2018

SOLANO TRAVEL SAFETY PLAN

FINAL APRIL 2018

STA
Solano Transportation Authority

Caltrans

THE CITY OF BENICIA CALIFORNIA

DIXON CALIFORNIA

FAIRFIELD

RIO VISTA

SOLANO COUNTY

CITY OF SUISUN CITY CALIFORNIA

VACAVILLE

City of VALLEJO California

2018
SOLANO TRAVEL SAFETY PLAN

Solano Transportation Authority

DKS

By signing and stamping this Systemic Safety Analysis Report, the engineer is attesting to this report's technical information and engineering data upon which local agency's recommendations, conclusions, and decisions are made.

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1 CONTEXT

SOLANO COUNTY

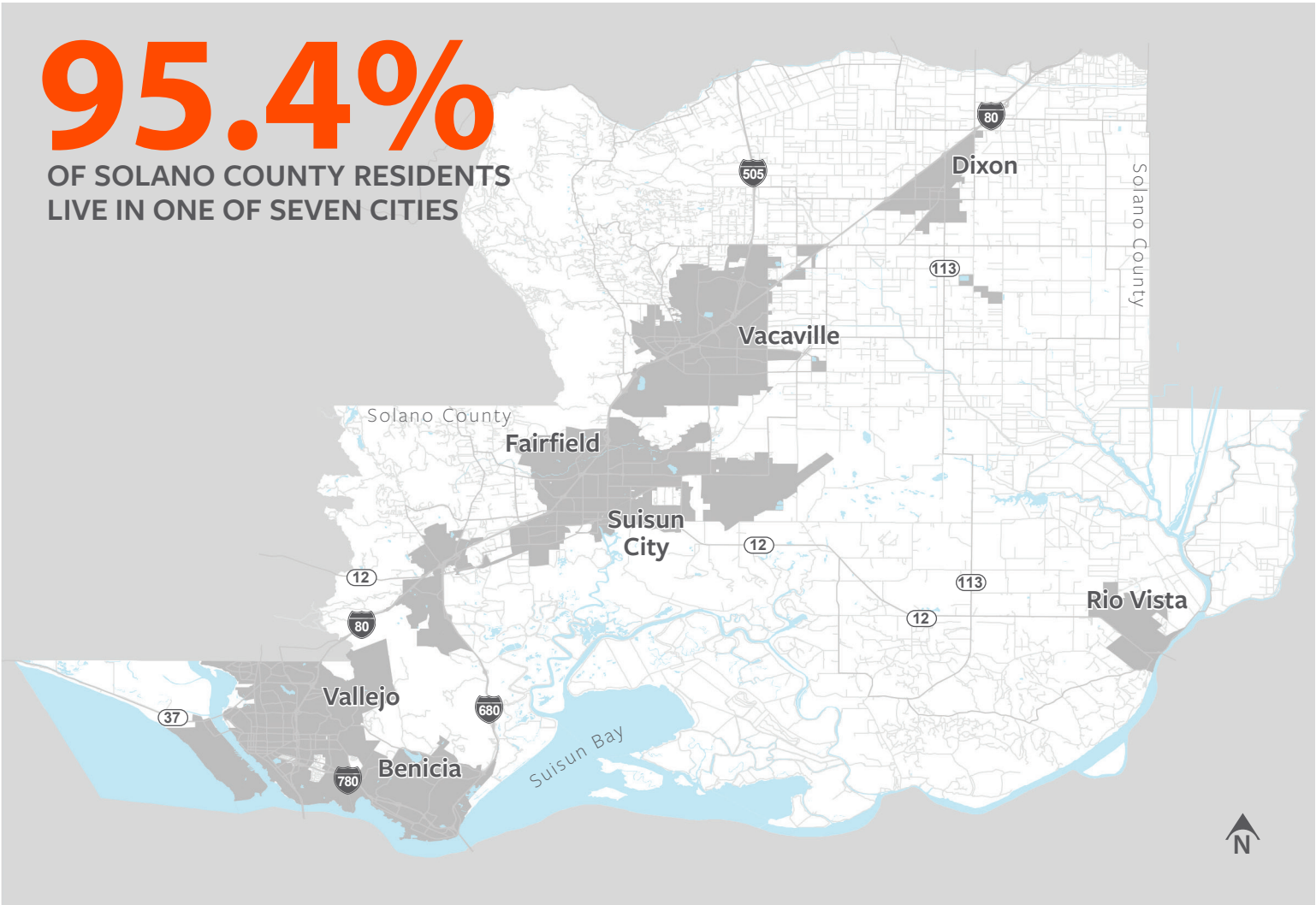
Located on the north shore of Suisun Bay between San Francisco and the state capitol Sacramento, Solano County includes a large unincorporated area as well as the cities of Dixon, Rio Vista, Vacaville, Fairfield, Suisun City, Benicia, and Vallejo. Most of these cities were established in the 1800s for their proximity to agriculture and ports with access to the Pacific Ocean, as gold rush settlements, and as early state capitols. The region contains several wildlife areas, including the San Francisco Bay National Estuarine Research Reserve, the Joice Island State Game Refuge, and the Grizzly Island Wildlife Area. Large employers in the area include Travis Air Force Base and Kaiser Permanente.

The County's existing transportation infrastructure consists of several interstate highways, railroads, ferries, state highways, and local roadways. The interstates serve as major transportation connections to communities throughout the area and beyond. Solano Transportation Authority (STA) has identified goals and plans to improve roadways to reduce congestion and improve access, double transit trips in the next 25 years, and improve alternative modes of transportation, such as bicycling and walking.

Most of the cities described in this report provide fixed-route transit services. In addition to local services, SolTrans connects Benicia, Vallejo and Fairfield and the FAST system serves riders traveling between Fairfield and Suisun City. Amtrak runs two lines through Solano County, the California Zephyr, which operates between the Bay Area and Chicago and the Coast Starlight, which runs along the west coast from Seattle to Los Angeles. Amtrak's Capitol Corridor Train Service operates between the Bay Area and Sacramento with a stop in Suisun City.

95.4%

OF SOLANO COUNTY RESIDENTS LIVE IN ONE OF SEVEN CITIES

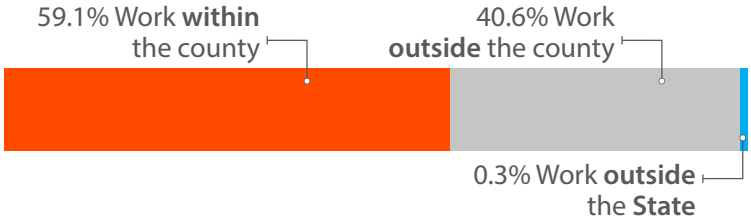


COMMUTING IN SOLANO COUNTY

Based on the 2016 US Census data, Solano County has 203,069 working-age residents. 'Working age' means everyone in the county who is over the age of 16, so it is also a good metric for driving-age residents.

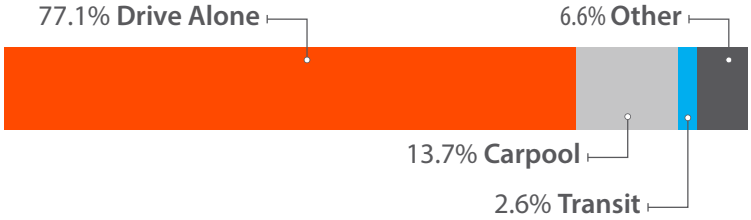
Commute Destinations

More workers are employed within the county.



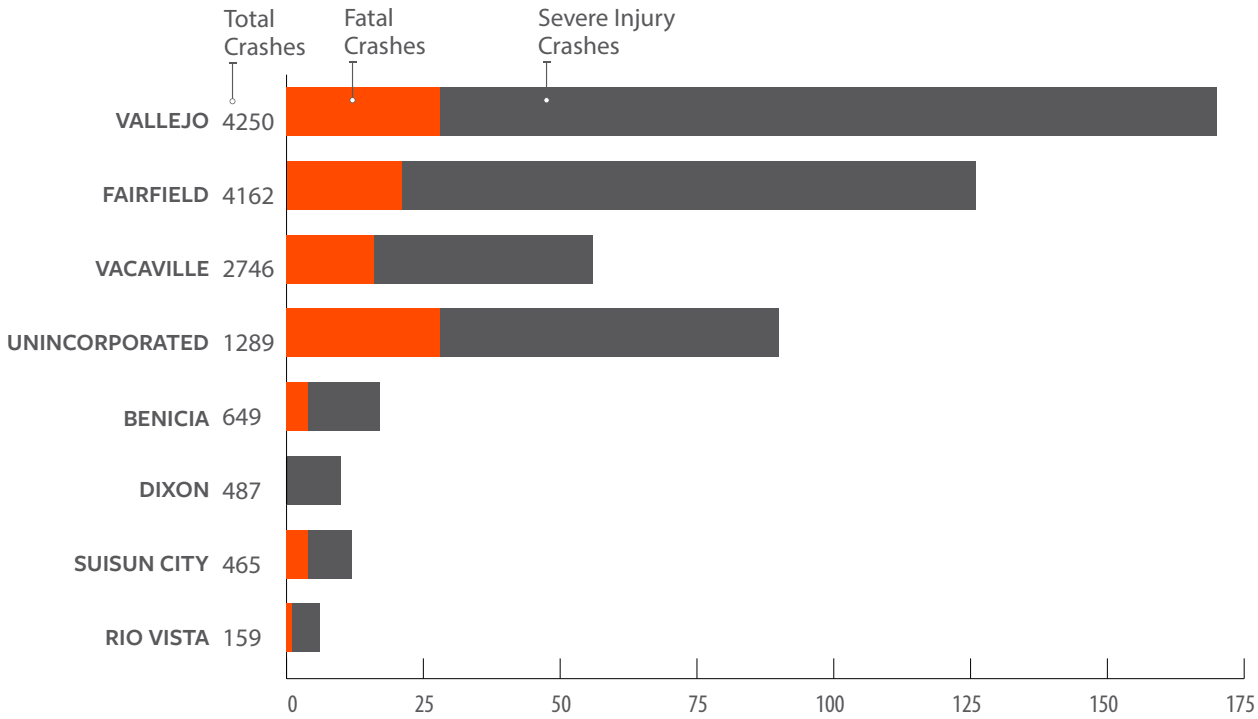
Commute Modes

Most of these workers drive alone to their jobs.



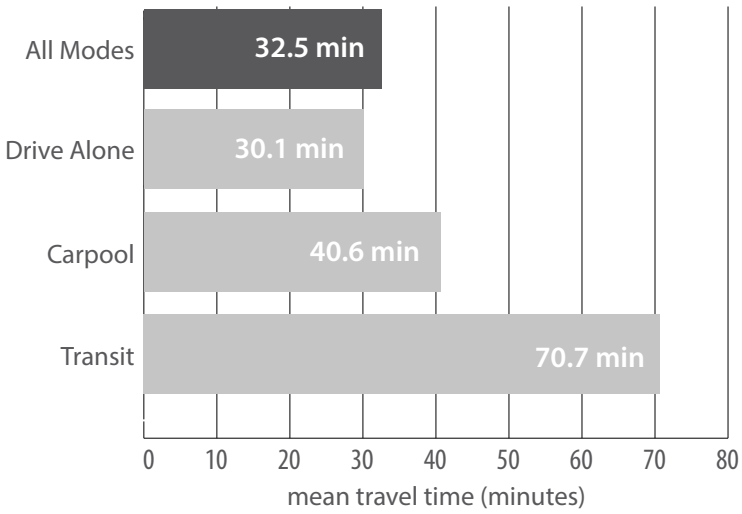
Crashes on the Roadway Network

Between 2012 and 2017 there were 14,207 crashes on the Solano County roadway network, of these 487 were fatal or severe injury crashes.



Commute Travel Time

Mean travel time to work for all working-age Solano County residents is 32.5 minutes.



THE TRAVEL SAFETY PLAN

Solano County and its seven cities have nearly 3,500 miles of roadway. Many of these roadways were built decades ago, when the county was more rural. In the subsequent years, residential and commercial development has resulted in increased traffic volumes at many locations—significantly higher than the original design intention—and increased associated safety issues. The numerous fatal and injury crashes that occur throughout the roadway network represent a significant financial and societal cost to the County.

As an ongoing effort to identify and address safety needs across the county, STA prepared Travel Safety Plans in 1998, 2005, and 2016. The 2016 Safety Plan departs from the methodology used in the previous plans, primarily as a result of the lack of recent and comprehensive traffic volume count data needed to determine collision rates. Instead, the 2016 Solano Travel Safety Plan used input from local jurisdictions to identify locations with safety issues and recommended improvements. Many of those project recommendations were made in response to recent collisions. This methodology helped each city identify its own safety locations, but did not prioritize safety improvements in the format necessary for Highway Safety Improvement Program (HSIP) funding.

The jurisdictions throughout Solano County have varying levels of experience in applying for and delivering HSIP-funded projects, based partially on the availability of staff resources and level of experience in conducting the data-driven analysis required to identify and prioritize safety treatments using the HSIP benefit/cost (B/C) ratio format. This 2018 Solano Travel Safety Plan, funded by the Caltrans-created Systemic Safety Analysis Report Program (SSARP) grant, expands the 2016 project list with projects identified through a data-driven analysis.

The 2018 Travel Safety Plan is a systemic analysis of trends and patterns from the crash record that allows for system-wide identification of improvements to address observed and potential safety issues. The resulting project list and analysis will assist local agencies in prioritizing safety improvements that will qualify for HSIP funding.

The 2018 Travel Safety Plan will also act as a policy and guidance document to provide ongoing assistance to STA and staff from all of the Solano County jurisdictions in continuing to identify needed safety improvements as the roadway network and travel patterns continue to evolve.

OBJECTIVES

This document meets three objectives that were defined for this project:

- Providing guidance for staff from STA, Solano County, and City staff for ongoing safety analysis and identification of relevant countermeasures and safety-based projects.
- Identifying a list of safety projects to implement based on the data-driven crash analysis and work done for the 2016 Travel Safety Plan, including a subset of projects to be included in HSIP Cycle 9 grant applications.
- Meeting the Caltrans SSARP funding requirements.

METHODOLOGY

Source of Safety Data

The raw collision data used to develop the 2018 Solano Travel Safety Plan was retrieved from the Statewide Integrated Traffic Records System (SWITRS) for the most recent 5 years (January 2012 through December 2016) for each of the seven cities and Solano County. Prior to beginning the analysis, extensive data processing standardized street names, verified jurisdiction boundaries, and verified the accuracy of location information. Interstates were excluded from the dataset and state routes were removed from the unincorporated County study area. The processed dataset includes date, time, location, traffic control, weather, severity, primary collision factor, lighting, and California Highway Patrol (CHP) notes for each collision.

Data Analysis Techniques

The Highway Safety Manual (HSM) includes numerous safety performance measures and safety analysis approaches, which require varying types of data. In Solano County, comprehensive traffic volume data is not available, limiting the types of analyses that can be utilized to evaluate safety performance.

The project team used the Equivalent Property Damage Only (EPDO) methodology outlined in the HSM to evaluate safety performance and identify locations that warrant improvements. This method, which accounts for the severity and frequency of crashes without the need for traffic volume, is described further on Page 7.

STATE OF PRACTICE

The published literature related to data-driven, systemic safety analysis methods, including the Highway Safety Manual (HSM), national guidance documents, and other useful resources, provides a baseline understanding of best practices in safety performance analysis.

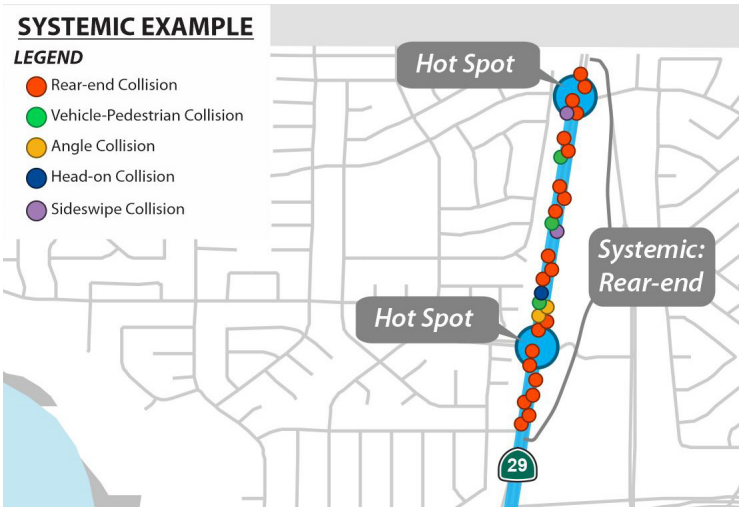
WHAT IS SYSTEMIC SAFETY ANALYSIS?

The Federal Highway Administration (FHWA) describes systemic safety analysis as a three-step approach to reducing the frequency and severity of crashes on the nation's roadways. The first step, identifying the crash types and characteristics that contribute to the occurrence of fatal and serious injury crashes, reveals the underlying characteristics, called 'risk factors', that relate to high severity crashes across the network. In the second step, appropriate countermeasures for mitigating the prevalent risk factors are identified. These countermeasures are typically low-cost strategies that have been previously proven to reduce the risk of specific types of crashes. The final step in the FHWA's systemic safety analysis approach is the development of a list of locations that have one or more of the identified risk factors and deployment of the most cost-effective countermeasures at those locations.[1]

Improving system-wide safety performance is more effective in improving safety performance than addressing a small number of hot-spot locations in isolation. This approach also provides the following benefits.[2]

- Aims to prevent future crashes from occurring rather than waiting to treat locations based on a history of serious crashes.
- Can be tailored to address agency-specific priorities (e.g., rural two-lane highways or mid-block pedestrian crashes).
- Is data-driven and can be applied with a broad range of data availability.

Systemic vs. Hot-Spot Location Identification Example



SYSTEMIC ANALYSIS METHODOLOGIES

The Highway Safety Manual (HSM), published in 2010, is the first national guidance document that outlines recommendations for comprehensive and quantitative safety analysis procedures.[3] The HSM includes numerous safety performance measures and safety analysis approaches that require varying types of data.

