA-21 are allowed on Minnesota DOT roadways. Devices are typically installed by the city or county via a permit.

Topic	Description
Application	• Intersection • Midblock • School zone
Design Criteria	• Currently local agencies identify locations and eight district offices approve the locations. • Minnesota DOT is developing criteria to provide better consistency for deploying these devices.
Benefits	A formal review has not yet been completed. Anecdotal evidence suggests that RRFBs provide better driver compliance.
Maintenance Issues	RRFBs are installed via permit. Ongoing maintenance can be an issue for local partners.

Ohio Department of Transportation

Topic	Description
Application	• Midblock • High-volume road • School zone • Bicycle facilities
Successful Implementation	The agency is tracking many locations statewide. (An Excel spreadsheet tracking these locations has been provided to Caltrans separately.)
Design Criteria	• Road width • Number of lanes • Traffic speed • Crash data
Benefits	• Reduced vehicle speed • Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Criteria Established	In its forthcoming Multimodal Design Guide, the agency includes considerations like RRFBs and raised crosswalks as recommended treatments in uncontrolled intersections based on bicycle and pedestrian safety.
Safety Issues	Anecdotally, sometimes low compliance is associated with RRFBs.
Other Issues	As RRFBs become more prevalent across the state, and time and resources are limited, tracking them becomes a burden.

Topic	Description
Successes	Rapid implementation of low-cost improvements for pedestrian safety and mobility.
Challenges	• Public education • Awareness of stopping/yielding
Implementation Recommendations	Use overhead installations to increase visibility and compliance.

Pushbutton-Activated Pedestrian Blinker Sign

City of Rocklin

Topic	Description
Application	• Midblock • Roundabout • School zone
Successful Implementations	• 2530 Sierra Meadows Drive • 4241 Rocklin Road • Ranch View Drive
Design Criteria	• Road width • Roadway classification • Number of lanes • Traffic volume • Traffic speed • Traffic type • Pedestrian volume
Benefits	• Increased visibility of signs
Safety Issues	Possible false sense of security for pedestrians/bicyclists
Operational Issues	• Vehicle knockdowns • Maintenance
Other Issues	• Solar-powered signs, so depending on angles and trees, mounting can be an issue, as well as ongoing tree trimming. • Access to spare parts for knockdowns, failures, etc.
Successes	Citizen approval: People like the extra sense of security.
Challenges	• Some pedestrians cross without activating signs. • Some vehicles do not stop for signs. • Access to spare parts can be challenging.
Implementation Recommendations	• Coordinate with news/social media outlets to educate the public. • Ensure agency enforces signs initially, and periodically later.
Additional Information	Sign vendors: • Tapco • Availed Technologies • SignAlert

Pedestrian Pushbutton Signs

Delaware Department of Transportation

- Interim guidance related to the pilot light used for pedestrian pushbuttons.
- If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation.
- Purpose of guidance: To improve maintenance challenges with existing devices and technology.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Bicycle facilities
Design Criteria	• Roadway classification • Traffic volume • Traffic speed • Crash data
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Criteria Established	Interim guidance developed for this device.

Accessible Pedestrian Signals

Delaware Department of Transportation

- Interim guidance provides a process to evaluate and prioritize accessible pedestrian signal (APS) installations when they are requested to ensure that all APS installation requests receive a fair and equal assessment and that funds are expended effectively.
- An intersection must first meet basic conditions to be considered for APS:
    1. A blind or visually impaired individual or a person or agency filing on the individual's behalf must complete the Request for the Installation of Accessible Pedestrian Signals form.
    2. Intersections must be signalized.
    3. Retrofitting the signal to include APS must be feasible.

    In addition, no current improvements proposed by Delaware DOT should be planned to the existing pedestrian signal.
- The intersection must be evaluated to determine the need relative to other locations where APS have been requested. During a site visit of the intersection, the evaluation team and the requestor should discuss minor intersection improvements, installation of new crosswalks, installation of pedestrian signals with APS on crossings for which APS are not being requested, consideration of the needs of other potential blind or visually impaired individuals, consideration of the intersection's characteristics after improvements are made and, if APS are to be installed at nearby signalized

intersections, determination that signals from one intersection cannot be heard at other intersections.

- Factors used in the evaluation include intersection configuration, crossing width, pedestrian crashes, posted speed limit or 85th percentile speed on street to be crossed, traffic volumes or queues, right-turn operations, free right-turn operations, special signal conditions, proximity of the intersection to key facilities, and other special traffic and mobility conditions.
- Evaluation scores are used to determine the relative need and to develop a prioritized list of intersections to be funded.

Topic	Description
Application	• Intersection • Midblock • High-volume road • Bicycle facilities
Design Criteria	• Roadway classification • Traffic volume • Traffic speed • Crash data
Benefits	• Improved pedestrian/bicyclist compliance • Reduced crashes/conflicts • Reduced fatalities/serious injuries • Improved/equitable access
Safety Criteria Established	Interim guidance is developed for the device.

Agencies Considering Implementing Non-Standard Traffic Control Devices

Nine agencies are considering using non-standard traffic control devices:

- City of Belmont.
- City of Carlsbad.
- City of Montague.
- City of Oakdale.
- City of Pismo Beach.
- City of Redding.
- City of West Sacramento.
- City of Windsor.
- Ventura County.

Respondents from six of these agencies described potential implementations:

Traffic signs:

- *Bicycle symbol instead of a pedestrian symbol on an R10-15 sign* (City of Carlsbad).
- *Stop and yield signs specifically for pedestrians and bicyclists* (City of Redding).
- *Modifying an SW4-1 sign (size and logo) to enhance bicycle safety* (Ventura County).

Pavement markings:

- *Greenback sharrows* (City of Belmont).
- *Buffered bike lane delineators*, specifically, wave delineators (City of Windsor).

Traffic signals:

- *Lighted crossings for pedestrians and bicyclists* (West Sacramento).

The respondent from the City of Carlsbad added that to reduce liability and increase message consistency, the city avoids devices that are not compliant with the CA MUTCD. It does consider minor modifications to existing devices as long as they do not conflict with CA MUTCD. For example, the city would consider the modification to replace the pedestrian symbol on an R10-15 sign with a bicycle symbol as compliant with CA MUTCD.

In the City of Oakdale, the discussion of non-standard signs has been "very preliminary and very infrequent." The respondent noted that the city is "trying to move beyond the white noise of standard street signs."

Potential Applications

Non-standard traffic control devices could be implemented in the following locations:

- Intersection.
- Midblock.
- Driveway.
- High-volume road.
- Work zone.
- Railroad/light rail transit crossing.
- School zone.
- Bicycle facilities (such as a bike path or bikeway).
- Other location/application.

Agencies are mostly likely to locate these traffic control devices in bicycle facilities, midblock locations and intersections. Locations that are least likely to see an implementation are school zones, railroad or light rail transit crossings, and driveways. None of these respondents have plans to implement a device in a work zone. Other possible locations are trail crossings (City of Redding), steep two-lane rural roads (Ventura County) and areas with pedestrian movements (City of Oakdale). Table 1 summarizes survey responses.