One safety analysis method that does not require traffic volume data is the Equivalent Property Damage Only (EPDO) method. The EPDO method accounts for both the severity and frequency of collisions by converting each collision to an equivalent number of property damage only (PDO) collisions. The EPDO method assigns a crash cost and score to each collision according to the values shown in Table 1. The EPDO scores for all collisions can then be aggregated in a variety of ways to identify collision patterns, such as location (hot-spots), collision type, driver behavior, or roadway characteristics, among others. The comprehensive crash costs are used to calculate the benefit/cost (B/C) ratio to determine which treatments are feasible and would potentially provide the most improvement.

Since the HSIP and SSARP programs for which this analysis is tailored focus on reducing or eliminating fatal and severe crashes, these two collision severities are assigned equal EPDO scores. The comprehensive crash costs of fatal and severe injury crashes, however, are significantly different.

Table 1. EPDO Score and Crash Cost by Collision Severity

Collision Severity	EPDO Score	Comprehensive Crash Cost
Fatal	100	$4,008,900
Severe Injury	100	$216,000
Visible Injury	10	$79,000
Possible Injury	10	$44,900
PDO	1	$7,400

RESOURCES FOR CONDUCTING SYSTEMIC SAFETY PROJECTS

Highway Safety Manual

The HSM provides comprehensive guidance on the standard of practice for safety analysis methodologies and their applications. The HSM describes the life-cycle safety management process in six steps, all of which correspond directly to standard systemic and hot-spot safety analyses.

Step 1 – Network Screening (HSM Chapter 4): Uses one or more performance measure(s) and screening method(s) to identify sites that are best suited for safety improvements.

Step 2 – Diagnosis (HSM Chapter 5): Provides guidance on identifying the factors that contribute to common crash patterns.

Step 3 – Countermeasure Selection (HSM Chapter 6): Contains useful information for identifying the treatments that are most likely to improve safety performance based on the crash patterns diagnosed in Step 2.

Step 4 – Economic Appraisal (HSM Chapter 7): Provides guidance on the proper methods for evaluating the cost effectiveness of implementing a given safety improvement.

Step 5 – Project Prioritization (HSM Chapter 8): Outlines the recommended procedures for prioritizing projects through one of three methods: economic effectiveness measures, benefit-cost rankings, or optimization.

Step 6 – Safety Effectiveness Evaluation (HSM Chapter 9): Provides guidance for evaluating the true effectiveness of a countermeasure after it has been implemented, including both observational and experimental studies.

CMF Clearinghouse

Crash Modification Factors (CMFs) and Crash Reduction Factors (CRFs) represent the reduction in crash frequency expected after implementation of a given countermeasure. The HSM includes detailed discussions of a variety of the most commonly applied countermeasures and their associated crash modification factors (CMFs) and crash reduction factors (CRFs). The CMF Clearinghouse, a companion resource to the HSM, is a free online database of countermeasures, CMFs, CRFs, and details of the supporting research studies. The CMF Clearinghouse database is updated regularly and currently includes over 6,000 CMFs[4].

NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

In response to AASHTO's Strategic Highway Safety Plan, the National Cooperative Highway Research Program (NCHRP) developed a series of guidance documents aimed at helping local and state agencies improve the safety performance of their roadways[5]. Each guide serves as a comprehensive resource for addressing specific crash patterns or emphasis areas, including speeding, younger drivers, older drivers, work zones, bicyclists and pedestrians, roadway departure, signalized intersections, driving under the influence, and many others.

NCHRP Report 500 also includes a guidance document focused on safety data and analysis techniques that outlines methodologies for implementing strategic safety plans depending on the available crash data and roadway data.

Caltrans Local Road Safety Manual

The Caltrans Local Road Safety Manual (LRSM) provides information and support to local agencies who wish to proactively address safety performance issues and compete for funding as part of statewide, data-driven calls for projects[6]. The Proactive Safety Analysis process outlined in the LRSM is based on the six-step safety management process outlined in the HSM summarized above. While the underlying methodologies are the same, the LRSM is geared toward implementation of a streamlined, consistent HSIP application process without explanation of the underlying theory. It presents detailed requirements for each stage of the process, including data sources, analysis techniques, countermeasure selection, benefit-cost evaluations, and project prioritization.

The LRSM includes a list of 77 pre-approved countermeasures. Although applications for funding through the Caltrans HSIP call for projects must utilize only the listed countermeasures, agencies are encouraged to consider other treatments with documented safety benefits (e.g., those in the CMF Clearinghouse) for projects with non-HSIP funding sources.

IMPLEMENTING SYSTEMIC APPROACHES

The Caltrans Division of Local Assistance (DLA) manages California's local agency share of Highway Safety Improvement Program (HSIP) funds[7]. California's Local HSIP focuses on infrastructure projects with nationally recognized crash reduction factors (CRFs). Local HSIP projects must be identified on the basis of crash experience, crash potential, crash rate, or other data-supported means.

HSIP Program Funding

An HSIP call-for-projects[8] is typically made at an interval of one to two years. The applicant must be a city, county, or tribal government federally recognized within the State of California. The timing and size of the call is determined by the program apportionments, HSIP FTIP capacity and the delivery of the existing HSIP projects. HSIP Cycle 8, the most recent call for projects, closed on August 12, 2016.

In 2016, Solano County was successful in their grant application for $2.029 million of federal HSIP funds to upgrade existing painted edgelines and centerlines to thermoplastic with Raised Pavement Markers (RPMs) and to add thermoplastic markings for stop signs[9]. The project is focused on systemic improvements to address roadway departure and head-on collisions on 139 miles of roadways. The new pavement markings will be applied at locations on public roadways throughout unincorporated Solano County. Locations were identified after staff reviewed Traffic Collision Reports from the CHP and generated a report of crashes of all severity. Staff found that many of the crashes that occurred between 2009 and 2013 involved cars running off the road and then striking roadside objects and ditches. Staff evaluated the benefit of installing edge lines and centerlines on roadways using a Caltrans calculator, which confirmed the viability of the project and the potential for the County to have a winning HSIP grant application.

SSARP Funding

For smaller jurisdictions without the staff or data analysis resources to identify projects and prepare a grant application, HSIP funds are difficult to obtain. In 2016, to expand the reach of the program, Caltrans exchanged $10 million from the local Highway Safety Program (HSIP) federal funding for State Highway Account (SHA) funds to implement a new safety analysis program, the Systemic Safety Analysis Report Program (SSARP)[10]. The program assists local agencies with funding to develop future HSIP and other safety program applications. SSARP grant funds can be used to perform collision analysis, identify safety issues on the roadway network, and develop a list of low-cost systemic countermeasures that can be used to prepare future HSIP and other safety program applications.

Caltrans made SSARP calls for applications in two phases, in February 2016 and April 2016. 108 applications requesting $17.6 million of state funds were received. After prioritization, 61 projects allocating a total of $10 million of SSARP state funds were selected for implementation. In January 2017, another $7.7 million of state funding was allocated by the California Transportation Commission (CTC) to the SSARP applications that were initially submitted in, but unfunded by, the 2016 SSARP calls for applications.

ENDNOTES

1 Federal Highway Administration. Systemic Safety Project Selection Tool. *Federal Highway Administration*. [Online] August 2015. https://safety.fhwa.dot.gov/systemic/fhwasa13019/index.cf

2 Applying the Systemic Safety Approach on Local Roads. *US Department of Transportation: Federal Highway Administration*. [Online] 2014. www.safety.fhwa.dot.gov/local_rural/training/fhwasa14081/systemic_app.

3 American Association of State Highway and Transportation Officials. *Highway Safety Manual*. Washington, D.C. : s.n., 2010.

4 Federal Highway Administration. *Crash Modification Factors Clearinghouse*. [Online] January 2017. www.cmfclearinghouse.org

5 *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. Washington, D.C. : Transportation Research Board of the National Academies, 2003-2009.

6 Caltrans. *Local Roadway Safety: A Manual for California's Local Road Owners*. 2016

7 Highway Safety Improvement Program (HSIP). *Caltrans Divison of Local Assistance*. [Online] http://www.dot.ca.gov/hq/LocalPrograms/hsip.html.

8 Calls for Projects – HSIP and SSARP. *Caltrans Division of Local Assistance*. [Online] http://www.dot.ca.gov/hq/LocalPrograms/HSIP/apply_now.htm

9 Solano County. *Application Form for Cycle 8 Highway Safety Improvement Program*. 2016.

10 Caltrans. Systemic Safety Analysis Report Program (SSARP). *Caltrans Division of Local Assistance*. [Online] http://www.dot.ca.gov/hq/LocalPrograms/HSIP/SSARP.htm.

2 COUNTERMEASURES

In 2008, the Federal Highway Administration (FHWA) began promoting a set of infrastructure improvements and strategies that had been proven to effectively reduce serious injuries and fatalities on American highways. With this Proven Safety Countermeasures initiative, most recently updated in September 2017, FHWA encouraged widespread implementation by State, tribal, and local transportation agencies.

In recognizing that the Highway Safety Manual (HSM) is essentially a static document, while countermeasures studies are continually performed and updated, The U.S. Department of Transportation—Division of Local Assistance created and funded the CMF Clearinghouse with the goal of providing dynamic resources and sourcing countermeasures at multiple levels of confidence and study. This ensures that planners and engineers have the best and most up to date list of available countermeasures to address safety needs for local roadways. CMF Clearinghouse is a web-based tool purposed as a repository for Crash Modification Factors (CMF) and other resources related to reducing crashes on roadways.

Caltrans used information from the CMF Clearinghouse and three other FHWA published safety manuals — Roadway Departure Safety, Intersection Safety, and Roadways Safety Information Analysis — in conjunction with its own research with the Safe Transportation Research and Education Center (SafeTREC) to develop the Caltrans Local Roadway Safety Manual (CA-LRSM). The CA-LRSM is a tool intended to provide focused roadway safety information in a single document and was paramount in the selection of improvements in this document.

FUNDING IMPLEMENTATION OF COUNTERMEASURES

The Highway Safety Improvement Program (HSIP) is one of the core federal-aid programs in the federal surface transportation act, Fixing America's Surface Transportation Act (FAST), which was signed into law on December 4, 2015. The purpose of the HSIP program is to achieve a significant reduction in traffic fatalities and serious injuries on all public roads, including non-State-owned public roads and roads on tribal land, by funding the implementation of proven countermeasures prioritized through a systemic safety analysis.

The Systemic Safety Analysis Report Program (SSARP), established and funded by the State of California in 2016, exchanges federal local Highway Safety Program (HSIP) funds for State Highway Account (SHA) funds to provide grants to smaller jurisdictions for the preparation of Systemic Safety Analysis reports that can compete for HSIP funding.

SOLANO COUNTY COUNTERMEASURES

Solano Transportation Authority, in receiving SSARP funds, is leading an effort for unincorporated Solano County and the seven incorporated jurisdictions of Benicia, Dixon, Fairfield, Rio Vista, Suisun City, Vacaville, and Vallejo to proactively identify and analyze safety issues through a data-driven systematic process, to identify key hotspot locations, and to prioritize countermeasures that will most effectively improve safety.

The countermeasures outlined in this chapter have been identified as applicable to the crash types and locations found in the county. These countermeasures have been drawn from both HSIP-qualified countermeasures and from non-HSIP sources. They have been approved by staff from each city jurisdiction and the County.

The approved countermeasures have been divided into three groups — signalized intersections, unsignalized intersections, and roadway segments — indicating the type of location where each countermeasure is to be applied. Appendix A: Countermeasures Toolbox includes a comprehensive list of possible countermeasures as well as more information for each.

On the following pages, each countermeasure is associated with an identification letter and number. The letters refer to the following shorthand:

S. countermeasures apply to **Signalized** intersections.
NS. countermeasures apply to **Unsignalized** intersections.
R. countermeasures apply to **Roadway Segments**.
NH. countermeasures **do not qualify for HSIP funding**.

For each countermeasure, the following information is also provided.

- **Crash Reduction Factor (CRF):** the expected reduction of crashes associated with the countermeasure, along with any criteria (night time, severity, etc) or range of available studies.
- **Baseline Cost:** a high-level planning cost for each countermeasure improvement, used for the benefit-cost analysis (based on previous cost estimates/projects)

COUNTERMEASURES FOR SIGNALIZED INTERSECTIONS

S2. **Improve signal hardware.**
May include lenses, back-plates, mounting, size and number of heads.
CRF: 15%
Baseline Cost: $40,000 per intersection.

S3. **Improve signal timing.**
May include coordination, phasing, clearance intervals.
CRF: 15%
Baseline Cost: $1,000 per intersection.

S4. **Provide advance dilemma-zone detection for high speed approaches.**
CRF: 40%
Baseline Cost: $50,000 per intersection.

S6. **Provide protected left turn phase for left turn lanes that already exists.**
CRF: 30%
Baseline Cost: $12,000 per intersection.

S9. **Install flashing beacons as advance warnings of intersection.**
CRF: 30%
Baseline Cost: $70,000 per intersection.

S10. **Install cameras to detect red-light running.**
CRF: 15%
Baseline Cost: $70,000 per intersection.

S12. **Install raised median on approaches.**
CRF: 25%
Baseline Cost: $200,000 per intersection.

S19. **Install pedestrian countdown signal heads.**
This treatment is only applicable to pedestrian related crashes.
CRF: 25%
Baseline Cost: $1,500 per intersection.

S20. **Install pedestrian crossing.**
This treatment is only applicable to pedestrian related crashes.
CRF: 25%
Baseline Cost: $5,000 per intersection.

S23. **Install pedestrian median fencing on approaches.**
This treatment is only applicable to pedestrian related crashes.
CRF: 35%
Baseline Cost: $3,000 per intersection.

NOT HSIP FUNDABLE

NH2. **Install or upgrade pedestrian signals.**
Applicable to bike and pedestrian crash trends with a CRF between 15-69% and with an approximate cost of $200,000.

NH4. **Reduce curb radius at intersections.**
CMF clearance does not provide crash reduction factor data or relevant crash trends.

NH6. **Install curb extension.**
Applicable to bike and pedestrian crash trends with a CRF between 8-56% and with an approximate cost of $200,000.

NH8. **Provide school route improvements.**
Relevant trends, CRF, and cost vary.

NH9. **Restrict or eliminate turning maneuvers (including right turns on red).**
Applies to all types of crash trends with a CRF of 51% and an estimated cost of $75,000.

NH11. **Provide longer left-turn lanes at intersections.**
No relevant trends provided by CMF Clearinghouse; but, has a CRF between 31-44% and an approximate cost of $200,000.

NH15. **Provide longer right-turn lanes at intersections.**
No CMF Clearinghouse data on crash trends. Has a CRF between 14-27% with an approximate cost of $200,000.

NH17. **Provide right-turn acceleration lanes at intersections.**
Relevant to all trends with CRF between 10-75% with an approximate cost of $200,000.

NH28. **Implement automated speed enforcement cameras**
CMF Clearinghouse does not provide relevant crash trends. CRF varies between 16-34% with an estimated cost of $70,000

NH35. **Implement access management strategies.**
Trends, CRF, and cost vary.

NH43. **Implement education and/or enforcement campaigns (DUI, distracted driving, etc.).**
CMF Clearinghouse does not disclose Crash Reduction Factor data nor relevant crash trends.

NH44. **Adjust lane geometry.**
Relevant to all trends at a varied cost, but CMF Clearinghouse does not disclose CRF.

COUNTERMEASURES FOR UNSIGNALIZED INTERSECTIONS

NS1. Add intersection lighting.
This treatment is only applicable to night-time related crashes.
CRF: 40%
Baseline Cost: $8,000 per intersection.

NS2. Convert two-way stop control to all-way stop control.
CRF: 50%
Baseline Cost: $5,000 per intersection.

NS3. Convert unsignalized intersection to signalized.
CRF: 25%
Baseline Cost: $900,000 per intersection.

NS4. Convert intersection to roundabout (from 2-way stop or yield control).
CRF: 27%
Baseline Cost: $2,000,000/$500,000 per intersection.

NS5. Install/upgrade larger or additional stop signs or other intersection warning signs.
CRF: 15%
Baseline Cost: $1,000 per intersection.

NS6. Upgrade intersection pavement markings.
CRF: 25%
Baseline Cost: $10,000 per intersection.

NS8. Install flashing beacons as advanced warning at unsignalized intersections.
CRF: 30%
Baseline Cost: $75,000 per intersection.

NS10. Improve sight distance to intersection.
CRF: 20%
Baseline Cost: $100,000 per intersection.

NS11. Install splitter-islands on the minor road approaches.
CRF: 40%
Baseline Cost: $50,000 per intersection.

NS12. Install raised median on approaches.
CRF: 25%
Baseline Cost: $200,000 per intersection.

NS13. Create directional median openings to allow (and restrict) left-turns and U-turns.
CRF: 50%
Baseline Cost: $75,000 per intersection.

NS14. Install right-turn lane.
CRF: 20%
Baseline Cost: $200,000 per intersection.

NS15. Install left-turn lane.
CRF: 35%
Baseline Cost: $200,000 per intersection.

NS16. Install raised medians (refuge islands).
This treatment is only applicable to pedestrian related crashes.
CRF: 40%
Baseline Cost: $50,000 per intersection.

NS18. Install pedestrian crossing at uncontrolled locations.
This treatment is only applicable to pedestrian related crashes.
CRF: 35%
Baseline Cost: $50,000 per intersection.

NS19. Install pedestrian signal or HAWK.
This treatment is only applicable to pedestrian related crashes.
CRF: 55%
Baseline Cost: $200,000 per intersection.

NOT HSIP FUNDABLE

NH7. Install a raised intersection.
CMF clearance does not provide Crash Reduction Factor data or relevant crash trends.

NH8. Provide school route improvements.
Relevant trends, CRF, and cost vary.

NH15. Provide longer right-turn lanes at intersection.
No CMF Clearinghouse data on crash trends. Has a CRF between 14-27% with an approximate cost of $200,000.

NH18. Provide full-width paved shoulders in intersection areas.
Relevant to all trends with a CRF between 15-22% and an estimated cost of $50,000.

NH19. Realign intersection approaches to reduce or eliminate intersection skew.
Relevant to all trends at a cost that varies, but CMF Clearinghouse does not provide data for CRF.

NH35. Implement access management strategies.
Trends, CRF, and cost vary.

NH42. Install bicycle facilities through intersection.
Relevant to bike and pedestrian crash trends with a CRF of between 0-53% and with a cost of $10,000.

NH43. Implement education and/or enforcement campaigns (DUI, distracted driving, etc.).
CMF clearance does not provide disclosure data or relevant crash trends & Crash Reduction Factor.

NH44. Adjust lane geometry.
Relevant to all trends at a varied cost, but CMF Clearinghouse does not disclose CRF.

COUNTER MEASURES FOR ROADWAY SEGMENTS

R11. Install acceleration/ deceleration lanes.
CRF: 25%
Baseline Cost: $700,000 per intersection.

R15. Implement a road diet by reducing travel lanes from four to three and by adding two way left-turn and bike lanes.
CRF: 30%
Baseline Cost: $750,000 per intersection.

R16. Widen and pave shoulder.
CRF: 30%
Baseline Cost: $150,000 per intersection.

R17. Widen shoulder (unpaved).
CRF: 20%
Baseline Cost: $50,000 per intersection.

R18. Pave existing shoulder.
CRF: 15%
Baseline Cost: $50,000 per intersection.

R25. Provide tapered edge for pavement edge drop-off.
CRF: 10%
Baseline Cost: $25,000 per intersection.

R27. Install chevron signs on horizontal curves.
CRF: 40%
Baseline Cost: $1,000 per intersection.

R28. Install curve advance warning signs.
CRF: 25%
Baseline Cost: $1,000 per intersection.

R29. Install curve advance warning signs in the form of a flashing beacon.
CRF: 30%
Baseline Cost: $25,000 per intersection.

R30. Install dynamic/variable speed warning signs.
CRF: 30%
Baseline Cost: $100,000 per intersection.

R34. Install centerline rumble strips/stripes.
CRF: 20%
Baseline Cost: $3,000 per mile.

R35. Install edgeline rumble strips/stripes.
CRF: 15%
Baseline Cost: $3,000 per mile.

R36. Install bike lanes.
This treatment is only applicable to bicycle-related crashes.
CRF: 35%
Baseline Cost: $100,000 per intersection.

NOT HSIP FUNDABLE

NH8. Provide school route improvements.
Relevant trends, CRF, and cost vary.

NH20. Eliminate parking that restricts sight distance.
Relevant to all trends with a CRF between 20-48% and varied cost.

NH23. Modify speed limit.
Base on supporting data from a speed citation survey. Relevant to all trends with a CRF of 8% and varies in cost.

NH24. Install overpass/underpass.
Relevant to all trends with a CRF between 24-67% and cost that varies.

NH25. Install traffic-calming measure.
Relevant to all trends with a CRF and cost that varies.

NH26. Install roadway signage for bicyclists.
CMF Clearinghouse provides information on Bike and Pedestrian crashes, but no relevant crash trends & Crash Reduction Factor.

NH29. Install crash cushions at fixed roadside features.
Relevant to all trends with a CRF between 5.50% and an estimated cost of $5,000.

NH38. Install through-route activated warning system.
Relevant to all trends with CRF between 36-62% and an estimated cost of $70,000.

NH39. Widen Overpass.
CMF clearance does not disclose CRF data or relevant crash trends.

NH40. Consider changes to internal site circulation.
CMF provides information on Bike and Pedestrian crashes, but no relevant crash trends or Crash Reduction Factor.

NH41. Install additional signs and markings for railroad crossings.
Applicable to all crash trends with a CRF of 50% and a cost that varies.

NH42. Install bicycle facilities through intersection.
Relevant to bike and pedestrian crash trends with a CRF of between 0-53% and with a cost of $10,000.

NH43. Implement education and/or enforcement campaigns (DUI, distracted driving, etc.).
CMF clearance does not provide disclosure data or relevant crash trends & Crash Reduction Factor.

NH44. Adjust lane geometry.
Relevant to all trends at a varied cost, but CMF Clearinghouse does not disclose CRF.

3 COLLISION TRENDS

Between 2012 and 2017 there were 487 fatal or severe injury crashes on the Solano County roadway network. The majority of these crashes were due to unsafe speeds, impaired driving, improper turning, or pedestrian violations.

Of the urban areas, Vallejo and Fairfield had the highest frequency of crashes (indicated by the number of collisions) and the highest severity of crashes (indicated by the EPDO Score). The cities of Rio Vista, Suisun City, Dixon, and Benicia have significantly lower collision frequencies than the rest of the County.

Table 2. 2012–2017 Collisions by Severity by Jurisdiction

	Collisions	Fatal Injuries	Severe Injuries	EPDO Score
Vallejo	4250	28	142	36821
Fairfield	4162	21	105	34888
Vacaville	2746	16	40	18757
Unincorporated	1289	28	62	14357
Benicia	649	4	13	4348
Dixon	487	0	10	2512
Suisun City	465	4	8	2553
Rio Vista	159	1	5	1086
County (Total)	14207	102	385	115322

COLLISION TRENDS REVIEWED

This section provides an overview of the county's common crash trends and types by jurisdiction, general causes for each crash type, and a summary of best practice countermeasures for reducing crash risk. The following collision trends relative to physical characteristics are discussed:

- Pedestrian & Bicycle-Involved Collisions
- Rear-End Collisions
- Broadside Collisions
- Roadway Departure Collisions

Human Behavior Factors

While this study is based on connecting physical characteristics with crash types, it is also important to recognize that a portion of crashes are caused by human behaviors rather than roadway characteristics. The following human behavior factors in collision trends are also discussed:

- Unsafe Speeds
- Improper Turns
- Automobile Right-of-Way
- DUI/DWI
- Pedestrian Violation/ Pedestrian ROW
- Failure to Yield to Traffic Signal/Sign

Environmental Factors

Environmental factors, such as time of day, weather conditions, and roadway characteristics are also a factor in collisions. While countermeasures cannot always solve for environmental factors, they can be used to mitigate results, either by providing drivers more visibility in dark conditions, higher friction pavement treatments in slick conditions or clearing sight distance to reduce the severity of resulting collisions.

GLOSSARY OF COLLISION FACTORS

- **Pedestrian Violation:** Violation of traffic laws by a pedestrian. Relevant laws include jaywalking and crossing against signal indications.
- **Pedestrian Right-of-Way Violation:** Failure of a driver to yield right-of-way to a pedestrian. For example, failure of a driver to yield to a pedestrian who is occupying a crosswalk.
- **Automobile Right-of-Way Violation:** Failure of a driver, bicyclist, or pedestrian to yield right-of-way to another driver or bicyclist.
- **Traffic Signal/Sign Violations:** Failure to obey regulatory traffic control devices.
- **DUI/DWI Violation:** Involves a driver who is impaired by alcohol or other drugs to a level that they cannot operate a vehicle properly.
- **Unsafe Speed Violation:** Driving too fast for the traffic conditions, regardless of the posted speed limit.
- **Wrong Side of Road:** Failure of a driver to travel with the direction of traffic.
- **Unsafe Lane Change:** An unsafe lane change violation can include failure to drive within the lane as well as changing lanes without regard for reasonable safety.
- **Unsafe Starting/Backing:** Failure of a driver to check for a sufficient gap before starting/backing up vehicle, often occurs at driveways.
- **Following too Close:** A driver following another vehicle so closely that a collision could not be avoided if the front driver brakes suddenly.
- **Improper Turning:** An improper turn can take many different forms. Broadly, an improper turn violates the rules of the road and puts others in danger. Examples include turning when there is a 'No Turn on Red' sign at a red light, turning at a stop sign or red light without coming to a complete stop or yielding, or failing to properly navigate a curve.

COUNTERMEASURE KEY

Countermeasures are grouped by the type of crash they best address. Countermeasures indicated with the symbol ▶ are appropriate for addressing the primary collision factors in that crash type.

COLLISIONS INVOLVING PEDESTRIANS & BICYCLISTS

Bicyclists and pedestrians are the two most vulnerable road users in a transportation system. As a result, crashes involving bicyclists and pedestrians tend to be higher severity, often resulting in fatal and severe injuries. Although the relative volume of bicyclists and pedestrians is low compared to other modes of travel, their vulnerability places increased emphasis on understanding and minimizing the risk of vehicle-pedestrian and vehicle-bicycle crashes.

PEDESTRIAN-INVOLVED COLLISIONS

Crashes involving pedestrians in urban areas typically occur where the travel paths of vehicles and pedestrians cross, such as at intersections. Pedestrian crashes also commonly occur where pedestrians cross major roadways mid-block, particularly in dark or low-visibility conditions. Mid-block pedestrian crossings are more prevalent in areas with mid-block attractions, e.g. convenience stores or transit stops, and long distances between protected (signalized) crossings.

In Solano County, the two most common factors in pedestrian-involved collisions were pedestrian violations and pedestrian ROW violations. While the number of collisions attributed to each were roughly the same, pedestrian violations resulted in significantly higher severity crashes. Pedestrian violations often occur mid-block where vehicle speeds are higher, while pedestrian right-of-way violations most commonly involve turning vehicles, which are traveling at slower speeds.

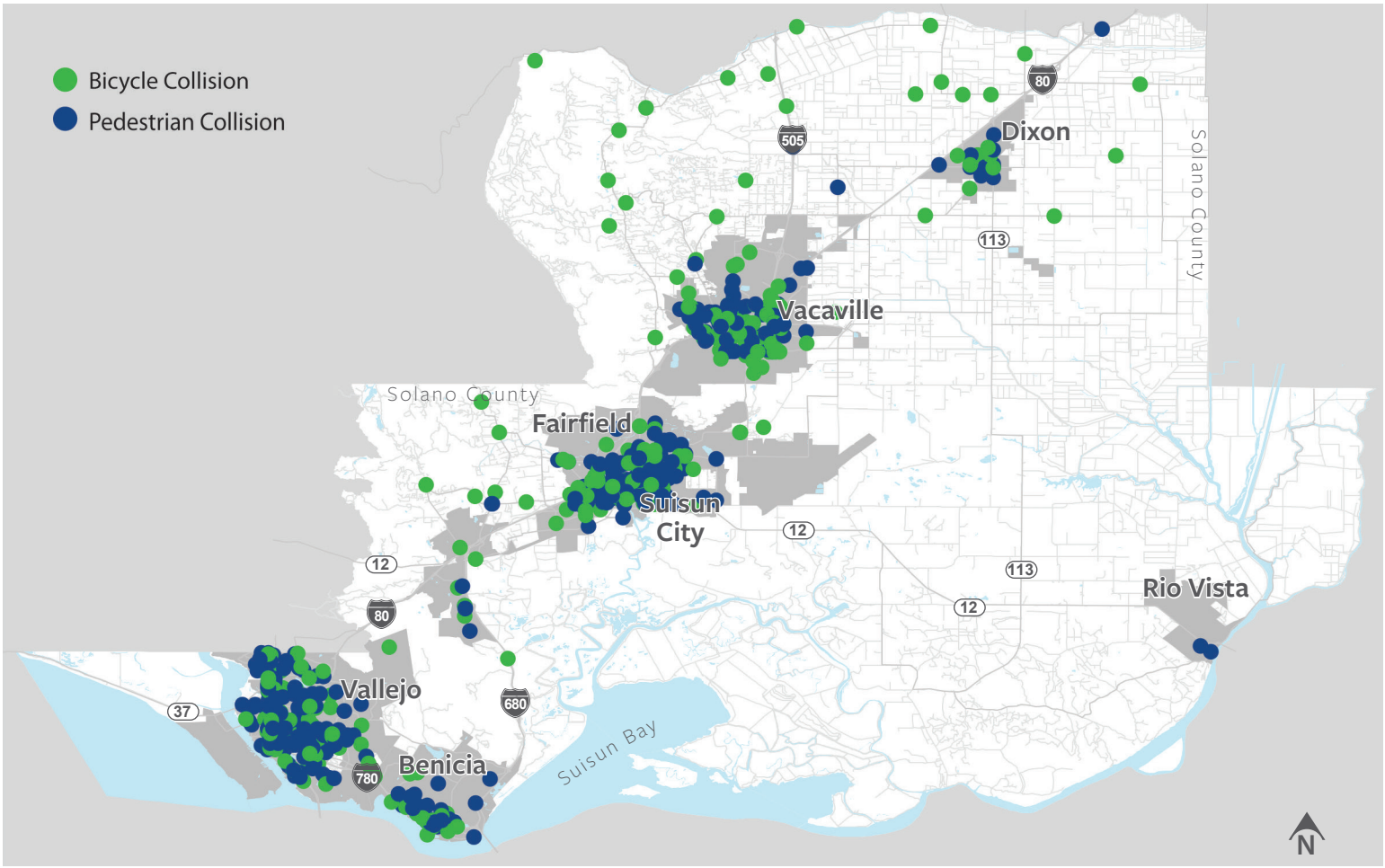
Primary Jurisdictions

Vehicle-pedestrian collisions do not account for more than 10% of the total number of collisions in any of the jurisdictions. Vehicle-pedestrian collisions however make up a large portion of the severe collisions in the following jurisdictions:

- 27% of the total EPDO score in Dixon (6% of total crashes)
- 23% of the total EPDO score in Vallejo (7% of total crashes)
- 21% of the total EPDO score in Suisun City (7% of total crashes)

Recommended Countermeasures

- Install pedestrian countdown signal heads, pedestrian crossings, pedestrian median fencing on approaches (**S19, S20, S23**)
- Install pedestrian crossing at uncontrolled locations (**NS17, NS18, NS19**)



- ▶ Install pedestrian crossing with enhanced safety features and/or build a raised pedestrian crossing (**R38, R39**)
- » Improve signal timing (**S3, S6**)
- » Install pedestrian refuge islands (**NS16**)
- » Widen paved or unpaved shoulder, depending on location (**R16, R17**)
- » Pave existing shoulder (**R18**)
- » Convert from two-way to one-way traffic (**R23**)
- » Install bike lanes and sidewalks/pathway to prevent walking along roadway (**R36, R37**)
- » Install pedestrian median fencing (**R42**)

Pedestrian-Involved Collisions near Schools

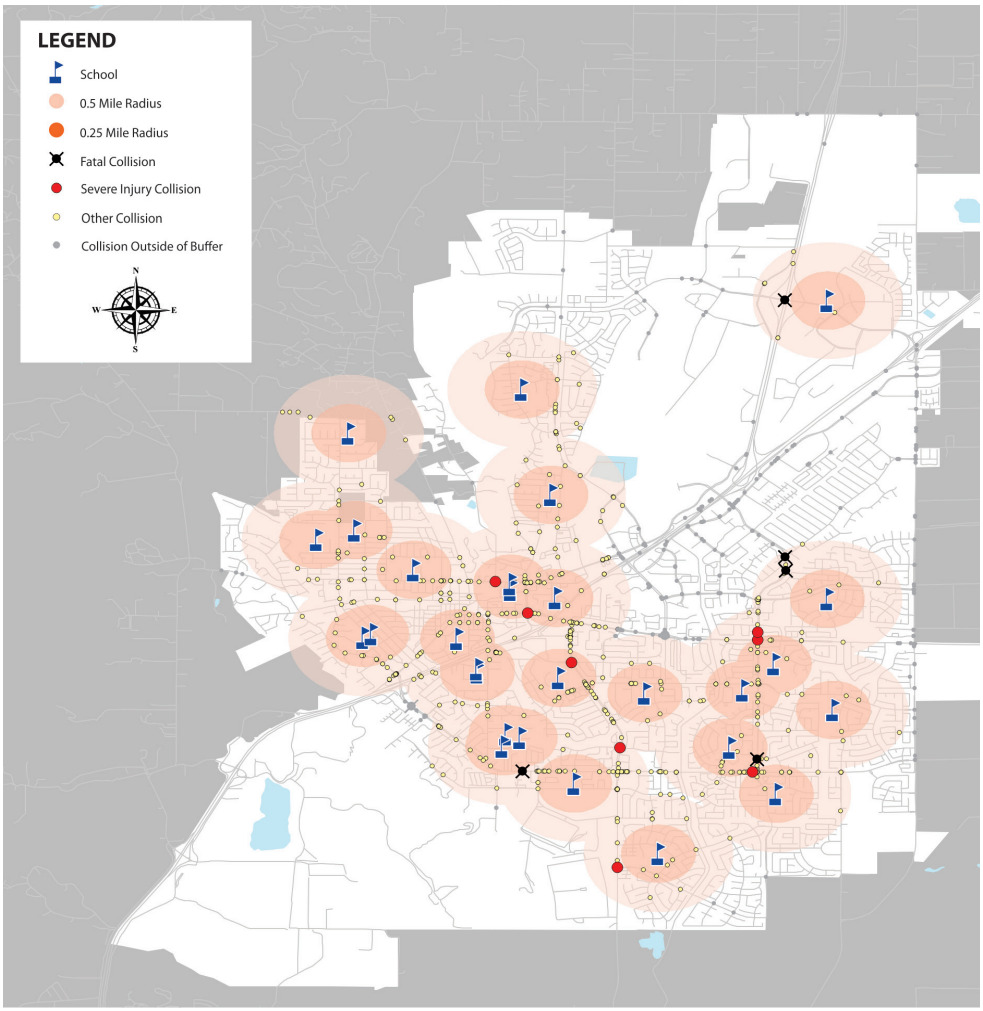
Pedestrian collisions near schools are particularly concerning as they tend to involve young children — one of the most vulnerable subsets of pedestrians. Since increased levels of pedestrian activity along specific routes in the vicinity of schools typically occur at the same time as increased vehicle traffic, it is important to identify and address locations with a high potential for conflicts between pedestrians and vehicles.

The Safe Routes to School (SR2S) program addresses safety for students traveling to schools in Solano County. The program's goal is to increase the number of children walking and biking to and from school by funding projects to remove obstacles, including unsafe existing infrastructure. The SR2S program has been running since 2007 and the most recent plan was released in 2013. Some of the main safety countermeasures identified in the 2008 and 2013 SR2S plans include:

- » Speed Feedback Signs
- » Road Diet
- » Installation of transverse high-visibility yellow and white crosswalks
- » Installation of bulb-outs

More information on projects and programs at specific locations can be found in the 2013 SR2S Plan1.