Table 1. Potential Applications of Non-Standard Traffic Control Devices

Agency	Intersection	Midblock	Driveway	High-Volume Road	RR/Light Rail Crossing	School Zone	Bicycle Facilities	Other
Belmont		X					X	
Carlsbad	X							
Montague	X			X	X	X		
Oakdale		X				X		Pedestrian movements
Pismo Beach	X	X	X					
Redding							X	Trail crossings
West Sacramento	X	X					X	
Windsor		X		X			X	
Ventura County				X			X	Steep two-lane rural roads
Total	**4**	**5**	**1**	**3**	**1**	**2**	**5**	

Design Criteria

The following design criteria could be considered in these implementations:

- Road width.
- Roadway classification.
- Number of lanes.
- Traffic volume.
- Traffic speed.
- Traffic delay.
- Traffic type.
- Crash data.

Traffic volume, speed and crash data are the primary design factors driving implementations along with road width and classification. Of least significance are traffic delay and type. Additional design criteria used in the City of Carlsbad are bicycle volumes and the potential for conflicts between vehicles and bicycles. The City of Oakdale has not yet determined design criteria. Table 2 summarizes survey responses.

Table 2. Design Criteria for Non-Standard Traffic Control Devices

Agency	Road Width	Road Classi-fication	Number of Lanes	Traffic Volume	Traffic Speed	Traffic Delay	Traffic Type	Crash Data	Other
Belmont		X		X	X			X	
Carlsbad				X				X	• Bicycle volumes • Potential for vehicle/ bicycle conflicts
Montague					X				
Pismo Beach	X			X			X		
Redding		X		X	X			X	
West Sacramento	X	X	X	X	X	X	X	X	
Windsor	X		X						
Ventura County	X	X	X	X	X			X	
Total	**4**	**4**	**3**	**6**	**5**	**1**	**2**	**5**	

Benefits of Non-Standard Implementations

Respondents indicated the benefits of using non-standard traffic control devices from the following options:

- Reduced vehicle speed.
- Improved pedestrian and bicyclist compliance.
- Reduced crashes or conflicts.
- Reduced fatalities or serious injuries (severity).
- Improved/equitable access.

Improved pedestrian and bicyclist compliance was noted by eight of nine respondents in this group. Other key benefits include reduced crashes or conflicts, and improved or equitable access. Only three respondents noted reduced speed as a benefit. Additional advantages of these implementations include the opportunity to personalize signs (City of Oakdale) and to

address concerns received from the public (City of Carlsbad). The Ventura County respondent added that the agency will begin to collect performance measure data when the modified sign is installed. Table 3 summarizes survey responses.

Table 3. Potential Benefits of Non-Standard Implementations

Agency	Reduced Speed	Improved Compliance	Reduced Crashes/ Conflicts	Reduced Fatalities/ Serious Injuries	Improved/ Equitable Access	Other	Description
Belmont		X	X		X		
Carlsbad			X	X	X	X	Address concerns from the public.
Montague	X	X					
Oakdale		X				X	Personalize sign.
Pismo Beach		X	X				
Redding		X	X	X			
West Sacramento	X	X	X	X	X		
Windsor		X			X		
Ventura County	X	X	X	X	X		
Total	**3**	**8**	**6**	**4**	**5**	**2**	

Agencies Not Implementing Non-Standard Traffic Control Devices

Nearly two-thirds of agencies (41) are not using any traffic signs, pavement markings or traffic signals other than those included in the MUTCD to improve pedestrian and bicyclist safety:

California Cities

- City of Apple Valley.
- City of Bell.
- City of Buellton.
- City of Buena Park.
- City of Calexico.
- City of Carson.
- City of Claremont.
- City of Del Rey Oaks.
- City of Duarte.
- City of El Cajon.
- City of El Segundo.
- City of Eureka.
- City of Exeter.
- City of Fullerton.
- City of Garden Grove.
- City of Hemet.
- City of Indian Wells.
- City of Indio.
- City of Irwindale.
- City of Laguna Beach.
- City of Laguna Hills.
- City of Lomita.
- City of Maywood Public Works.
- City of Menifee.
- City of Poway.
- City of San Bernardino.
- City of San Juan Capistrano.
- City of San Ramon.
- City of Simi Valley.
- City of Tustin.
- City of Winters.
- City of Yorba Linda.

California County

- Sutter County.

Caltrans

- Headquarters (HQ)/Maintenance.
- District 7.
- District 8 (two responses).
- District 10.
- District 12.

State DOTs

- Connecticut DOT.
- Utah DOT.
- Wisconsin DOT.

Explanation of Practice

Reasons for not using non-standard traffic control devices include:

- *Potential liability* of using non-MUTCD signs (15 responses).
- *Traffic control uniformity* (10 responses). Some respondents indicated that non-standard traffic control devices may increase the risk of unintended and unexpected motorist behavior.
- *Sufficient guidance from MUTCD* for pedestrian and bicyclist signage (10 responses).

Several respondents noted that traffic signs should conform with MUTCD standards, including the respondent from Connecticut DOT who noted that the agency "[c]losely follow[s] and implement[s] FHWA proven safety countermeasures wherever practical and justified. Others like the City of Buellton rely on and follow Caltrans guides if there is a change to allow non-standard traffic control devices. The respondent from Caltrans District 12 noted that the CA MUTCD is "comprehensive," and non-standard devices must have experimental approval from the California Traffic Control Devices Committee (CTCDC). Survey responses, when available, are summarized in Table 4.

Table 4. Considerations for Not Using Non-Standard Traffic Control Devices

Agency	Liability	Uniformity/ Standardization	MUTCD Sufficient	Other	Description
Apple Valley				X	Ensure safety and coverage of the MUTCD.
Bell	X				Be consistent in implementing MUTCD standards.
Buellton	X				Adhere to city risk management policies and goals.
Buena Park		X			Maintain traffic control uniformity. Non-standard traffic control devices may increase the risk of unintended and unexpected motorist behavior.
Calexico				X	Use federal and/or state guidelines.
Claremont	X				
Del Rey Oaks			X		
Duarte	X				
El Cajon			X		Most signs used are in the MUTCD.
El Segundo		X			Comply with MUTCD standards.
Eureka	X				

Agency	Liability	Uniformity/ Standardization	MUTCD Sufficient	Other	Description
Fullerton	X	X			• Do not want to create confusion by using non-standard signage. • Have liability concerns with using traffic control device not vetted by state.
Garden Grove	X				
Hemet	X				Rely on MUTCD and Caltrans vetting process.
Indio	X				
Irwindale			X		
Laguna Beach		X			
Laguna Hills		X			
Lomita				X	Use devices that Los Angeles County traffic engineer recommends (may or may not be MUTCD).
Maywood Public Works		X			
Menifee		X		X	Focus on standard devices and educating public about these devices.
Poway			X		
San Bernardino			X		
San Ramon			X		
Simi Valley		X			Only use markings or signage that falls within established standards of care.
Tustin	X				Maintain liability and design immunity.
Winters			X		
Yorba Linda	X				
Sutter County			X		
Caltrans HQ		X			All traffic signs should conform with the MUTCD standards.
District 7	X				Required to follow MUTCD standards/guidance.
District 8A	X				
District 8B	X				
District 10			X		Unnecessary. If needed, agency modifies standard devices.
District 12	X		X		• CA MUTCD is comprehensive. • Non-standard devices must have experimental approval from CTCDC.
Connecticut DOT		X			• Strive to follow MUTCD on state roadways. • Closely follow and implement FHWA-proven safety countermeasures where practical and justified.
Total	**15**	**10**	**10**	**4**	

Consideration for Modifications to Existing Traffic Control Device

Of this group of respondents, six would consider modifying an existing traffic control device application to improve pedestrian and bicyclist safety, including the City of San Ramon, which would "if the need arises." The District 7 respondent noted that design flexibility may help with improving pedestrian and bicyclist safety. Other specific efforts are described below:

- *City of Buena Park*: Adding bicycle detection to various intersections to improve active transportation infrastructure.
- *City of Fullerton*: After completing its Local Road Safety Plan, will investigate specific locations that "may warrant more aggressive traffic control due to collision history."
- *City of Irwindale*: Using orange color (construction) for permanent delineators to improve visibility. (Drivers often hit white delineators.)
- *City of Laguna Beach*: If recommended by professional traffic engineers, will consider new technologies and innovative ideas.
- *District 8A*: Sometimes considers using roadway stencils that are not in the MUTCD to provide direction to drivers.
- *Caltrans HQ*: Adopting Complete Streets policies.

Additional information from respondents is provided below:

- In *City of Fullerton*, safety is "paramount." The city is willing to implement non-standard items that may improve safety for residents. Any experimentation is requested according to FHWA and Caltrans requirements.
- The *City of Menifee* respondent noted that the traffic engineering profession and government do "a poor job" educating the public about standard signs, pavement markings, signals and other traffic control devices. Instead of adding more "confusing signs that nobody seems to understand," agencies should educate the public about standard signs.

  The respondent added that Caltrans needs to reconsider its promotion of Class IV bikeways. He noted that after another city implemented them, more than 40 bicycle accidents occurred in one year where none had occurred before.
- *Connecticut DOT* has mined information through its involvement in national pooled fund studies. As a member of these pooled funds, it uses data from these studies to find "opportunities to improve safety with proven safety devices."

Related Research and Resources

A literature search of recent publicly available resources identified publications that are organized into the following topic areas:

- General design guidance.
- Traffic signs.
- Pavement markings.
- Traffic signals.

Resources may be further categorized as national, state or related research and resources.

General Design Guidance

National Research and Resources

Research in Progress: NCHRP 15-74: Safety Evaluation of On-Street Bicycle Facility Design Features, start date: September 2020; expected completion date: August 2023. Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4763
From the project description: As state DOTs and other transportation agencies expand and improve their bicycle networks, they need detailed information on anticipated safety improvements of design features for a range of sites and contexts, and the relationship between design features and the risk of midblock (nonintersection) bicycle-involved crashes and conflicts.
….
The objective of this research is to provide practitioners at state DOTs and other transportation agencies with data-driven guidelines for selecting context-appropriate design features for safety improvements to existing separated and nonseparated on-street bicycle facilities and for the planning of new facilities. The guidelines will be based on an up-to-date, quantitative analysis of crash patterns as well as an evaluation of the roadway characteristics, land use patterns and human factors that increase conflicts and the risk and severity of midblock crashes that involve bicyclists.

Fostering Innovation in Pedestrian and Bicycle Transportation, Transportation Pooled Fund Study, Federal Highway Administration, commitment end year: 2022.
https://www.pooledfund.org/Details/Solicitation/1441
From the study description:

> The overall goals for this Transportation Pooled Fund (TPF) study are to:
>
> 1. Provide answers to emerging questions about innovative facility design, planning, and implementation to improve safety and mobility for pedestrians and bicyclists.
> 2. Conduct effective and efficient research of innovative traffic control devices to accelerate their incorporation into the Manual on Uniform Traffic Control Devices (MUTCD).
> 3. Facilitate the collection and reporting of robust transportation facility data that will allow for updating [f]ederal, [s]tate, local, and other design guidelines, such as the American Association of State Highway and Transportation Officials (AASHTO) design guides.

4. Support research on addressing rural multimodal transportation needs, regulatory streamlining, opportunities to improve cost effectiveness and efficiencies in the transportation system, and multimodal investment analysis.

Pedestrian and Bicycle Information Center, Federal Highway Administration and National Highway Traffic Safety Administration, undated.
https://www.pedbikeinfo.org/about.cfm
From the web site: Since its inception in 1999, the Pedestrian and Bicycle Information Center's [PBIC's] mission has been to improve the quality of life in communities through the increase of safe walking and bicycling as a viable means of transportation and physical activity. As a national leader in pedestrian and bicycle research and resources, the PBIC develops and shares resources vital to advancing mobility, access, equity and safety for pedestrians and bicyclists. To support this mission, the PBIC:

- Develops, synthesizes, promotes and distributes accurate and current bicycling and walking information.
- Provides expert technical assistance to various audiences to ensure that citizens and professionals have access to the best available information.
- Generates a network of informed individuals and organizations who can increase the exposure of ped/bike issues to the general public.

Related Resources:

Leap Not Creep: Accelerating Pedestrian and Bicyclists Safety Improvements, Federal Highway Administration, December 2021.
https://www.pedbikeinfo.org/webinars/webinar_details.cfm?id=114
From the web page: Many countermeasures have proven to be effective in reducing crashes among those walking and bicycling, but there are numerous obstacles to delivering these solutions quickly. In this webinar, panelists from [f]ederal, [s]tate and local transportation agencies will share strategies for accelerated delivery of safety countermeasures and offer recommendations for project development and implementation. Following their presentations, panelists will respond to questions from participants.

Improving Traffic Signals for Bicycling and Walking, Federal Highway Administration, June 2021.
https://www.pedbikeinfo.org/webinars/webinar_details.cfm?id=109
From the web page: This webinar focused on how transportation professionals and practitioners can use traffic signals to make intersections safer and more comfortable for nonmotorized road users. Panelists, including Peter Koonce, PE, of Portland, Oregon, and Peter Furth, of Northeastern University, described strategies for improving intersections through signal timing, cycle lengths, speed management, protected phasing and more. Presentations shared the latest advances and trends in managing traffic signals to prioritize bicycling and walking.

Going Dutch: Translating Dutch Cycling Ideas to an American Context, Federal Highway Administration, July 2020.
https://www.pedbikeinfo.org/webinars/webinar_details.cfm?id=102
From the web page: U.S. transportation planners and advocates have long admired the Netherlands' impressive cycling infrastructure and culture, and frequently make the trip across the Atlantic to marvel at its bustling bike lanes and traffic-calmed streets. But coming from a more sprawling, car-dominated environment, it's difficult to imagine replicating their amazing success, where the average resident now pedals over 600 miles per year.