STA is currently undergoing an effort to identify schools with a high propensity for pedestrian and bicycle crashes and to prioritize relevant treatments. The figure below is a representative sample of a map showing crashes occurring nearby schools to be analyzed as part of that effort.



Recommended Countermeasures

- » Install pedestrian crossings at uncontrolled locations, signal and markings with enhanced safety features (**S20, NS17, NS18, NS19**)
- » Install sidewalk/pathway to prevent walking along roadway
- » Install midblock pedestrian crossings with enhanced safety features and raised pedestrian crossing (**R37,R38, R39**)

Pedestrian-Involved Collisions at Night

Nearly 40% of all pedestrian-involved collisions occurred in dark conditions, with or without street lighting present. Pedestrian collisions at night tend to be more severe than those during daylight conditions and warrant special consideration for reducing crash risk. Pedestrian violations and pedestrian right-of-way violations were attributed to over half of the pedestrian-involved collisions at night, by frequency and EPDO score.

Recommended Countermeasures

- » Install intersection lighting (**S1, NS1**)
- » Install segment lighting (**R1**)

1 http://www.solanosr2s.ca.gov/app_pages/view/4440

BICYCLE-INVOLVED COLLISIONS

Bicycle-involved collisions are most common in urban areas, where there is the highest percentage of bicycle travel. In rural areas, bicycle collisions occur more frequently than pedestrian collisions where recreational cycling is popular on country roads. In rural areas, factors contributing to bicycle-involved collisions include a lack of space for bicyclists, i.e. limited shoulders and narrow lanes, combined with higher vehicle speeds. In urban areas, limited bicycle facilities force vehicles and bicycles to share the same space, which contributes to the risk for collisions. This potential risk is compounded where vehicle and bicycle travel paths intersect, such as in turning movements at intersections and driveways and where vehicles change lanes and merge.

There were 444 bicycle collisions in Solano County between 2012 and 2017. Bicyclists traveling on the wrong side of the road is the most frequent collision factor. However, automobile right-of-way, improper turning and traffic signal/sign violations resulted in the highest severity crashes.

It should be noted that in the crash records, bicyclists are considered a type of automobile; therefore, violations of 'automobile right-of-way' include instances where bicyclists did not yield right-of-way to vehicles as well as where drivers did not properly yield right-of-way to bicycles.

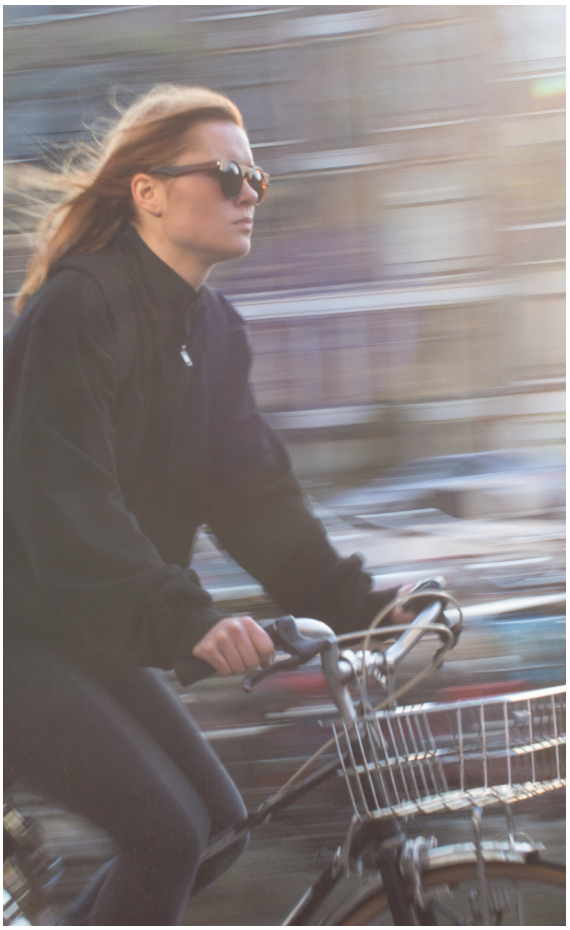
Primary Jurisdictions

Bicycle collisions do not account for more than 5% of the total number of collisions in any of the jurisdictions. Bicycle collisions however make up a larger portion of the severe collisions in the following jurisdictions:

- 12% of the total EPDO score in Benicia (5% of total crashes)
- 9% of the total EPDO score in Vacaville (4% of total crashes)
- 8% of the total EPDO score in Unincorporated County (3% of total crashes)

Recommended Countermeasures

- ▶ Install advance stop bar before crosswalk, bicycle box (**S21**)
- ▶ Road diet, widen paved or unpaved shoulder and pave existing shoulder (**R15, R16, R17, R18**)
- ▶ Install bike lanes or side pathway (**R36, R37**)
- » Improve signal timing (**S3, S6**)
- » Install pedestrian signal or HAWK (**NS19**)
- » Convert from two-way to one-way traffic (**R23**)



REAR-END COLLISIONS

Rear-end collisions result from a speed differential between lead and following vehicles, typically occurring at intersections and along roadways with a high density of driveways. There were 3,842 rear-end collisions in Solano County between 2012 and 2017. Unsafe Speed is the major contributing factor based on the frequency of collisions and the sum of EPDO score. Overall, however, DUI/DWI violations resulted in a higher severity, or EPDO score, per collision.

PRIMARY JURISDICTIONS

Rear-end collisions account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 30% of the total EPDO score in Rio Vista (33% of total crashes)
- 28% of the total EPDO score in Fairfield (33% of total crashes)
- 26% of the total EPDO score in Vacaville (31% of total crashes)

RECOMMENDED COUNTERMEASURES

Along the Roadway

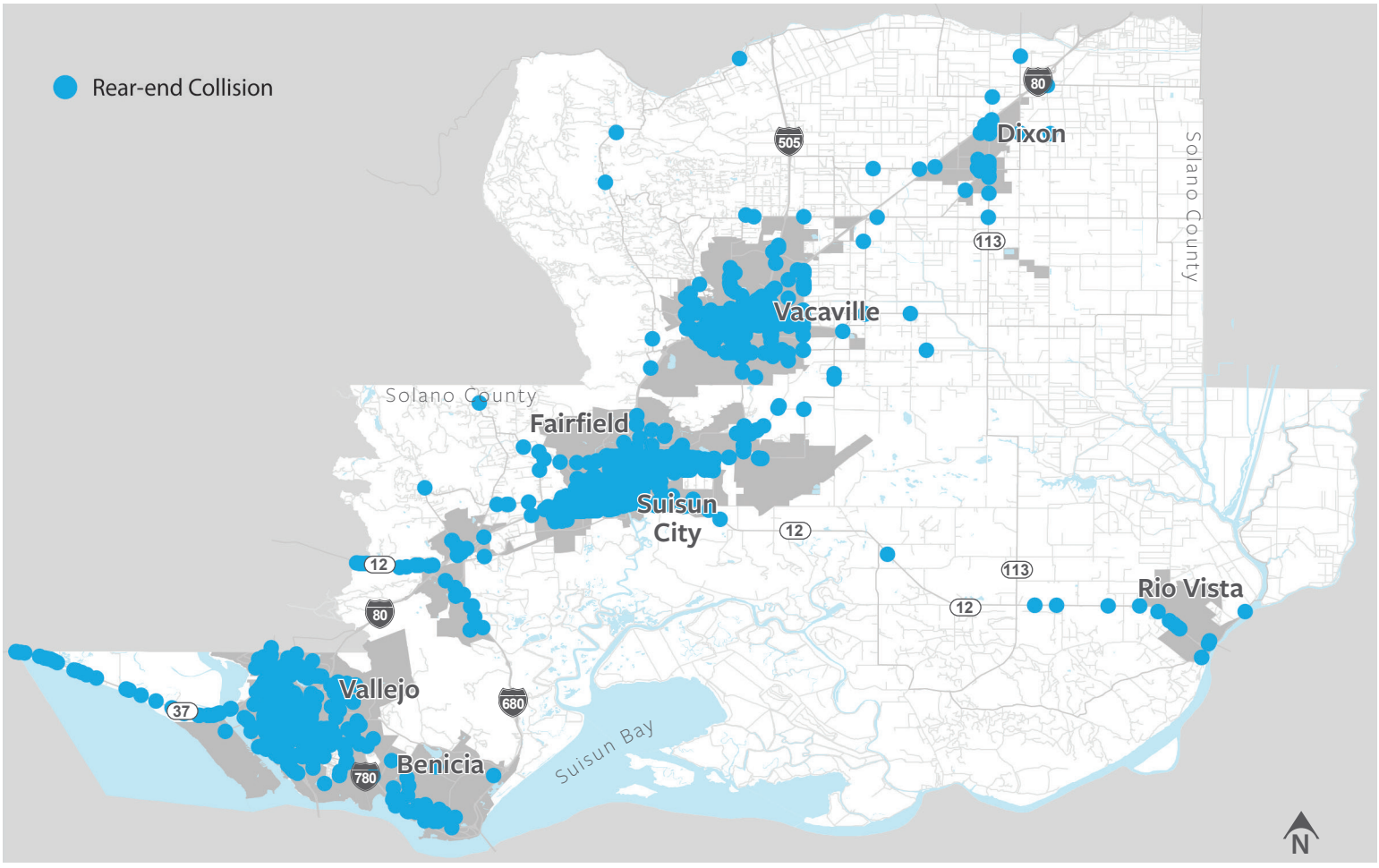
- Installation of acceleration/deceleration lane (**R12**)
- Add a two-way left-turn lane to the existing travel lanes (**R14, R15**)
- Improve curve superelevation and horizontal and vertical alignment by flattening the curves (**R19,R20,R21, R22**)
- Improve pavement friction (**R24**)

Signalized Intersections

- Improve signal hardware and signal timing (**S2,S3**)
- Install right-turn and left-turn lane and add turn phase (**S14, S15, S17**)
- Provide advanced dilemma-zone detection for high speed approaches (**S4**)
- Provide protected left-turn phase where left-turn lane exists (**S6**)
- Convert signal to mast arm from pedestal-mounted and install flashing beacons as advance warnings (**S7, S9**)

Stop-Controlled Intersections

- Install/upgrade large or additional stop signs or other intersection warning/regulatory signs (**NS5**)
- Install right-turn or left-turn lane (**NS14**)
- Upgrade intersection pavement markings (**NS6**)
- Install flashing beacons at stop-controlled intersection (**NS7, NS8**)
- Improve sight distance to intersection (**NS10**)
- Install transverse rumble strips on approaches, splitter-islands on the minor road approaches, and raised medians on approaches (**NS9, NS11, NS12**)



BROADSIDE COLLISIONS

In broadside collisions, the side of one vehicle is impacted by the front or rear of another vehicle, forming a 'T'. Vehicle damage and occupant injury are likely to be severe, but severity varies based on the part of the vehicle that is struck, safety features present, the speed of both vehicles, and vehicle weight and construction. The struck vehicle may be spun or rolled over, potentially causing it to strike other vehicles, objects, or pedestrians.

There were 3182 broadside collisions in Solano County between 2012 and 2017. Automobile Right-of-Way violations account for the majority (40%) of the EPDO score for all broadside collisions in the county. Traffic Signal/Sign Violations are the second highest primary collision factor, accounting for 25% of the EPDO score.

PRIMARY JURISDICTIONS

Broadside collisions account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 34% of the total EPDO score in Vacaville (29% of total crashes)
- 26% of the total EPDO score in Vallejo (22% of total crashes)
- 26% of the total EPDO score in Fairfield (21% of total crashes)

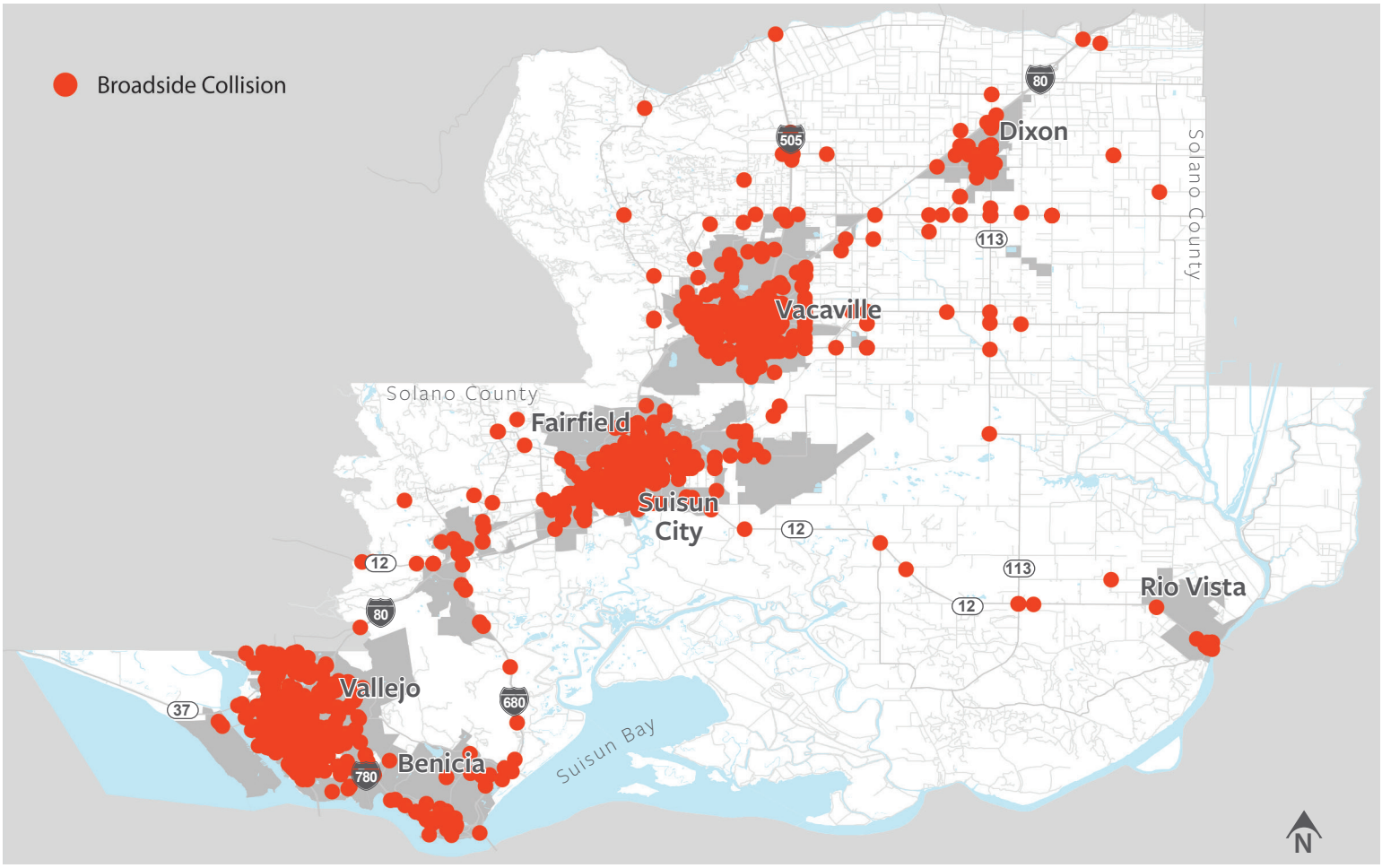
RECOMMENDED COUNTERMEASURES

Signalized Intersections

- Improve signal hardware and signal timing (**S2,S3**)
- Provide protected left turn phase when left turn lane already exists (**S6**)
- Provide advanced dilemma-zone detection for high speed approaches (**S4**)
- Convert signal to mast arm from pedestal-mounted and install flashing beacons as advance warnings (**S7, S9**)

Stop/Regulatory Intersections

- Install/upgrade larger or additional stop signs or other intersection warning/ regulatory signs (**NS5**)
- Improve intersection sight distance (**NS10**)
- Convert two-way stop control to all-way stop control (**NS2**)
- Upgrade intersection pavement markings (**NS6**)
- Install flashing beacons (**NS7, NS8**)
- Install transverse rumble strips, splitter-islands, or raised median on approaches (**NS9, NS11, NS12**)



ROADWAY DEPARTURE COLLISIONS

A roadway departure collision is a non-intersection crash that occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the travel way.

Roadway departure collisions include both 'overturned vehicle' and 'fixed object' crashes, which are the two most predominant results of a vehicle leaving the roadway.

There were an estimated 1,256 roadway departure collisions in Solano County between 2012 and 2017, occurring predominantly in rural areas. Approximately 25% of fatalities in roadway departure collisions involved head-on or opposing-flow sideswipe crashes. Driving violations such as speeding, alcohol, and unbelted driving are major factors and many of these crashes involve multiple driving violation factors.