Discover the key principles that were developed by the Dutch over those fifty years, draw out concrete lessons for America to follow their lead, and learn how some of these ideas are already being implemented in U.S. cities, as they face a crisis forcing many of them to reevaluate how they allocate space on their curbs and streets.

Considerations for Selecting Pedestrian Hybrid Beacon Locations, Federal Highway Administration, April 2020.
https://www.pedbikeinfo.org/webinars/webinar_details.cfm?id=96
From the web page: The pedestrian hybrid beacon (PHB) is one of several countermeasures available to improve safety for pedestrians or bicyclists crossing busy and/or wide streets at uncontrolled crossing locations. While agencies have been using this countermeasure for over a decade, transportation professionals still have questions about when and where they should install PHBs. Webinar panelists will share new research that evaluated safety and driver yielding at PHB locations on higher speed roads (among other findings) and discuss how this research and other factors have influenced their guidelines for installing PHBs.

Toolbox of Countermeasures and Their Potential Effectiveness, Office of Safety Programs, Federal Highway Administration, September 2018.
https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa18041/
From the web page: This "toolbox" documents estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to pedestrian crashes. The crash reduction estimates are presented as Crash Reduction Factors (CRFs). Traffic engineers and other transportation professionals can use the information contained in this toolbox when trying to figure out which countermeasures would be effective in improving safety at a certain type of locations (such as a signalized intersection).

Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations, Lauren Blackburn, Charles Zegeer and Kristen Brookshire, Office of Safety Programs, Federal Highway Administration, July 2018.
https://safety.fhwa.dot.gov/ped_bike/step/docs/STEP_Guide_for_Improving_Ped_Safety_at_Unsig_Loc_3-2018_07_17-508compliant.pdf
From the abstract:

This guide assists [s]tate or local transportation or traffic safety departments that are considering developing a policy or guide to support the installation of countermeasures at uncontrolled pedestrian crossing locations. This document provides guidance to agencies, including best practices for each step involved in selecting countermeasures. By focusing on uncontrolled crossing locations, agencies can address a significant national safety problem and improve quality of life for pedestrians of all ages and abilities. Agencies may use this guide to develop a customized policy or to supplement existing local decision-making guidelines.

Countermeasures for bicyclists and pedestrians begin on page 15 of the guide, page 21 of the PDF.

Related Resources:

Proven Safety Countermeasures, Office of Safety Programs, Federal Highway Administration, February 2022.
https://safety.fhwa.dot.gov/provencountermeasures/
(Scroll to "Pedestrian/Bicyclist.")
From the web page: FHWA's Proven Safety Countermeasures initiative (PSCi) is a collection of countermeasures and strategies effective in reducing roadway fatalities and serious injuries on our [n]ation's highways. Transportation agencies are strongly encouraged to consider widespread implementation of PSCs [proven safety countermeasures] to accelerate the achievement of local, [s]tate and [n]ational safety goals.

Pedestrian and Bicycle Safety, Office of Safety Programs, Federal Highway Administration, February 2022.
https://safety.fhwa.dot.gov/ped_bike/
From the web page: Pedestrian and bicyclist safety improvements depend on an integrated approach that involves the 4 E's: [e]ngineering, [e]nforcement, [e]ducation and [e]mergency [s]ervices. The FHWA's Office of Safety develops projects, programs and materials for use in reducing pedestrian and bicyclist fatalities. All of these materials can be found here.

Literature Review: Resource Guide for Separating Bicyclists From Traffic, Bill Schultheiss, Rebecca Sanders, Belinda Judelman, Jesse Boudart, Lauren Blackburn, Kristen Brookshire, Krista Nordback, Libby Thomas, Dick Van Veen and Mary Embry, Office of Safety Programs, Federal Highway Administration, July 2018.
https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18030.pdf
From the abstract: This report summarizes the results of the literature review conducted for the development of a Resource Guide for Separating Bicyclists [F]rom Traffic. The purpose of this literature review is to identify and evaluate existing guidance for separating bicyclists from traffic, identify common bikeways for separating bicyclists from traffic, summarize the relative safety impact on bicyclists for these bikeways, and identify and evaluate decision making strategies for selecting a bikeway considering potential tradeoffs. This literature review also discusses the history of guidance for separating bicyclists from traffic in the United States to provide context for current bicycling activity and safety. The literature identifies example practices and metrics for selecting an appropriate bikeway treatment to accommodate bicyclists on public roadways.

Advancing Pedestrian and Bicyclist Safety: A Primer for Highway Safety Professionals, Kristen Brookshire, Laura Sandt, Carl Sundstrom, Libby Thomas and Richard Blomberg, National Highway Traffic Safety Administration, April 2016.
https://www.nhtsa.gov/staticfiles/nti/pdf/812258-Peds_Bike_Primer.pdf
From the abstract: This primer is intended for highway safety professionals, including [s]tate [h]ighway [s]afety [o]fficials, as well as their partners and grantees, as a reference for an integrated and comprehensive effort to improve pedestrian and bicycle safety and support broader transportation-related goals. The primer summarizes the most promising infrastructure treatments and behavioral programs available for addressing specific safety problems and highlights how these approaches can be combined and implemented. It identifies opportunities for various agencies to collaborate and combine their respective approaches and funding for a more comprehensive program. It also offers real-world examples of what [s]tates and local jurisdictions are doing to address pedestrian and bicycle issues in a comprehensive manner.

Bicycle Safety Guide and Countermeasure Selection System, Federal Highway Administration, 2014.
http://pedbikesafe.org/BIKESAFE/index.cfm
From the web page: The Bicycle Safety Guide and Countermeasure Selection System is intended to provide practitioners with the latest information available for improving the safety and mobility of those who bike. The online tools provide the user with a list of possible engineering, education or enforcement treatments to improve bicycle safety and/or mobility based on user input about a specific location.

Pedestrian Safety Guide and Countermeasure Selection System, Federal Highway Administration, 2013.
http://pedbikesafe.org/PEDSAFE/index.cfm
From the web page: The Pedestrian Safety Guide and Countermeasure Selection System is intended to provide practitioners with the latest information available for improving the safety and mobility of those who walk. The online tools provide the user with a list of possible engineering, education or enforcement treatments to improve pedestrian safety and/or mobility based on user input about a specific location.

Guide for the Development of Bicycle Facilities, 4th Edition, American Association of State Highway and Transportation Officials, 2012.
Publication description available at https://store.transportation.org/Item/CollectionDetail?ID=116
From the web page: This guide provides information on how to accommodate bicycle travel and operations in most riding environments. It is intended to present sound guidelines that result in facilities that meet the needs of bicyclists and other highway users. Sufficient flexibility is permitted to encourage designs that are sensitive to local context and incorporate the needs of bicyclists, pedestrians and motorists. However, in some sections of this guide, suggested minimum dimensions are provided. These are recommended only where further deviation from desirable values could increase crash frequency or severity.

Bicycle and Pedestrian Program, Federal Highway Administration, undated.
https://www.fhwa.dot.gov/environment/bicycle_pedestrian/index.cfm
From the web page:

> The Federal Highway Administration's Bicycle and Pedestrian Program promotes safe, comfortable, and convenient walking and bicycling for people of all ages and abilities. We support pedestrian and bicycle transportation through funding, policy guidance, program management, and resource development.

Resources are available in topic areas such as program guidance, funding and legislation.

State Research and Resources

Colorado

"Chapter 14, Bicycle and Pedestrian Facilities," Roadway Design Guide, Colorado Department of Transportation, October 2015.
https://www.codot.gov/business/designsupport/bulletins_manuals/roadway-design-guide/ch14
From the introduction:

> This chapter provides detailed design criteria, standards and guidance for the development of bicycle and pedestrian facilities.

Pavement markings and other treatments are addressed throughout this chapter, including tables of recommended traffic control devices.

Massachusetts

Separated Bike Lane Planning and Design Guide, Massachusetts Department of Transportation, 2015.
https://www.mass.gov/lists/separated-bike-lane-planning-design-guide
From the overview:

> The Massachusetts Department of Transportation's (MassDOT) Separated Bike Lane Planning [and] Design Guide (the Guide) presents considerations and strategies for the development of separated bike lanes. The Guide provides a framework for determining when separated bike lanes are appropriate and feasible. It presents design guidance for separation strategies, bike lane configuration, and considerations for transit stops, loading zones, utilities, drainage, parking and landscaping. The Guide defines separated bike lane design principles for intersections, introduces intersection design treatments and provides examples of typical intersection configurations.

Pavement markings and signage are presented in Chapter 3 beginning on page 41 of the guide (page 21 of the PDF) and in Chapter 4 beginning on page 80 of the guide (page 30 of the PDF).

Minnesota

Minnesota's Best Practices for Pedestrian and Bicycle Safety, Minnesota Department of Transportation, January 2021.
http://www.dot.state.mn.us/stateaid/trafficsafety/reference/best-practices-ped-bike-safety.pdf
From the purpose: This guide is intended to assist practitioners in their efforts to improve bicycle and pedestrian safety on their roadway networks. The strategies included in this handbook include a mix of treatments that have been used widely across the state and are considered proven strategies, along with emerging treatments that are considered experimental.
….

Each best practice contained within this document includes the following information to help practitioners answer common questions about these practices and provide tools to help use them.

- **What is its purpose?** A description of the purpose of the strategy.
- **Is it a proven strategy?** Refer to the following text on determining the efficacy of a certain treatment.
- **Where would we use it?** A description of where this strategy is typically used. It's important to note that strategies may still be used in other situations not listed within this guide, however their efficacy may vary from what's noted in the guide. Practitioners should use judgment when applying treatments in other situations.
- **What are the maintenance impacts?** A summary of the maintenance impacts associated with the strategy.
- **What are the advantages?** Advantages associated with implementing the strategy.
- **What are the challenges?** Challenges associated with implementing the strategy.
- **Best practices.** The best practices for implementing the strategy.
- **Design features.** Typical design features of the strategy.
- **Resources.** List of resources for more information on the strategy.

Pedestrian Crosswalk Policy Development Guidelines, Kate Miner and Tim Arvidson, Minnesota Department of Transportation, May 2020.
https://www.dot.state.mn.us/research/reports/2020/2020RIC01.pdf
From the abstract: This study was driven by the need to improve consistency in the methods and approach that local agencies use to address crosswalks. This study focuses on the question of how a crosswalk should be enhanced with additional countermeasures, if any, once the decision is made to mark it. During the research portion of this project, it was found that the primary information agencies use that provides guidance for decisions on how to mark crosswalks comes from the Federal Highway Administration. A quick reference guide was developed from the Federal Highway Administration's (FHWA's) Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations, July 2018, that will help agencies determine when to use different countermeasures based on roadway type, vehicle volumes and posted speed limits. In addition, fact sheets for [12] countermeasures identified in the document were developed to explain what the benefit of each one is, when it is best applied and how to provide high-level planning cost for each one.

Related Resource:

> **Uncontrolled Pedestrian Crosswalk Quick Reference Guide**, Kate Miner and Tim Arvidson, Minnesota Department of Transportation, May 2020.
> http://www.dot.state.mn.us/research/reports/2020/2020RIC01G.pdf
> *From the introduction:*
>
> > A consistent approach and methods for treating uncontrolled crosswalks in Minnesota will improve pedestrian safety throughout the state. This quick reference guide helps local agencies select appropriate crosswalk treatments based on roadway type, vehicle volumes and posted speed limits.
>
> Twelve countermeasures, including crosswalk pavement marking, are identified along with their benefits and design, cost and location considerations.

Oregon

Research in Progress: Impacts of Intersection Treatments and Traffic Characteristics on Bicyclist Safety, Oregon Department of Transportation, start date: September 2019, expected completion date: June 2021.
(*Note*: The status of this project is listed as active.)
Project description at https://rip.trb.org/view/1672694
From the project description: The primary research objectives for this project are as follows: (1) Determine which factors affect the frequency and/or severity of bicycle vehicle-conflicts at intersections with different bicycle-related treatments such as mixing zones, leading bike interval (LBI), split LBI, as well as those traditional bicycle lanes and with no treatments, and others as feasible identified through consultation with [the] TAC [Technical Advisory Committee]. (2) Provide data-driven guidance as to the efficacy of certain intersection treatments in mitigating vehicle-bicycle conflicts (thereby improving bicyclist safety by this surrogate measure), including consideration of how traffic and site characteristics impact these conflicts. (3) Develop a countermeasure selection "toolbox" [that] describes the performance (in terms of bicycle-vehicle conflicts) of bicycle-specific intersection treatments under different geometric and traffic conditions. A desired outcome of this research will be determination of threshold bicycle and vehicle volumes where specific levels of treatments (e.g., pavement markings, geometry, signal treatments or combinations of these) should be considered over others. Recommendations will be provided on the advantages/disadvantages of different treatments, and descriptions of conditions under which each treatment should/could be considered (both traffic and geometric conditions), as well as approximate time frames for implementation for each treatment.

"An Analysis of the Safety Effectiveness of Pedestrian Crossing Enhancements in Oregon," Christopher M. Monsere, Sirisha Kothuri, Ali Razmpa and Miguel A. Figliozzi, *TRB 97th Annual Meeting*, Paper #18-00737, 2018.
Citation at https://trid.trb.org/view/1494553
From the abstract: Over the last decade, the transportation agencies in Oregon have systematically enhanced many pedestrian crossing enhancements at mid-block locations with Rectangular Rapid Flashing Beacons (RRFBs), Flashing Yellow Beacons (Flash), and high visibility crosswalk markings (Hi-Vis). Enhancements often included the installation of refuge medians. This study explored the safety performance of these enhanced crossings, categorized by enhancement type. Data were collected on 191 crossings that included installation year, geometric features, surrounding land use, traffic volumes and the number of crashes. Because pedestrian volume at the locations was unavailable, a pedestrian activity level variable was developed. Target crashes for analysis were identified as pedestrian and rear-end. The analysis of the before-after crash patterns showed a reduction in the pedestrian crash severity after the installation of the crosswalk enhancements. Risk ratios, calculated by the unadjusted crash frequency relative to the years of operation in each analysis category, were calculated. For pedestrian crashes, risk ratios increased with the number of lanes, posted speed and estimated pedestrian activity level. Similar trends were observed for rear-end crashes. Due to sample size limitations, safety effectiveness was only estimated for the 19 RRFBs locations. Lack of pedestrian volumes limited the development of a safety performance function (SPF) for the pedestrian crash type. However, a rear-end crash SPF was estimated. Standard methods to estimate a crash modification factor (CMF) were attempted. The recommended CMF for pedestrian crashes is 0.64 +/- 0.26 using a simple before-after analysis and 0.93 +/- 0.22 for rear-end crashes using an empirical Bayes analysis.