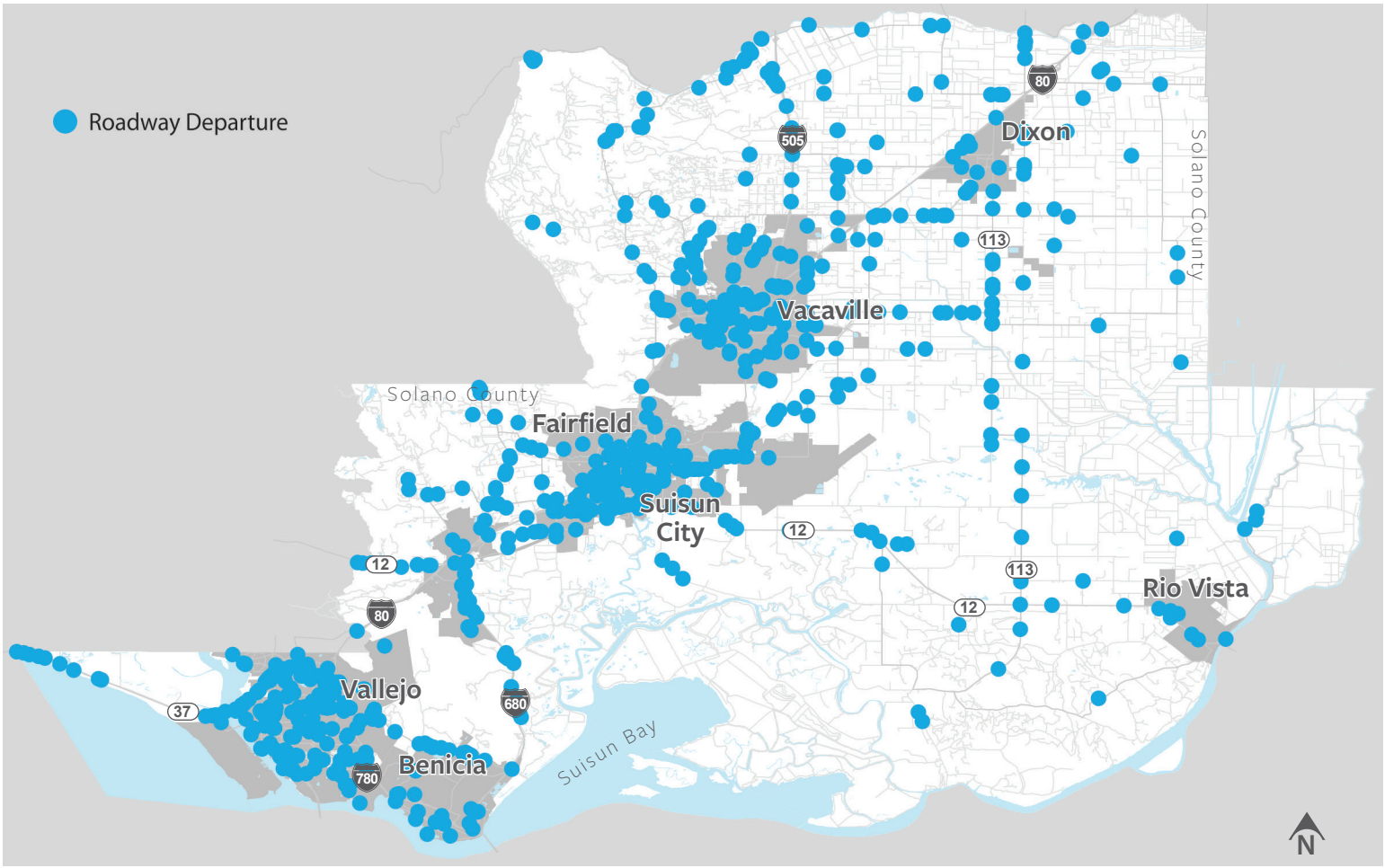
PRIMARY JURISDICTIONS

Roadway departure collisions account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 18% of the total EPDO score in Unincorporated County (13% of total crashes)
- 10% of the total EPDO score in Benicia (4% of total crashes)
- 5% of the total EPDO score in Vacaville (2% of total crashes)

RECOMMENDED COUNTERMEASURES

- ▶ Install guardrail and impact attenuators (**R4, R5**)
- ▶ Widen shoulder for both paved and unpaved (**R16, R17**)
- ▶ Install edge-lines, rumble strips/stripes and centerlines (**R32, R35**)
- » Flatten side slopes (**R6**)
- » Upgrade bridge railing (**R8**)
- » Widen lane that is less than 10ft initially (**R13**)
- » Pave existing shoulder (**R18**)
- » Improve curve superelevation and horizontal and vertical alignments (**R19, R20, R21, R22**)
- » Provide tapered edge for pavement edge drop-off (**R25**)
- » Install/upgrade signs with new fluorescent sheeting, regulatory or warning (**R26**)
- » Install chevron signs on horizontal curves, curves advance signs and variable speed warning signs (**R27, R28, R29, R30**)
- » Install delineators, reflectors, and/or object markets (**R31**)



ENVIRONMENTAL FACTORS

Environmental factors, such as time of day, weather conditions, and roadway characteristics are also a factor in collisions.

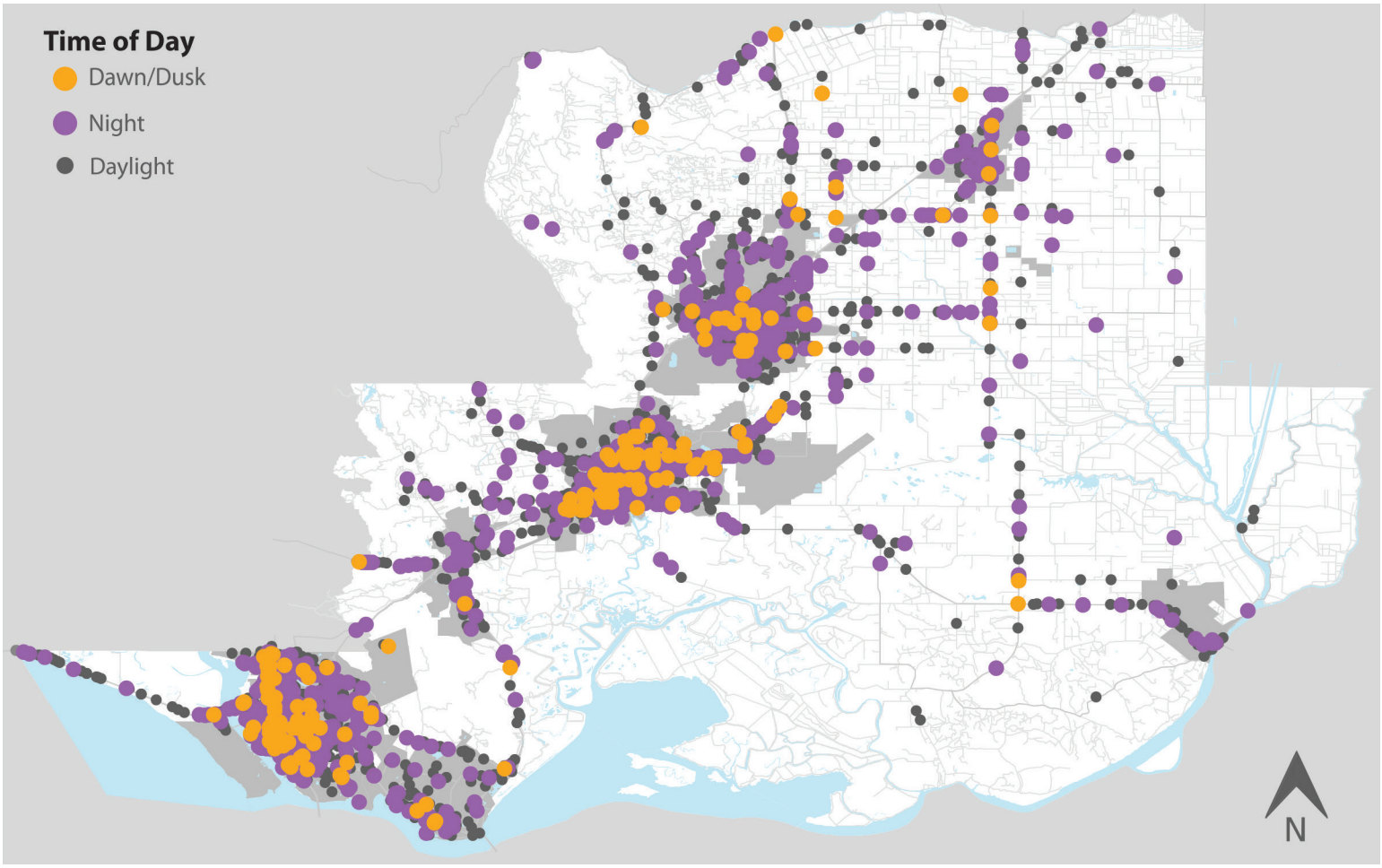
TIME OF DAY

Collisions in dark conditions account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 41% of the total EPDO score in Dixon (33% of total crashes)
- 38% of the total EPDO score in Rio Vista (26% of total crashes)
- 37% of the total EPDO score in Vallejo (34% of total crashes)

Recommended Countermeasures

- ▶ Add intersection lighting (**S1; NS1**)
- ▶ Install flashing beacons at stop-controlled intersections as advance warnings (**NS7, NS8**)
- Install raised pavement markers while improving pavement friction striping through intersection (**S8, S11**)
- Install/upgrade signs with new fluorescent sheeting as regulatory or warning (**R26**)
- Install delineators, reflectors and/or object markers (**R31**)



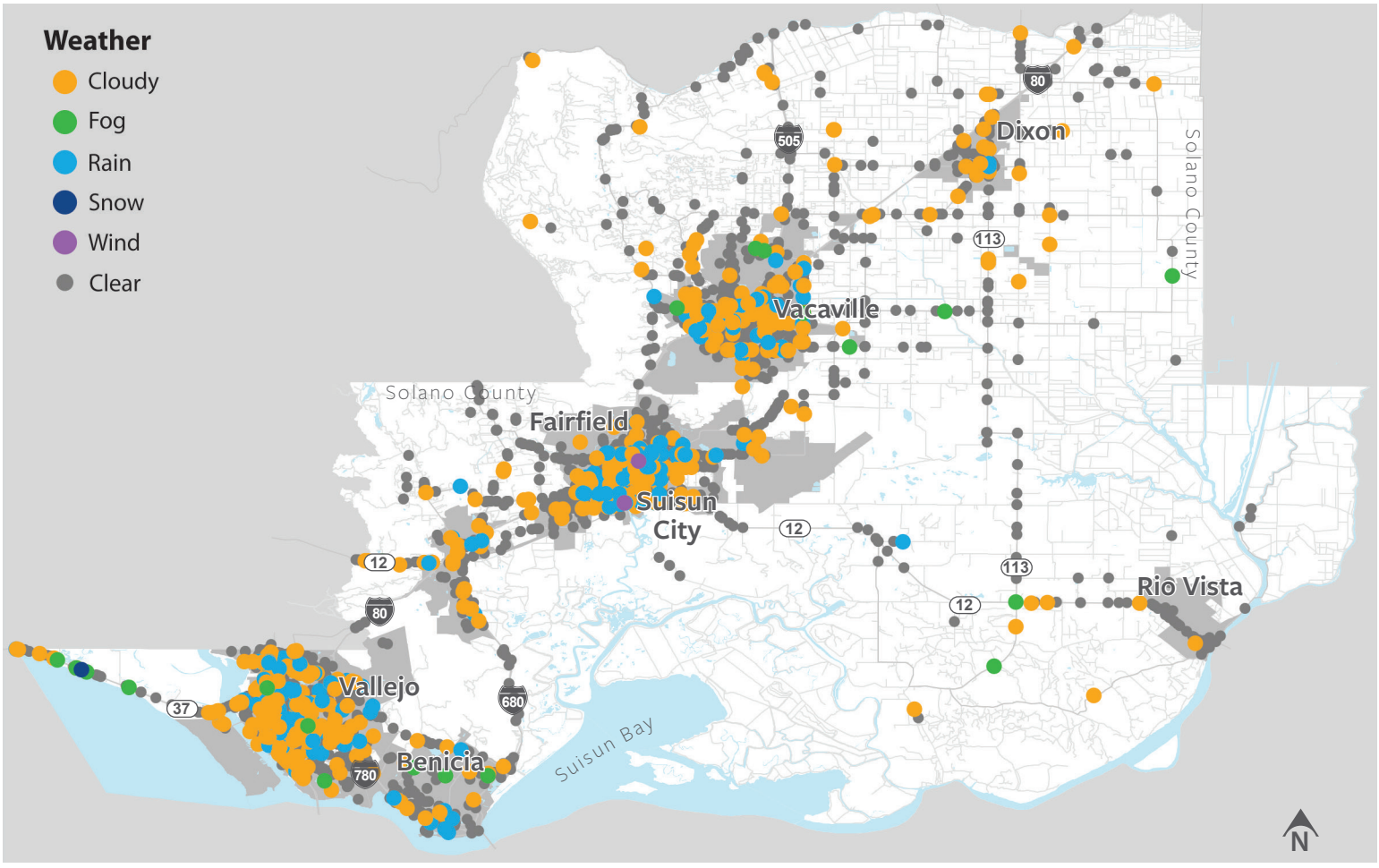
WEATHER

Collisions in rain/foggy conditions account for a portion of the severe and total number of collisions in the following jurisdictions:

- 8% of the total EPDO score in Benicia (5% of total crashes)
- 6% of the total EPDO score in Vallejo (6% of total crashes)
- 6% of the total EPDO score in Dixon (5% of total crashes)

Recommended Countermeasures

- ▶ Install high friction surface treatments (**NS20, R24**)
- ▶ Install delineators, reflectors and/or object markers (**R31**)
- » Install raised pavement markers while improving pavement friction striping through intersection (**S8, S11**)
- » Install edgeline and centerline rumble strip/stripes



ROADWAY CHARACTERISTICS

Roadway characteristics refer to a variety of factors including horizontal and vertical alignment, number of width of lanes, width and type of shoulder, and roadside hazards, among others.

Recommended Countermeasures

- Install guardrail, for run-off road crash type, and impact attenuators (**R4, R5**)
- Flatten side slopes, remove guardrail, and upgrade bridge railing (**R6, R7, R8**)
- Install climbing lane where large difference between car and truck speed and consider widening lane if initially less than 10 feet (**R12, R13**)
- Widen paved and unpaved shoulder and/or pave existing shoulder (**R16, R16,R18**)
- Improve geometric alignment (**R20, R21, R22**)
- Provide Tapered Edge for Pavement Edge Drop-off (**R25**)
- Install/upgrade signs with new fluorescent sheeting with regulatory or warning. (**R26**)
- Install chevron signs on horizontal curves and curve advance warning signs with flashing beacon (**R27, R28, R29**)
- Install dynamic/variables speed warning signs; and, delineators, reflectors and/or object markers; and, install edge-liner and centerlines (**R30, R31, R32**)
- Install edgeline rumble strips/stripes (**R35**)
- Install truck escape ramp (**R41**)

HUMAN BEHAVIOR FACTORS

Human capabilities, limitations, physical conditions, and/or psychological states, play a significant role in transportation accidents. Factors include operators' interactions with vehicular controls and systems and the types of errors that operators make that can contribute to accidents. While countermeasures cannot solve human behavior factors, they can be used to mitigate results, either by providing drivers with more time or space to recover or by minimizing the severity of resulting crashes.

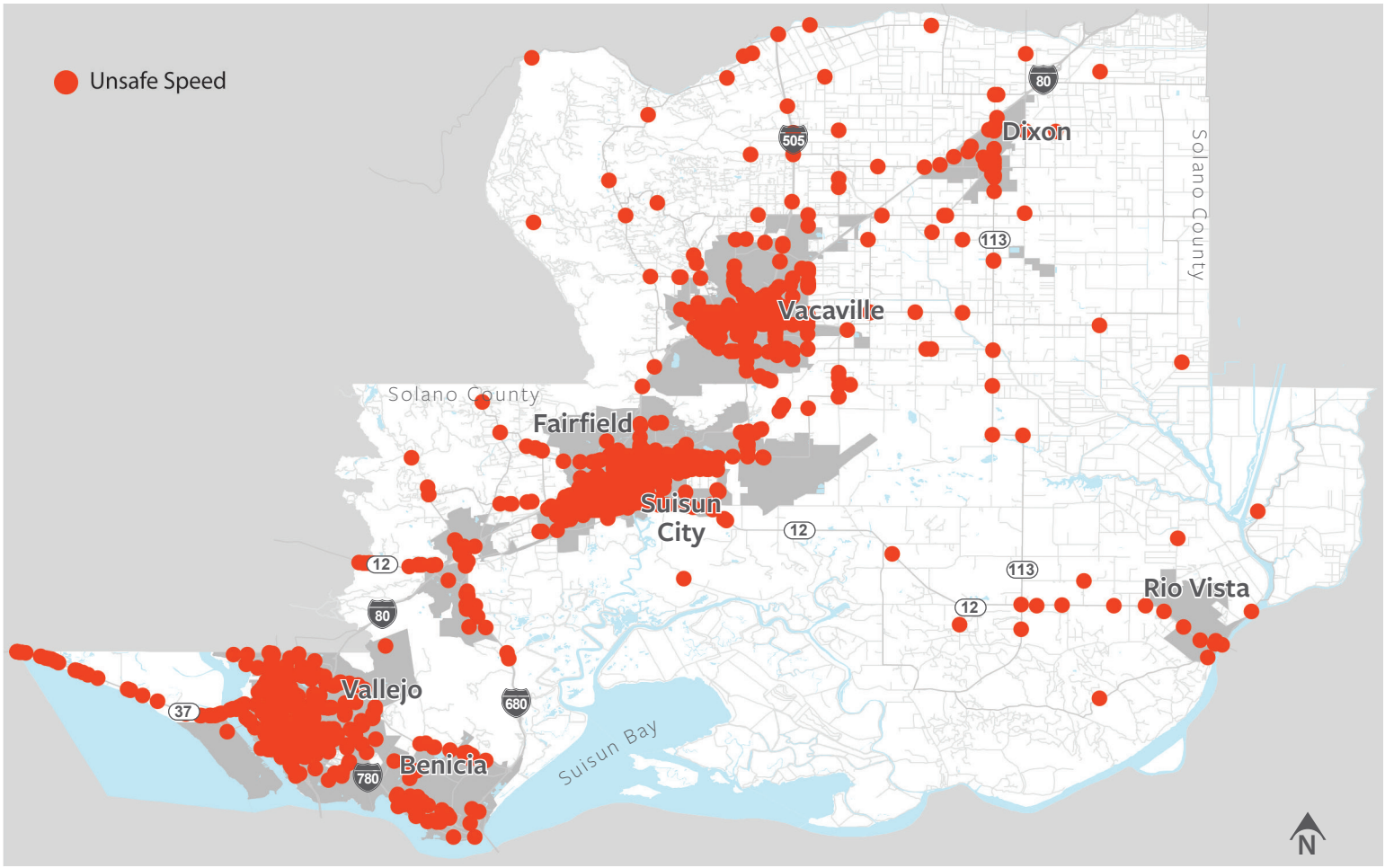
UNSAFE SPEEDS

Collisions with unsafe speed as the primary collision factor account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 38% of the total EPDO score in Suisun City (39% of total crashes)
- 31% of the total EPDO score in Rio Vista (28% of total crashes)
- 31% of the total EPDO score in Dixon (25% of total crashes)
- 30% of the total EPDO score in Fairfield (31% of total crashes)

Recommended Countermeasures

- ▶ Improve signal hardware and timing (**S2, S3**)
- ▶ Install flashing beacons (**NS7, NS8**)
- ▶ Install chevron signs on horizontal curves, advanced curve signs, and variable speed warning signs (**R27, R28, R29, R30**)
- » Provide advanced dilemma-zone detection for high speed approaches (**S4**)
- » Convert signal to mast arm from pedestal-mounted (**S7**)
- » Install flashing beacons, cameras, and raised median (**S9, S10, S12**)
- » Convert intersection to roundabout (**S18**)
- » Install/upgrade large or additional stop signs or other intersection warning/regulatory signs (**NS5**)
- » Upgrade intersection pavement markings (**NS6**)
- » Improve sight distance to intersection (**NS10**)
- » Install transverse rumble strips on approaches, splitter-islands on the minor road approaches, and raised median on approaches (**NS9, NS11, NS12**)
- » Install/upgrade signs with new fluorescent sheeting, regulatory or warning (**R26**)
- » Install delineators, reflectors and/or object markets (**R31**)
- » Install edge-lines, rumble strips/stripes, centerlines (**R32,R33,R34**)
- » Install traffic-calming measure (**NH25**)



IMPROPER TURNING

Hit object is the most predominant collision type for frequency and EPDO score for improper turning collisions.