Traffic Signs

National Research and Resources

University Transportation Center

Research in Progress: Optimizing Type and Location of Pedestrian Crossing Signs at Non-Signalized Intersections (Phase II), U.S. Department of Transportation University Transportation Centers Program, start date: October 2021, expected completion date: September 2023.
Project description at
https://cammse.charlotte.edu/sites/cammse.charlotte.edu/files/media/CAMMSE-UNCC-2022-UTC-Project-Information-06-Machemehl.pdf
From the project description: Safety of pedestrians sharing street crossings with automobiles has become increasingly problematic as numbers of pedestrian crossings have increased. A variety of signs and sign configurations are allowed by the Manual on Uniform Traffic Control Devices (MUTCD). Guidance provided by the MUTCD regarding types of signs and particularly mounting locations for pedestrian crossing signs at nonsignalized intersections is sparse. A recent study of signage for unsignalized pedestrian crossings by the research team showed potentially significant impact of signage location on likelihood of automobile compliance. The objective of this project is to identify optimal locations for signage at unsignalized pedestrian crossing locations, as well as, optimal signage configurations. The proposed work will address at least two CAMMSE [Center for Advanced Multimodal Mobility Solutions and Education] research thrusts: Generate innovations in multimodal planning and modeling for high-growth regions; and [i]nnovations to improve multimodal connections, system integration and security.

Pavement Markings

National Research and Resources

University Transportation Center

Deterioration of Green Conflict Paint for Bicycle Facilities, Emad Kassem, Michael Lowry, Ebenezer Fanijo and Maged Mohamed, U.S. Department of Transportation University Transportation Centers Program, February 2021.
https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/47750/Kassem%20Green%20Conflict%20Paint%20Draft-Report_EF.pdf?sequence=1&isAllowed=y
From the abstract: This study used a new procedure to evaluate different pavement markings used in bike lanes. Three different paints were evaluated, including green waterborne paint, green liquid methacrylate paint and white thermoplastic paint. The deterioration of these materials was tested under different conditions to simulate wear from motorized vehicles and street equipment. Surface polishing (i.e., repeated passing over the material) was examined under pneumatic tires, steel wheels and steel scraper blades. Different characteristics were measured, including durability, retroreflectivity, color changes and friction of the test materials.

State Research and Resources

Florida

Operational Analysis of Shared Lane Markings and Green Bike Lanes on Roadways With Speeds Greater Than 35 mph, Thobias Sando and W. Hunter, Florida Department of Transportation, January 2014.
https://rosap.ntl.bts.gov/view/dot/27240
From the abstract: This study analyzed the effectiveness of shared lane markings (sharrows), wide curb lanes, standard and buffered bike lanes, and green bike lanes on improving operations of bicycle facilities. Three measures of effectiveness were used in this study: lateral separation between the motor vehicle and bicyclist, the distance of bicyclists to the curb or edge of pavement, and the yielding behavior of drivers and cyclists at merge points. Also, motor vehicle speeds before, while and after passing bicyclists were analyzed. Except for the Bridge of Lions site, the before-and-after data indicate that installation of sharrows led to an increase in lateral separation between motor vehicles and bicyclists. At Riverside Drive, the separation increased by 0.67 feet, while at the North 56th Street site, an increase of 2.55 feet was observed after installing sharrows and increasing the outside lane width. Data also suggested a significant improvement in lateral separation of 0.86 feet at Sunset Drive, which was widened to create a wider outside lane (but had no shared lane markings), and Bailey Road, where a marked buffer between the travel lane and bike lane resulted in an increase in separation between motor vehicles and bicyclists of 0.72 feet. It was also observed that bicyclists rode further from the curb/edge of pavement for the after-period compared to the before-period for Riverside Drive, Bridge of Lions, North 56th Street and Sunset Drive. P-values less than 0.05 were observed for these five sites suggesting that the treatments were effective in moving bicyclists further from the curb/edge of pavement. Data also indicates that drivers slow down as they pass bicyclists on nonlimited access roadways (before speed of 32.02 mph to 29.97 mph while-passing) and then increase their speeds after overtaking the bicyclists (30.80 mph while-passing to 32.82 mph after-passing). The difference between the speeds before-passing and while-passing, and while-passing and after-passing, were both significant with a p-value less than 0.000. However, when the before-passing (32.02 mph) and after-passing (32.54 mph), excluding while-passing speeds, were analyzed, no significant difference was found (p-value = 0.110). For limited access facilities, the difference between the overtaking driver's speed before-

passing (37.35 mph) and while-passing (34.93 mph) the bicyclists was significant with a p-value of 0.000. However, the difference between motor vehicle speeds while-passing bicyclists (34.94 mph) and after-passing (35.48 mph) was not significant (p-value = 0.150). Contrary to the nonlimited access streets, the difference between vehicle speeds before- (37.33 mph) and after-passing (35.48 mph) was significant for the limited access facilities (p-value =0.017).

North Carolina

Research in Progress: Yielding Compliance at High Visibility Crosswalks, North Carolina Department of Transportation, start date: August 2018, expected completion date: May 2021. (*Note*: The status of this project is listed as in progress. No deliverables are publicly posted.)
Project description at
https://connect.ncdot.gov/projects/research/Pages/ProjDetails.aspx?ProjectID=2019-18
From the project description: The ITRE [Institute for Transportation Research and Education]-developed N[orth]C[arolina] Pedestrian Crossing Guidance is a useful resource to NCDOT and local agencies to help them determine when to consider marking a crosswalk. However, once a decision has been made to mark a crosswalk, the guide falls short in recommending a specific marking style outside of NCDOT's current policy to mark mid-block uncontrolled locations with a high-visibility marking. While the literature is clear that high visibility crosswalks (HVCs) are more visible to both drivers and pedestrians, the existing research is mixed on the effect that HVCs have on pedestrian safety, specifically as it is measured through driver yielding compliance. This can primarily be contributed to the difficulty of isolating the effect of HVCs specifically, as they are often used in conjunction with other crossing treatments such as signage, beacons, curb extensions or pedestrian refuge islands. Further, no research can be found that studied whether the increasing prevalence of HVCs within a community dilutes the effectiveness of HVCs.

This project seeks to: first, verify that HVCs are more effective at inducing driver yielding than other legal crosswalks (unmarked or marked with transverse parallel lines); and second,—assuming that they are found to be equally or more effective for the first measure—to determine if increasing the prevalence of HVCs within a given area negatively impacts their effectiveness at inducing driver yielding.