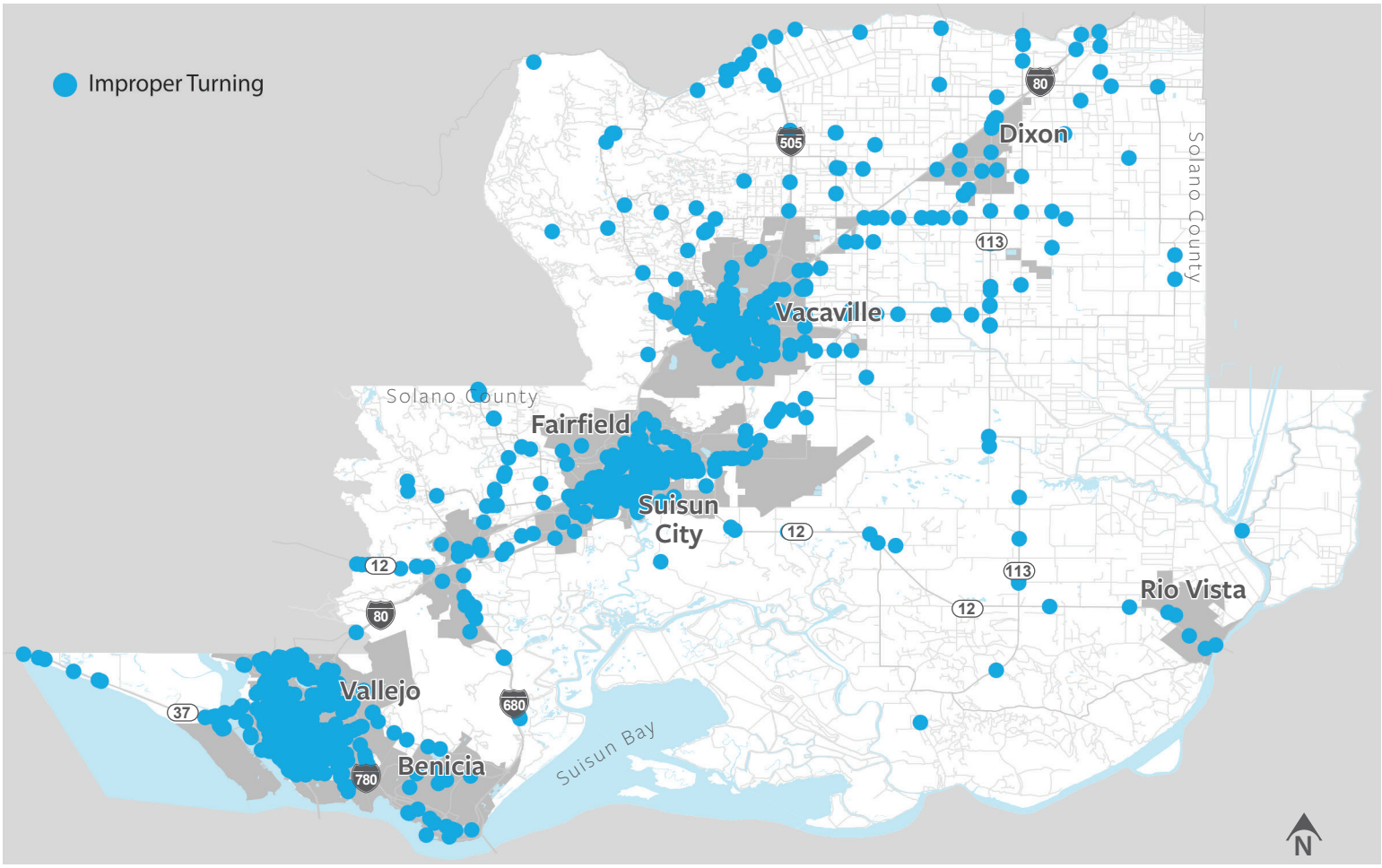
Primary Jurisdictions

Collisions with improper turning as the primary collision factor account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 25% of the total EPDO score in Unincorporated County (32% of total crashes)
- 19% of the total EPDO score in Benicia (24% of total crashes)
- 18% of the total EPDO score in Rio Vista (25% of total crashes)

Recommended Countermeasures

- ▶ Improve signal hardware and signal timing (**S2 &S3**)
- ▶ Provide protected left-turn phase where left-turn lane already exists (**S6**)
- ▶ Install chevron signs on horizontal curves, advanced curve signs, and variable speed warning signs (**R27, R28, R29, R30**)
- » Provide advanced dilemma-zone detection for high-speed approaches (**S4**)
- » Convert signal to mast-arm from pedestal-mounted (**S7**)
- » Install raised pavement markers and striping through intersection(**S8**)
- » Install flashing beacons, cameras and raised median (**S9, S10, S12**)
- » Improve pavement friction, high friction surface treatment (**S11, NS20, R24**)
- » Create directional median openings to allow and restrict left turns and U-turns (**S13**)
- » Install right-turn lane, left-turn lane and add turn phase (**S15, S16, S17, NS14, NS15**)
- » Convert intersection to roundabout from two-way stop or yield (**NS4**)
- » Install/upgrade larger or additional stop signs or other intersection warning/regulatory signs (**NS5**)
- » Upgrade intersection pavement markings (**NS6**)
- » Install flashing beacons (**NS7, NS8**)
- » Improve sight distance to intersection (**NS10**)
- » Install transverse rumble strips on approaches, splitter-islands on the minor road approaches (**NS9, NS11**)
- » Create directional median openings to allow and restrict left turns and U-turns (**NS13**)
- » Improve horizontal and vertical alignment (**R20,R21**)
- » Install centerline rumble strips/ stripes (**R34**)



AUTOMOBILE RIGHT-OF-WAY

Broadside collisions account for over half of the frequency and EPDO score for automobile right-of-way collisions.

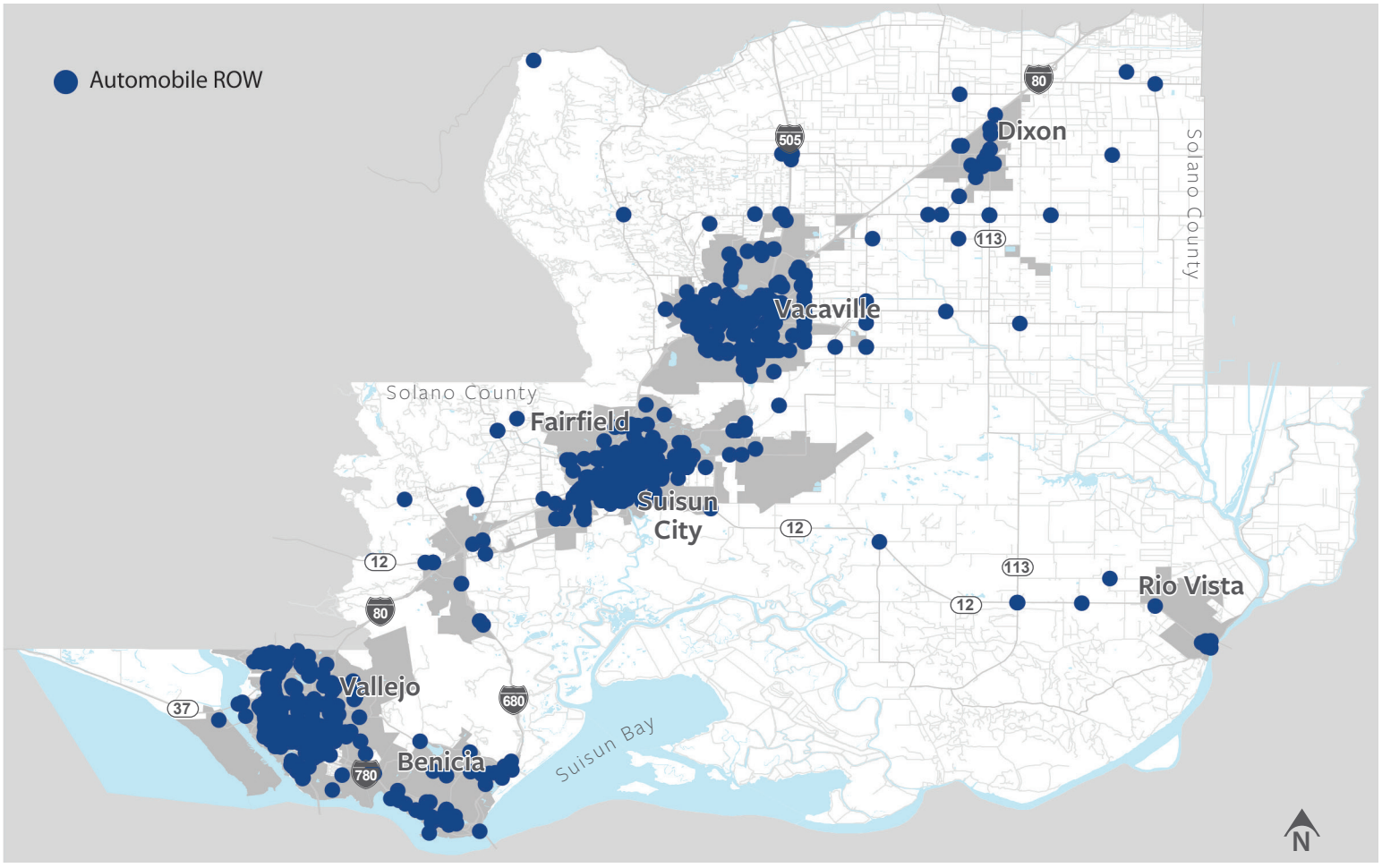
Primary Jurisdictions

Collisions with automobile ROW as the primary collision factor account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 19% of the total EPDO score in Vacaville (16% of total crashes)
- 16% of the total EPDO score in Benicia (15% of total crashes)
- 13% of the total EPDO score in Vallejo (12% of total crashes)

Recommended Countermeasures

- Provide protected left-turn phase where left turn already exists (**S6**)
- Convert intersection to roundabouts (**S18**)
- Create directional median openings to allow and restrict left turns and U-turns (**S13**)
- Improve curve superelevation and horizontal and vertical alignments by flattening curves (**R19, R20, R22**)
- Create directional median openings to allow and restrict left turns and U-turns (**NS13**)
- Add two-way left-turn lane without reducing travel lanes (**R14**)
- Convert from two-way to one-way traffic (**R23**)
- Install bike lanes, sidewalk/pathway, raised pedestrian crossing and pedestrian median fencing (**R36,R37,R38,R39,R42**)



DUI/DWI

The majority of DUI/DWI collisions occur in dark conditions with street lights. This may be due to people leaving bars late at night and driving impaired.

Primary Jurisdictions

Collisions with DUI/DWI as the primary collision factor account for a large portion of the severe and total number of collisions in the following jurisdictions:

» 25% of the total EPDO score in Unincorporated County (13% of total crashes)

» 15% of the total EPDO score in Suisun City (6% of total crashes)

» 12% of the total EPDO score in Vacaville (11% of total crashes)

Recommended Countermeasures

► Improve signal hardware and timing (**S2, S3**)

► Install chevron signs on horizontal curves, advanced curve signs, and variable-speed warning signs (**R27, R28, R29, R30**)

► Implement education and/or enforcement campaigns (**NH43**)

» Provide advanced dilemma-zone detection for high speed approaches(**S4**)

» Convert intersection to roundabouts (**S18**)

» Install/upgrade large or additional stop signs or other intersection warning/regulatory signs (**NS5**)

» Upgrade intersection pavement markings (**NS6**)

» Install flashing beacons (**S9, NS7, NS8**)

» Improve sight distance to intersection (**NS10**)

» Install transverse rumble strips on approaches, splitter-islands on the minor road approaches, and raised median on approaches (**NS9, NS11, NS12**)

» Install median barrier (**R3, R9,R10**)

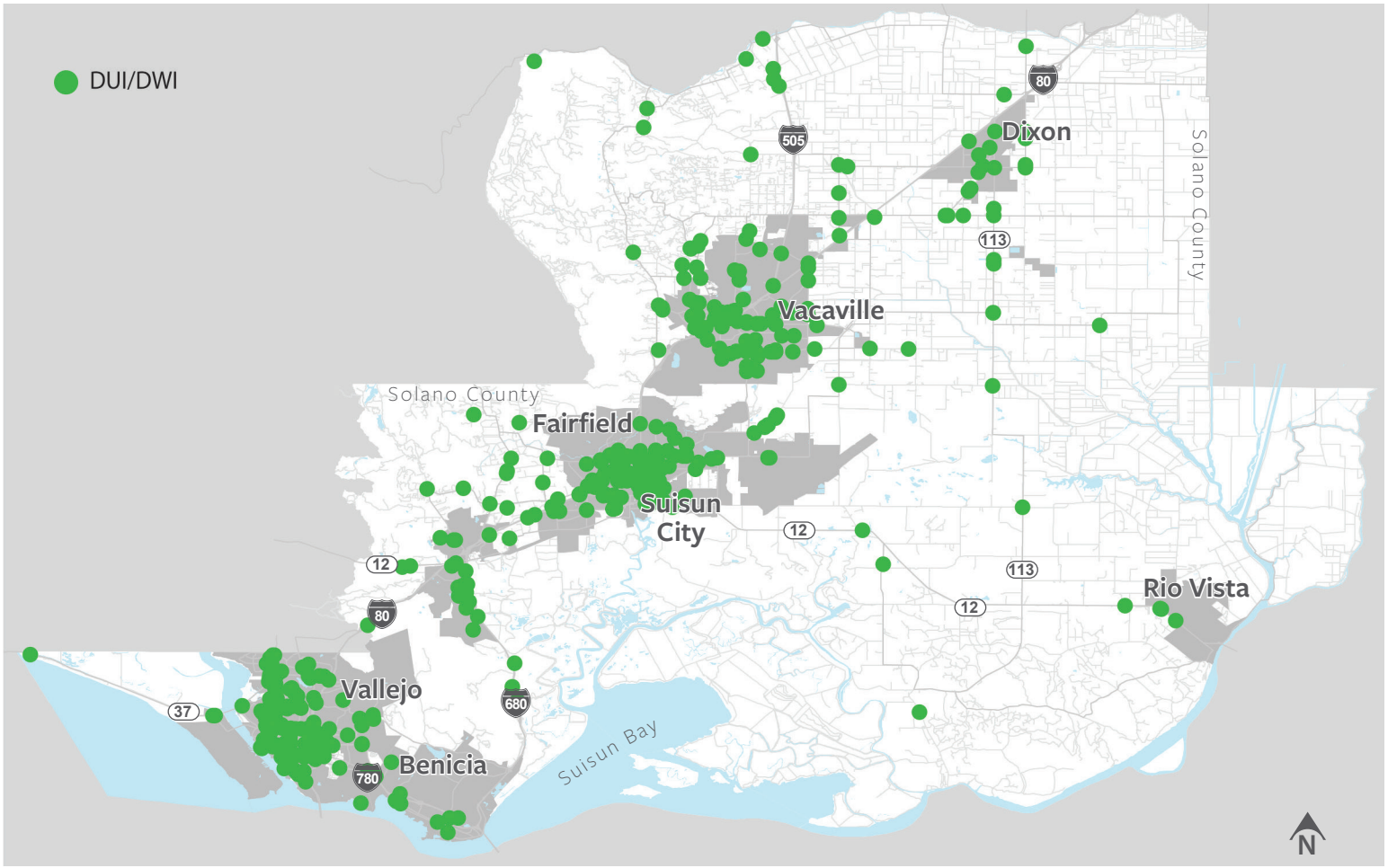
» Install guardrail and impact attenuators (**R4, R5**)

» Improve horizontal and vertical alignment (**R20,R21**)

» Install/upgrade signs with new fluorescent sheeting, regulatory or warning (**R26**)

» Install delineators, reflectors and/or object markets (**R31**)

» Install edge-lines, rumble strips/stripes, centerlines, and no-passing line (**R32,R33,R34**)



FAILURE TO YIELD TO TRAFFIC SIGNAL/SIGN

Collisions resulting from failure to yield to traffic signal/sign account for 8% of the total EPDO score and 7% of the total number of collisions in the County from 2012-2017. This type of error most often results in broadside collisions which represent 80% of the EPDO score and 79% of the total number of collisions attributed to failure to yield to a traffic signal or sign.

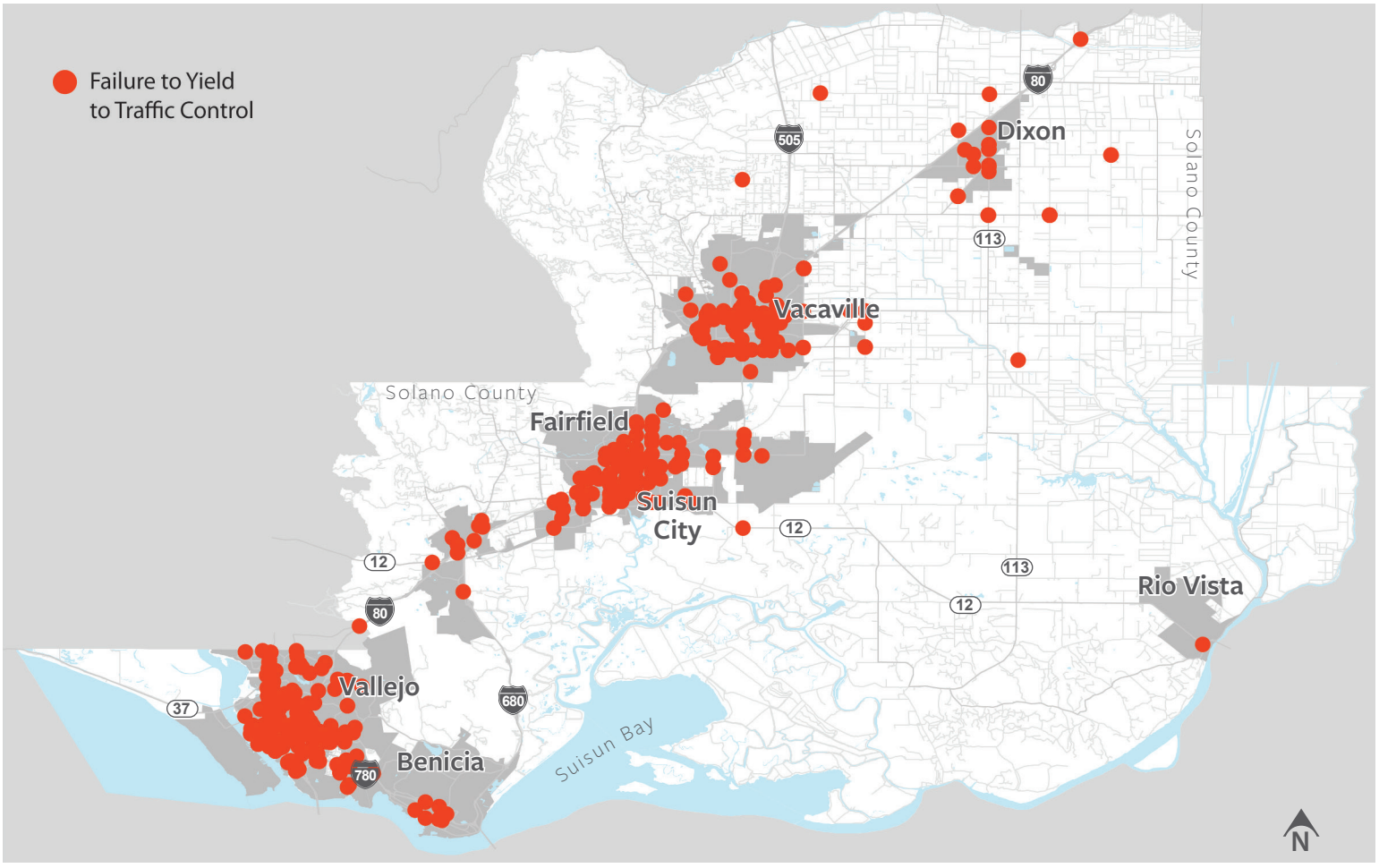
Primary Jurisdictions

Collisions with traffic signal/sign as the primary collision factor account for a portion of the severe and total number of collisions in the following jurisdictions:

- 10% of the total EPDO score in Vacaville (8% of total crashes)
- 10% of the total EPDO score in Rio Vista (2% of total crashes)
- 9% of the total EPDO score in Vallejo (8% of total crashes)

Recommended Countermeasures

- ▶ Improve signal timing (**S3**)
- ▶ Install flashing beacons (**S9, NS7, NS8**)
- ▶ Install/upgrade large or additional stop signs or other intersection warning/regulatory signs (**NS5**)
- » Provide protected left-turn phase (**S6**)
- » Convert intersection to roundabout (**S18**)
- » Install pedestrian countdown signal heads and pedestrian crossing, pedestrian overpass/underpass, pedestrian median fencing on approaches (**S19, S20,S21,S22,S23**)
- » Upgrade intersection pavement markings (**NS6**)
- » Install transverse rumble strips on approaches (**NS9**)



PEDESTRIAN VIOLATION/PEDESTRIAN ROW

Pedestrian Violation/ROW collisions do not account for more than 2% of the total number of collisions, however these collisions make up a large portion of the severe collisions (10% of EPDO score).

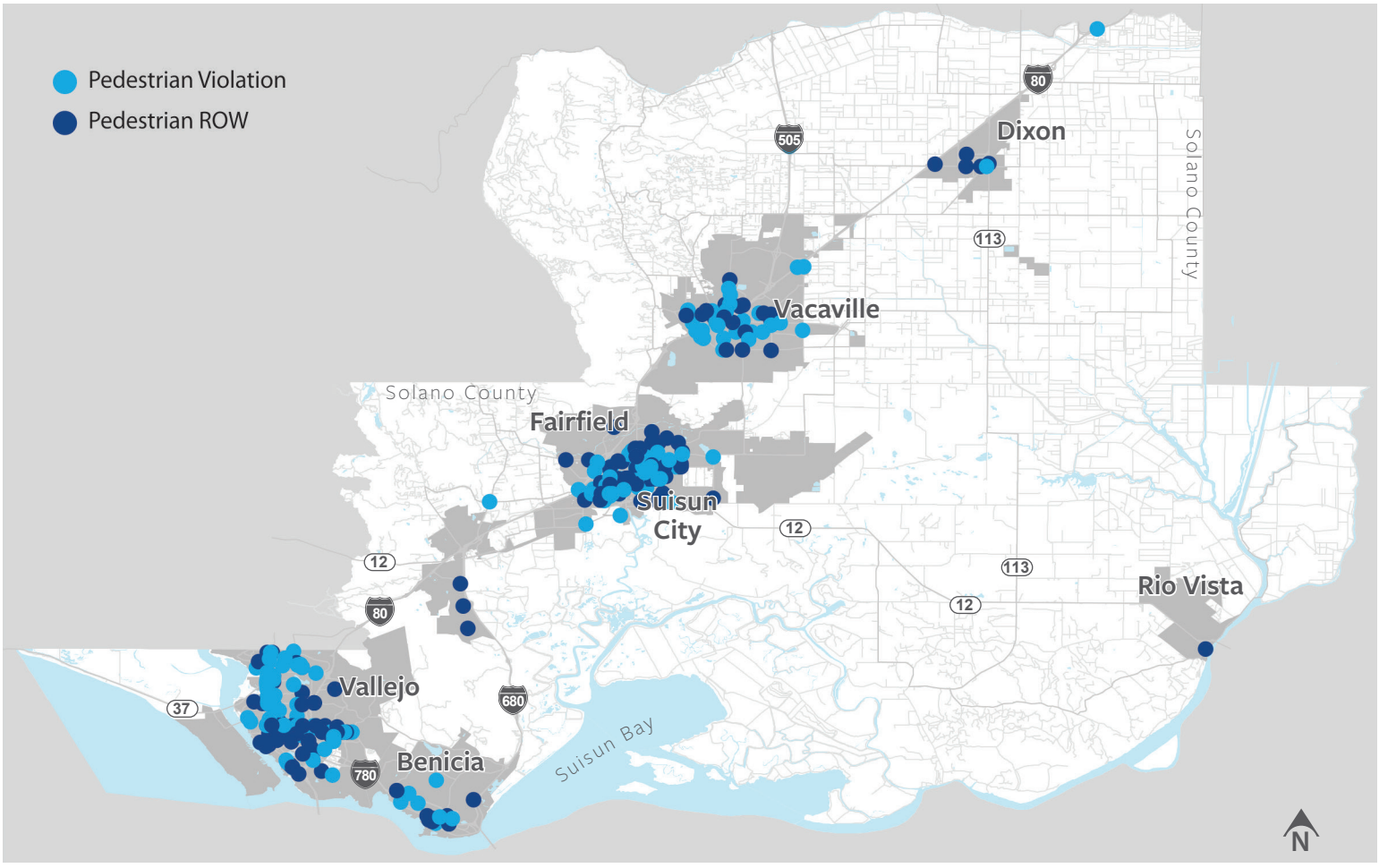
Primary Jurisdictions

Collisions with pedestrian violation/ROW as the primary collision factor account for a large portion of the severe and total number of collisions in the following jurisdictions:

- 15% of the total EPDO score in Vallejo (4% of total crashes)
- 10% of the total EPDO score in Fairfield (4% of total crashes)
- 9% of the total EPDO score in Benicia (4% of total crashes)

Recommended Countermeasures

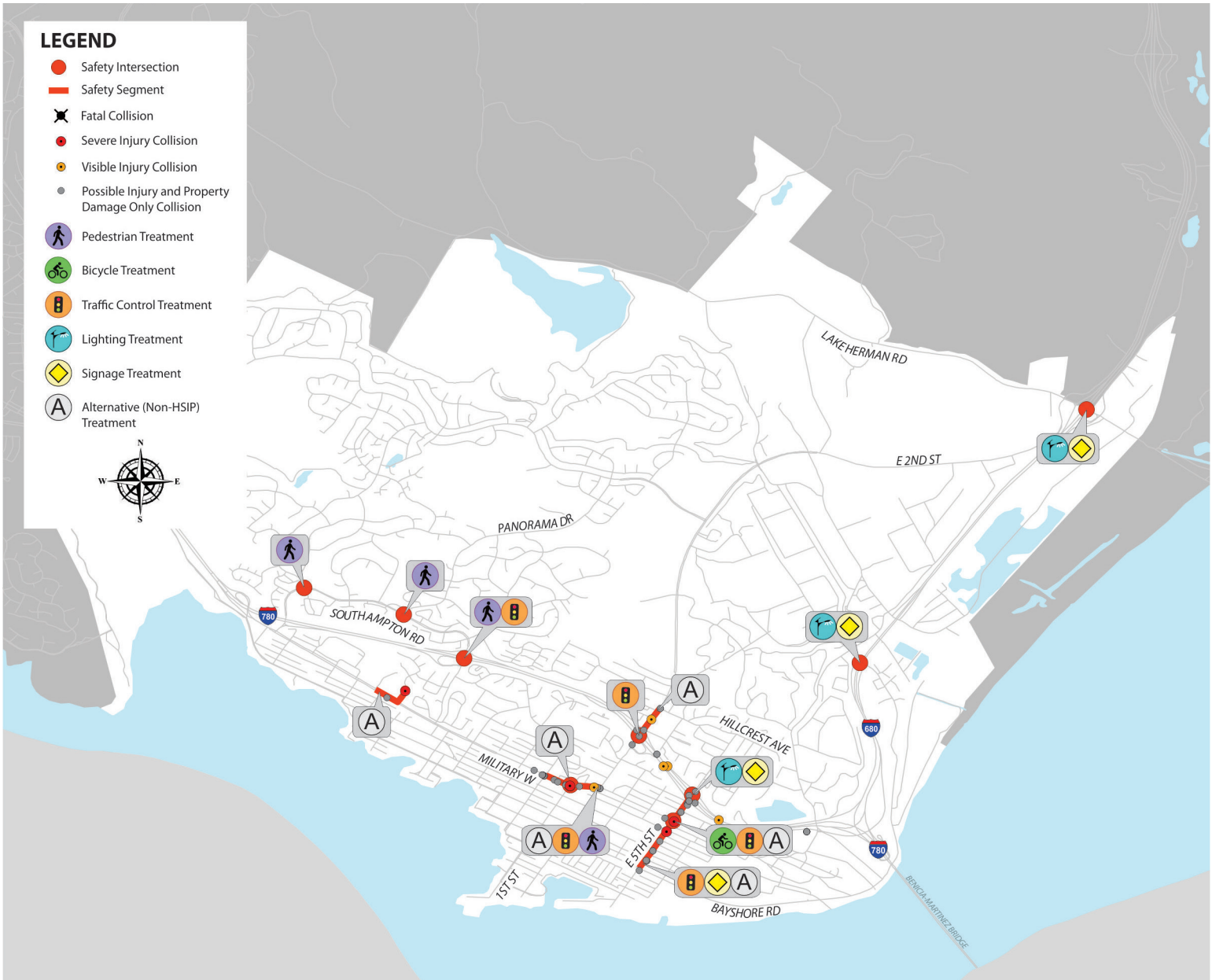
- Provide protected left-turn phase where left-turn lane already exists (**S6**)
- Install pedestrian countdown signal heads and pedestrian crossing, pedestrian overpass/underpass, and pedestrian median fencing on approaches (**S19, S20,S21,S22,S23**)
- Install pedestrian crossing at uncontrolled location (**NS17, NS18, NS19**)
- Improve signal timing (**S3**)
- Add intersection lighting (**NS1**)
- Install sidewalk/pathway and raised pedestrian crossing and pedestrian median fencing (**R37,R38,R39,R42**)



4 PROJECT LISTS

BENICIA

The City of Benicia experienced a total of 649 collisions during the study period, of which 17 resulted in a fatality or severe injury. The most predominant crash types in Benicia are hit-object, broadside, and rear-end. While relatively low in frequency, bicycle and pedestrian collisions comprised over 40% of the fatal and severe collisions in Benicia.



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Signalized Intersections – Signal Hardware and Left Turn Phase						
Military at 5th St E	S2	S6	-	S3	$54,000	
Military at E 2nd				S3, S10	$54,000	$108,000
Treatments at Unsignalized Intersections – Convert to All-Way Stop and Install Warning/Regulatory Signs						
E 5th St at E L St	NS2	NS5	-	NS4, NS11	$6,000	
E 5th St at E I St				NS4, NS11, NS12	$6,000	
E 5th St at E J St				NS4, NS11, NS12	$6,000	
E 5th St at E N St				NS12	$6,000	$24,000
Treatments at Segments – Install Bike Lanes						
Military at 5th St E	R36	-	-	-	$100,000	$100,000
Treatments at Unsignalized Intersections - Install Raised Median and Pedestrian Crossing						
E 2nd St & E S St.	NS16	NS18	-		$62,000	
Hastings Dr at Southampton Rd					$62,000	
Military W & Plaza De Oro					$62,000	
Southampton Rd. & Panorama Dr.					$62,000	$ 248,000
Treatments at Signalized Ramp Intersections - Signal Hardware						
I-780 and Southamption Rd	S2	-	-		$42,000	
I-780 and E 2nd					$42,000	$ 84,000
Treatments at Unsignalized Ramp Intersections - Install Lighting and Warning/Regulatory Signs						
I-780 and E 5th	NS1	NS5	-		$58,000	
I-680 and Bayshore					$58,000	
I-680 and Lake Herman					$58,000	
I-680 and Central					$58,000	$ 232,000

NON-HSIP-FUNDING QUALIFIED PROJECTS

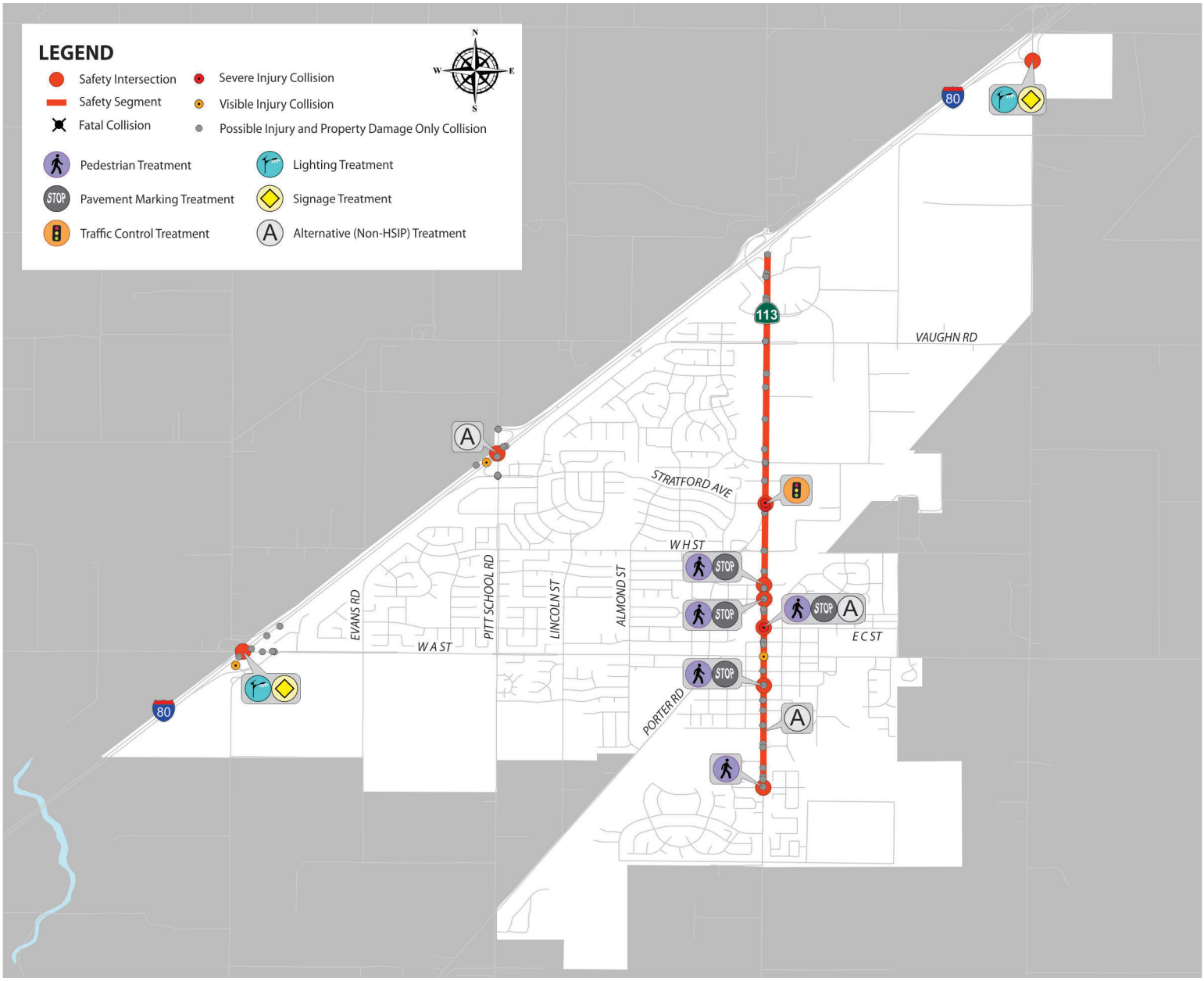
Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Drolette Wy and Military W near Elementary School	NH23	Modify speed limit	8%	Varies
Drolette Wy and Military W near Elementary School	NH25	Install traffic-calming	Varies	Varies
Drolette Wy and Military W near Elementary School	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
Drolette Wy and Military W near Elementary School	NH6	Install curb extensions	8 - 56%	$200,000
Drolette Wy and Military W near Elementary School	NH8	Provide school route improvements	Varies	Varies
E 2nd from E S St to Hillcrest	NH19	Realign intersection approaches to reduce or eliminate intersection skew	N/A	Varies
E 2nd from E S St to Hillcrest	NH23	Modify speed limit	8%	Varies
E 2nd from E S St to Hillcrest	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
E 2nd from E S St to Hillcrest	NH35	Implement access management strategies	Varies	Varies
E 5th from H St to I-780	NH23	Modify speed limit	8%	Varies
E 5th from H St to I-780	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
E 5th from H St to I-780	NH35	Implement access management strategies	Varies	Varies
Military at 1st St	NH25	Install traffic-calming	Varies	Varies
Military at 1st St	NH6	Install curb extensions	8 - 56%	$200,000
Military at 1st St	NH7	Install a raised intersection	N/A	Varies
Military at 1st St	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Military at 5th St E	NH6	Install curb extensions	8 - 56%	$200,000
Military at 5th St E	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Military from W 2nd to E 2nd	NH23	Modify speed limit	8%	Varies
Military from W 2nd to E 2nd	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
Military from W 2nd to E 2nd	NH35	Implement access management strategies	Varies	Varies