Texas

Research in Progress: Analyze the Use of Green Pavement Markings: Intersection Safety for Non-Motorized Users, Texas Department of Transportation, start date: May 2020, expected completion date: May 2022.
https://library.ctr.utexas.edu/Presto/content/Detail.aspx?ctID=UmVzZWFyY2gtaW4tUHJvZ3Jlc3NfMTExMjY%3D&rID=OTA2&ssid=c2NyZWVuSURfMTExODI%3D&bmdc=MQ==
From the project summary statement: This research will provide on-the-ground evidence on the impact of green colored pavement at intersections on safety. This research will provide TxDOT [Texas DOT] with the necessary input to either apply for MUTCD Interim Approval for the Green Colored Pavement (IA-14) and/or respond to FHWA's request for TxDOT's official response to cities' request for MUTCD interim approval.

The researchers will evaluate usage by bicyclist and pedestrian approaches and provide at least two pilot locations—likely in Houston and Austin. The research approach may include bicycle and pedestrian counts, STRAVA crowdsourced pedestrian and bicyclist data (already purchased by TxDOT), questionnaires, as well as observational surveys of pedestrian, bicyclist and motorist behaviors. These activities might be collected at intersections with green-colored paint and at control intersections without green paint. The research will be used to provide a report with recommended best-practices on the implementation of green-colored paint and as a

cost-benefit analysis of the usage of green-colored pavement markings to improve safety for non-motorized users. The research report will document the findings of the research, including new safety prediction models and updated features within the TRSD [Texas Roadway Safety Design] spreadsheet program.

Related Resource:

> **"Green Pavement Markings Could Make Texas Streets Safer for Cyclists,"** Herb Booth, News Releases, University of Texas at Arlington, October 2, 2020.
> https://www.uta.edu/news/news-releases/2020/10/02/kam-green-pavement
> *From the article*: A University of Texas at Arlington civil engineer is investigating the effectiveness of implementing green pavement markings to denote where bicyclists have dedicated lanes or share the road with motorists.
>
> This Texas Department of Transportation (TxDOT)-funded research project will examine the use, safety, longevity and performance of the pavement markings, which are painted green to increase their visibility to cyclists, pedestrians and motorists.

Virginia

Effectiveness of Innovative Pavement Markings in Facilitating Safe Bicycle Travel, Peter Ohlms and Young-Jun Kweon, Virginia Department of Transportation, Federal Highway Administration, April 2019.
https://www.virginiadot.org/vtrc/main/online_reports/pdf/19-r17.pdf
From the abstract: This study evaluated the effects of two bike boxes and two turn boxes installed in 2014 at an intersection in Charlottesville, Virginia. Videos collected during [three] days before the changes (nonconsecutive over a [one]-month period) and [five] days after the changes (nonconsecutive in the fall and spring seasons) provided volume counts and tallies of traffic infractions and conflict events such as near misses. Data were prepared in order to pair the "before" and "after" periods, resulting in eight 12-hour sets of observations starting at 7:30 a.m., each with 48 time intervals of 15 minutes. Because the data were not normally distributed, the Wilcoxon signed-rank test was employed to compare the before and after periods. To take advantage of the paired structure of the data (i.e., before and after), a matched-pair or related-sample version of the test was performed.

After the main analysis, a subset of data (1 hour in the morning and 1 hour in the afternoon for three before and three after count dates) was re-reviewed by one researcher in order to address concerns about inter-rater reliability from the initial data reduction. Several methods were used to compare this re-reviewed dataset to the original review results.

Results were mixed. Among other findings, the following results were statistically and practically significant:

- The two bike boxes were used properly/improperly by 46%/40% and 24%/10% of approaching bicyclists on the respective leg of the intersection.
- The two turn boxes had high levels of improper (but not necessarily unsafe) use, at 57% to 100% of approaching bicyclists.
- Uncategorized bicyclist traffic infractions on one approach decreased by 43% after the changes but increased by 80% on another approach.
- Prohibited direct left turns increased 200% for motorists (from 0.1% to 0.4% of approaching motorists) and 290% for bicyclists (from 13.3% to 51.3% of approaching bicyclists).

The study recommends that the Virginia Department of Transportation (1) create or improve education materials related to bike boxes and turn boxes and (2) evaluate the feasibility of submitting requests for interim approval for bicycle boxes and two-stage bicycle turn boxes.

Related Research and Resources

"Investigation of Alternative Bicycle Pavement Markings With the Use of a Bicycle Simulator," Henry Brown, Carlos Sun and Zhu Qing, *Transportation Research Record 2662*, pages 143-151, 2017.
Citation at https://trid.trb.org/view/1437338
From the abstract: The past decade has seen increased public interest in sustainable transportation modes in the United States. However, there is a relative lack of guidance regarding standards and specifications for bicycle facilities compared with the highway mode. This project sought to address this deficiency through the investigation of alternative pavement markings for bicycle wayfinding and proper bicycle placement at signalized intersections as part of the federal Nonmotorized Transportation Pilot Program in Columbia, Missouri. This evaluation was accomplished with a bicycle simulator study and postsimulator survey with 27 participants. A network of 37 intersections with characteristics similar to intersections in Columbia was created with the ZouSim simulator. The survey included questions regarding bicycling habits and preferences for the alternative markings. For wayfinding, two alternative types of pavement markings and the signage recommended by the Manual on Uniform Traffic Control Devices (MUTCD) were evaluated. Both the survey and the simulator results indicated that the Type 2 wayfinding markings with a green circle performed better with respect to visibility and delineating the bicycle route. The bicycle placement portion of the study investigated three alternative types of markings as well as the MUTCD markings and signage to help riders position their bicycle at the correct location to receive a green signal. The bicycle placement results indicated that the Type 1 and Type 2 experimental detector markings resulted in the fewest number of missed detections, while the Type 1 marking was the preferred alternative of the survey participants.

Traffic Signals

National Research and Resources

Anticipated Research: NCHRP 03-143: Warrants for a Pedestrian Traffic Control Signal and for Other Pedestrian Traffic Control Devices, expected completion date: unknown.

(From the web site: This project has been tentatively selected and a project statement (request for proposals) is expected to be available on this website. The problem statement below will be the starting point for a panel of experts to develop the project statement.)

Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5125
From the problem statement: The different classes of pedestrian treatments can range from no treatment to pavement crosswalk markings and a sign (side or in-roadway mounted) to yellow flashing devices (e.g., rectangular rapid flashing beacons, border LED warning signs, in-pavement warning lights, etc.) or devices that display red indications (e.g., pedestrian hybrid beacons or traffic control signal). In particular, the current Manual on Uniform Traffic Control Devices (MUTCD) warrants for a pedestrian traffic control signal currently do not permit consideration of additional pedestrians that would likely begin using the crossing if a signal were present. For example, pedestrians may avoid a crossing because they do not feel safe in attempting to cross a road at that location (resulting in using a less direct route or mode, such as car). A warrant that is based primarily on the existing number of crossing pedestrians limits the ability to adequately account for demand that would be expected if a safer crosswalk

treatment were present. Given the physical limitations of some pedestrians, such as the very young, very old or persons with disabilities, should the warrants better address the needs of these groups? Should the pedestrian signal warrant not be based on number of pedestrians but rather on the characteristics of the land uses, such as type and size, represented on either side of the street? Should it incorporate equity considerations of long spaces without safe crossings of large, high-volume, high-speed roadways? There is a growing interest from agencies in having information that guides them in choosing from the increasing variety of pedestrian crossing treatments to have a better understanding of the characteristics of each treatment and how they might be beneficial for a given location. In addition, as more agencies and programs promote walking and walkable communities, the interest (and need) for such guidance is growing. Issues of the standard of care in the logical and prudent progression of pedestrian crossing treatments (rather than a cumulative assembly of all treatments anywhere) is a growing local agency need. Guidance on treatment selection will provide practitioners with the ability to more confidently provide an improvement to a crossing with reduced concern about overtreating or undertreating those crossings or introducing unintended effects from a treatment or multiple overlapping treatments.

Contacts

The following people shared information about non-standard traffic control devices that their agencies have implemented or devices that their agencies are considering. Contact information for agencies not implementing non-standard devices is provided in a supplement to this report.

Local Agencies

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Appendix A: Survey Questions

The following survey was distributed to Caltrans traffic signal functional managers, Caltrans district signing and striping contacts, members of the League of California Cities, members of the County Engineers Association of California, and state department of transportation members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Traffic Engineering.

Survey on Promising New, Innovative Non-Standard Traffic Signs, Pavement Markings and Traffic Signals

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Note: The response to the question below determined how a respondent was directed through the survey.

(Required) Does your organization use any traffic signs, pavement markings or traffic signals that are currently not included in the Manual on Uniform Traffic Control Devices (MUTCD) to improve pedestrian and bicyclist safety?

Response Options:

- No. Our agency does not use any traffic signs, pavement markings or traffic signals for pedestrians and bicyclists that are currently not included in the MUTCD. (Directed the respondent to the **Agencies Not Implementing Non-Standard Devices** section of the survey.)
- No. While our agency does not use any traffic signs, pavement markings or traffic signals for pedestrians and bicyclists other than those included in the MUTCD, we are considering them. (Directed the respondent to the **Agencies Considering Implementing Non-Standard Devices** section of the survey.)
- Yes. Our agency uses non-standard traffic signs, pavement markings and/or traffic signals for pedestrians and bicyclists. (Directed the respondent to the **Description of Traffic Signs, Pavement Markings and Traffic Signals** section of the survey.)

Agencies Not Implementing Non-Standard Devices

1. Please briefly explain why your agency is not using any traffic signs, pavement markings or traffic signals other than those included in the MUTCD to improve pedestrian and bicyclist safety.
2. Is your agency considering modifying an existing traffic control device application to improve pedestrian and bicyclist safety?
    - No
    - Yes (Please describe.)

Note: After responding to the questions above, the respondent was directed to the **Wrap-Up** section of the survey.

Agencies Considering Implementing Non-Standard Devices

1. Please briefly describe the non-standard traffic sign, pavement marking or traffic signal for pedestrians and bicyclists that your agency is considering.
2. Where will the traffic sign, pavement marking or traffic signal be implemented? Select all that apply.
    - Intersection
    - Midblock
    - Driveway
    - High-volume road
    - Work zone
    - Railroad/light rail transit crossing
    - School zone
    - Bicycle facilities (e.g., bike path, bikeways)
    - Other location or application (Please describe.)
3. What design criteria will be considered? Select all that apply.
    - Road width
    - Roadway classification
    - Number of lanes
    - Traffic volume
    - Traffic speed
    - Traffic delay
    - Traffic type
    - Crash data
    - Other (Please describe.)
4. What benefits will using this traffic sign, pavement marking or traffic signal provide? Select all that apply
    - Reduced vehicle speed
    - Improved pedestrian and bicyclist compliance
    - Reduced crashes or conflicts
    - Reduced fatalities or serious injuries (severity)
    - Improved/equitable access
    - Other (Please describe.)

Note: After responding to the questions above, the respondent was directed to the **Wrap-Up** section of the survey.

Agencies Implementing Non-Standard Traffic Signs, Pavement Markings and Traffic Signals

The next sections of the survey ask you to describe the non-standard traffic control devices that your agency has implemented. The survey gives you the opportunity to describe three non-standard traffic control devices. If your organization offers more than three non-standard traffic control devices, please describe the three most frequently used devices.

Traffic Sign/Pavement Marking/Traffic Signal 1

1. Please briefly describe the non-standard traffic sign, pavement marking or traffic signal for pedestrians and bicyclists that your agency has implemented.
2. Where is the traffic sign, pavement marking or traffic signal implemented? Select all that apply.

- Intersection
- Midblock
- Driveway
- High-volume road
- Work zone
- Railroad/light rail transit crossing
- School zone
- Bicycle facilities (e.g., bike path, bikeways)
- Other location or application (Please describe.)

3. What design criteria were considered? Select all that apply.
    - Road width
    - Roadway classification
    - Number of lanes
    - Traffic volume
    - Traffic speed
    - Traffic delay
    - Traffic type
    - Crash data
    - Other (Please describe.)
4. What benefits has using this traffic sign, pavement marking or traffic signal provided? Select all that apply
    - Reduced vehicle speed
    - Improved pedestrian and bicyclist compliance
    - Reduced crashes or conflicts
    - Reduced fatalities or serious injuries (severity)
    - Improved/equitable access
    - Other (Please describe.)
5. (Required) Has your agency implemented other non-standard traffic signs, pavement markings or traffic signals for pedestrians and bicyclists?
    - No (Directed the respondent to the “Safety and Operational Issues” section of the survey.)
    - Yes (Directed the respondent to a section allowing the respondent to describe another non-standard traffic sign, pavement marking or traffic signal.)

Note: In the online survey, the questions above were repeated to allow respondents to describe two additional traffic signs/pavement markings/traffic signals.

Safety and Operational Issues

1. Has your agency established safety criteria for using non-standard traffic control devices in pedestrian or bicycle applications?
    - No
    - Yes (Please describe the safety criteria.)
2. What safety issues has your agency encountered with these treatments?
3. What operational issues has your agency encountered with these treatments?
4. Has your agency encountered any other issues with these treatments, such as installation, maintenance, patent approval, testing or other issues?
    - No

- Yes (Please describe how your agency determines the effectiveness of these treatments.)

Assessment and Recommendations

1. Has your agency measured the effectiveness (safety or operational) of using these treatments?
    - No
    - Yes (Please describe how your agency determines the effectiveness of these treatments.)
2. What successes has your agency experienced with these treatments?
3. What challenges has your agency experienced with these treatments?
4. What recommendations does your agency have for using these or other non-standard traffic signs, pavement markings or traffic signals?
5. Please provide the locations of successful non-standard treatments for research follow-up.
6. Please provide links to documents associated with your agency's use of these treatments. Send any files not available online to carol.rolland@ctcandassociates.com.

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses or anything that was not covered related to these non-standard traffic control devices.