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
3rd St from East S St to Hill Crest Ave	Widen sidewalks and install new sidewalks where needed	BEN2
5th St at East J St (St. Dominic's School)	Install pedestrian-actuated flashing beacon to aid safe crossing.	BEN3
Columbus Pkwy at Rose Dr	Unprotected turn phases, few gaps for left-turning vehicles.	BEN4
E 2nd St at Military East	Pedestrian crossing safety	BEN5
Hastings Dr at Southampton Rd	Pedestrian crossing safety	BEN7
Military West at W 2nd St	Pedestrian crossing safety	BEN8
Military West at W 7th St	Substandard intersection geometry	BEN9
Southampton Rd / Turner Rd, from James Ct to Panorama Dr	Widen sidewalks and install new sidewalks where needed	BEN10

DIXON

The City of Dixon experienced a total of 487 collisions during the study period, of which 10 resulted in a severe injury (there were zero fatalities). The most predominant crash types are broadside, rear-end, and sideswipe. While relatively low in frequency, pedestrian collisions comprised 50% of the severe injury collisions in Dixon.



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Unsignalized Intersections – Pavement Marking & Pedestrian Crossing						
CA-113 at C Street	NS6	NS18	-	NS5, NS12	$30,000	
CA-113 and E Walnut St				NS5, NS12	$30,000	
CA-113 and W F St				NS5, NS12	$30,000	
CA-113 and W E St				NS5, NS12	$30,000	$240,000
Treatments at Signalized Intersections - Signal Hardware and Signal Timing						
CA-113 at Stratford Ave	S2	S3	-		$ 120,500	$ 120,500
Treatments at Unsignalized Intersections - Install Raised Median and Pedestrian Crossing						
First St & Silveyville Cemetery/County Fair	NS16	NS18	-		$62,000	$ 62,000
Treatments at Unsignalized Ramp Intersections - Install Lighting and Warning/Regulatory Signs						
I-80 and Dixon	NS1	NS5	-		$58,000	
I-80 and Pedrick					$58,000	$ 116,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

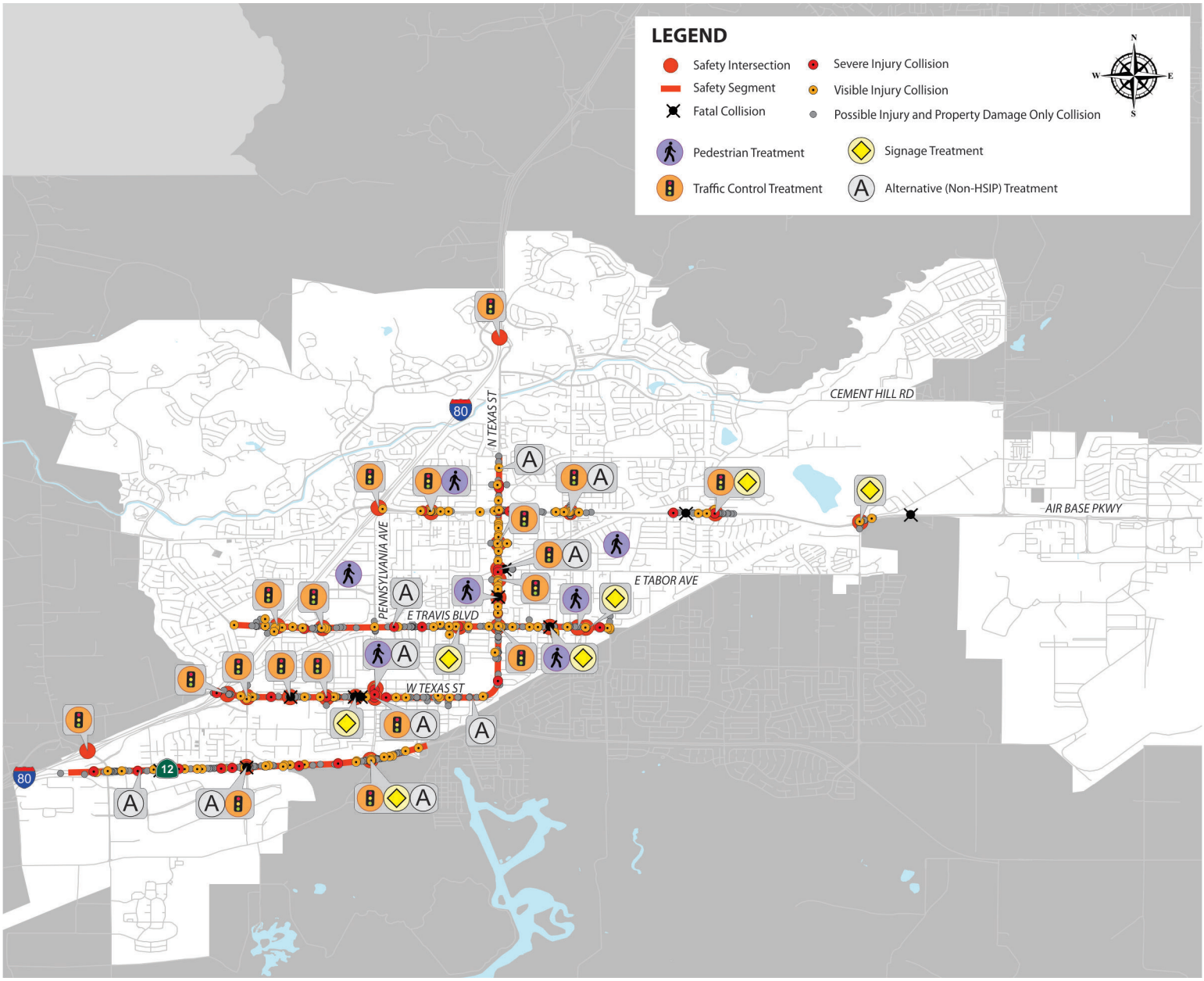
Location	CM ID	Countermeasure Description	CRF	Baseline Cost
CA-113 at 1st St from I-80 to Country Fair Dr	NH23	Modify speed limit	8%	Varies
CA-113 at 1st St from I-80 to Country Fair Dr	NH25	Install traffic-calming	Varies	Varies
CA-113 at 1st St from I-80 to Country Fair Dr	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
CA-113 at 1st St from I-80 to Country Fair Dr	NH35	Implement access management strategies	Varies	Varies
CA-113 at 1st St from I-80 to Country Fair Dr	NH6	Install curb extensions	8 - 56%	$200,000
CA-113 at 1st St from I-80 to Country Fair Dr	NH7	Install a raised intersection	N/A	Varies
CA-113 at 1st St from I-80 to Country Fair Dr	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
CA-113 at C Street	NH41	Install additional signs and markings for railroad crossing	50%	Varies
CA-113 at C Street	NH6	Install curb extensions	8 - 56%	$200,000
I-80 On/Off Ramps at Pitt School Road	NH39	Widen Overpass	N/A	Varies
CA-113 and E A St	S2, S20	Signal Hardware and Ped Crossing	36%	$47,000

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
1st St / CA-113, from A Str to Parkway Blvd	Install signal or lighted crosswalk	DXN2
I-80 On and Off Ramps at CA-113	Install signal and widen overcrossing	DXN3
I-80 On and Off Ramps at Dixon Ave / West A St	Install signal and widen overcrossing	DXN4
Pedrick Rd railroad crossing, north of Vaughn St	Pedrick Road Crossing is recommended for monitoring	DXN6

FAIRFIELD

The City of Fairfield experienced 4,162 collisions during the study period, of which 126 resulted in a fatality or severe injury. The most predominant crash types were rear-end, broadside, sideswipe, and hit-object. Over half of the collisions in Fairfield were attributed to either unsafe speed or improper turning (ie: failure to navigate a curve or turn, commonly due to excessive speed).



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Segments – Variable Speed Warning						
Air Base Parkway near Clay Bank Rd	R30	-	-	-	$100,000	
W Texas St near 1st St				-	$100,000	
Air Base Parkway near Heath Dr				-	$100,000	
CA-12 near Pennsylvania Ave				-	$100,000	
CA-12 near Chadbourne Rd Interchange				-	$100,000	
Air Base Parkway near N Texas St				-	$100,000	
W Texas and Pennsylvania Ave				-	$100,000	
W Texas St near 5th St				-	$100,000	
Air Base Parkway near Walters Rd				-	$100,000	
CA-12 near Jackson St/Webster St				-	$100,000	
W Texas St near Beck Ave				-	$100,000	
W Texas St near Gregory Ln				-	$100,000	
W Texas St near Clay St				-	$100,000	
W Texas St near 2nd St				-	$100,000	
W Texas and Washington St				-	$100,000	$1,500,000
Treatments at Signalized Intersections - Signal Hardware and Signal Timing						
CA-12 at Beck Ave	S2	S3	-		$120,500	
Pennsylvania Ave at CA-12					$120,500	$241,000
Treatments at Signalized Intersections - Signal Hardware and Signal Timing						
N Texas St at Tabor Ave	S2	S3	-		$120,500	
Texas St. & 5th St.					$120,500	
Airbase Pkwy at Dover Ave					$120,500	
Airbase Pkwy. & Clay Bank Rd.					$120,500	
Airbase Pkwy. & Heath Dr.					$120,500	
N Texas St. & E Travis Blvd.					$120,500	
N Texas St. & E Pacific Ave.					$120,500	
Pennsylvania Ave at W Texas St					$120,500	
N Texas St. & Acacia St.					$120,500	
Travis Blvd. & Gateway Blvd.					$120,500	
Texas St. & Gregory Ln.					$120,500	
Texas St. & Beck Ave.					$120,500	$ 1,446,000

HSIP-FUNDING QUALIFIED PROJECTS

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Unsignalized Intersections - Install Warning/Regulatory Signs and Advance Beacons						
Texas St. & 1st St.	NS5	NS8	-		$200,000	
E Travis Blvd. & San BruN St.					$200,000	
Airbase Pkwy. & Walters Rd.					$200,000	
Travis Blvd. & Washington St.					$200,000	
E Travis Blvd. & Phoenix Dr.					$200,000	$ 1,000,000
Treatments at Unsignalized Intersections - Install Raised Median and Pedestrian Crossing						
N Texas St at Oak St	NS16	NS18	-		$62,000	
E Travis Blvd. & San Brun St.					$62,000	
Pennsylvania Ave at Empire St					$62,000	
Airbase Pkwy. & Heath Dr.					$62,000	
E Travis Blvd. & Coolidge St.					$62,000	
E Travis Blvd. & Flamingo Dr.					$62,000	$372,000
Treatments at Signalized Ramp Intersections - Signal Hardware						
I-80 and Pittman	S2	-	-		$42,000	
I-80 and Travis					$42,000	
I-80 and Air Base Pkwy					$42,000	
I-80 and Texas					$42,000	
I-80 and Manuel Campos					$42,000	
I-80 and Waterman					$42,000	
I-80 and Chadbourne/Suisun/Abernathy					$42,000	
I-80 and Lopes					$42,000	$336,000
Treatments at Unsignalized Ramp Intersections - Install Lighting and Warning/Regulatory Signs						
I-80 and Suisun Valley	NS1	NS5	-		$58,000	$58,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Airbase Pkwy at Dover Ave	NH25	Install traffic-calming	Varies	Varies
CA-12 at Beck Ave	NH24	Install overpasses/underpasses	24 - 67%	Varies
CA-12 at Beck Ave	NH25	Install traffic-calming	Varies	Varies
N Texas St at Oak St	NH25	Install traffic-calming	Varies	Varies
N Texas St at Tabor Ave	NH25	Install traffic-calming	Varies	Varies
N Texas St from W Texas to Hawthorn Dr	NH11	Provide longer left-turn lanes at intersections	31 - 44%	$200,000
N Texas St from W Texas to Hawthorn Dr	NH23	Modify speed limit	8%	Varies
N Texas St from W Texas to Hawthorn Dr	NH25	Install traffic-calming	Varies	Varies
N Texas St from W Texas to Hawthorn Dr	NH35	Implement access management strategies	Varies	Varies
N Texas St from W Texas to Hawthorn Dr	NH6	Install curb extensions	8 - 56%	$200,000
N Texas St from W Texas to Hawthorn Dr	NH8	Provide school route improvements	Varies	Varies
N Texas St from W Texas to Hawthorn Dr	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Pennsylvania Ave at CA-12	NH24	Install overpasses/underpasses	24 - 67%	Varies
Pennsylvania Ave at CA-12	NH25	Install traffic-calming	Varies	Varies
Pennsylvania Ave at CA-12	NH29	Install crash cushions at fixed roadside features	5 - 50%	$5,000
Pennsylvania Ave at CA-12	NH43	Implement education and/or enforcement campaigns (DUI, distracted driving, etc.)	N/A	Varies
Pennsylvania Ave at Empire St	NH25	Install traffic-calming	Varies	Varies
Pennsylvania Ave at Empire St	NH6	Install curb extensions	8 - 56%	$200,000
Pennsylvania Ave at Empire St	NH8	Provide school route improvements	Varies	Varies
Pennsylvania Ave at W Texas St	NH25	Install traffic-calming	Varies	Varies
Pennsylvania Ave at W Texas St	NH26	Install roadway signage for bicyclists	N/A	Varies
Pennsylvania Ave at W Texas St	NH42	Install bicycle facilities through intersection	0 - 53%	$10,000
Travis Blvd from Oliver Rd to Sunset Ave	NH11	Provide longer left-turn lanes at intersections	31 - 44%	$200,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Travis Blvd from Oliver Rd to Sunset Ave	NH25	Install traffic-calming	Varies	Varies
Travis Blvd from Oliver Rd to Sunset Ave	NH35	Implement access management strategies	Varies	Varies
Travis Blvd from Oliver Rd to Sunset Ave	NH4	Reduce curb radius at intersections	N/A	Varies
Travis Blvd from Oliver Rd to Sunset Ave	NH6	Install curb extensions	8 - 56%	$200,000
Travis Blvd from Oliver Rd to Sunset Ave	NH8	Provide school route improvements	Varies	Varies
Travis Blvd from Oliver Rd to Sunset Ave	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
W Texas St from I-80 to N Texas	NH11	Provide longer left-turn lanes at intersections	31 - 44%	$200,000
W Texas St from I-80 to N Texas	NH20	Eliminate parking that restricts sight distance	20 - 48%	Varies
W Texas St from I-80 to N Texas	NH25	Install traffic-calming	Varies	Varies
W Texas St from I-80 to N Texas	NH35	Implement access management strategies	Varies	Varies
W Texas St from I-80 to N Texas	NH6	Install curb extensions	8 - 56%	$200,000

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
CA-12, from Pennsylvania Avenue to I-80	Increase capacity. Improve signal timing. Portions of roadway improvements are included in the I-80/I-680/CA-12 project managed by STA	FRFD3
East Tabor Avenue railroad track crossing, west of Railroad Avenue	Sidewalks be extended on the north side of East Tabor Avenue to the crossing to allow students to safely cross the at-grade crossing, and that protected bicycle facilities be implemented	FRFD4
North Texas Street at Travis Boulevard	Improved channelization	FRFD5
North Texas Street, from Alaska Avenue to East Pacific Avenue	Signal timing improvements. Additional signal face at all signalized intersections if pole can handle the additional load	FRFD6
Oliver Road at Rockville Road / West Texas Street	Install two-way left-turn lane	FRFD7
Travis Boulevard, from Oliver Road to Sunset Avenue	Improved signal timing	FRFD8

RIO VISTA

The City of Rio Vista experienced a total of 159 collisions during the study period, of which six resulted in a fatality or severe injury. The most predominant crash types in Rio Vista are rear-end, broadside, and sideswipe. Unsafe speed and improper turning contributed to over 50% of the collisions in Rio Vista, while the most severe collisions were attributed to unsafe lane changes and disregarding traffic signals or signs.

NON HSIP-FUNDING-QUALIFIED PROJECTS

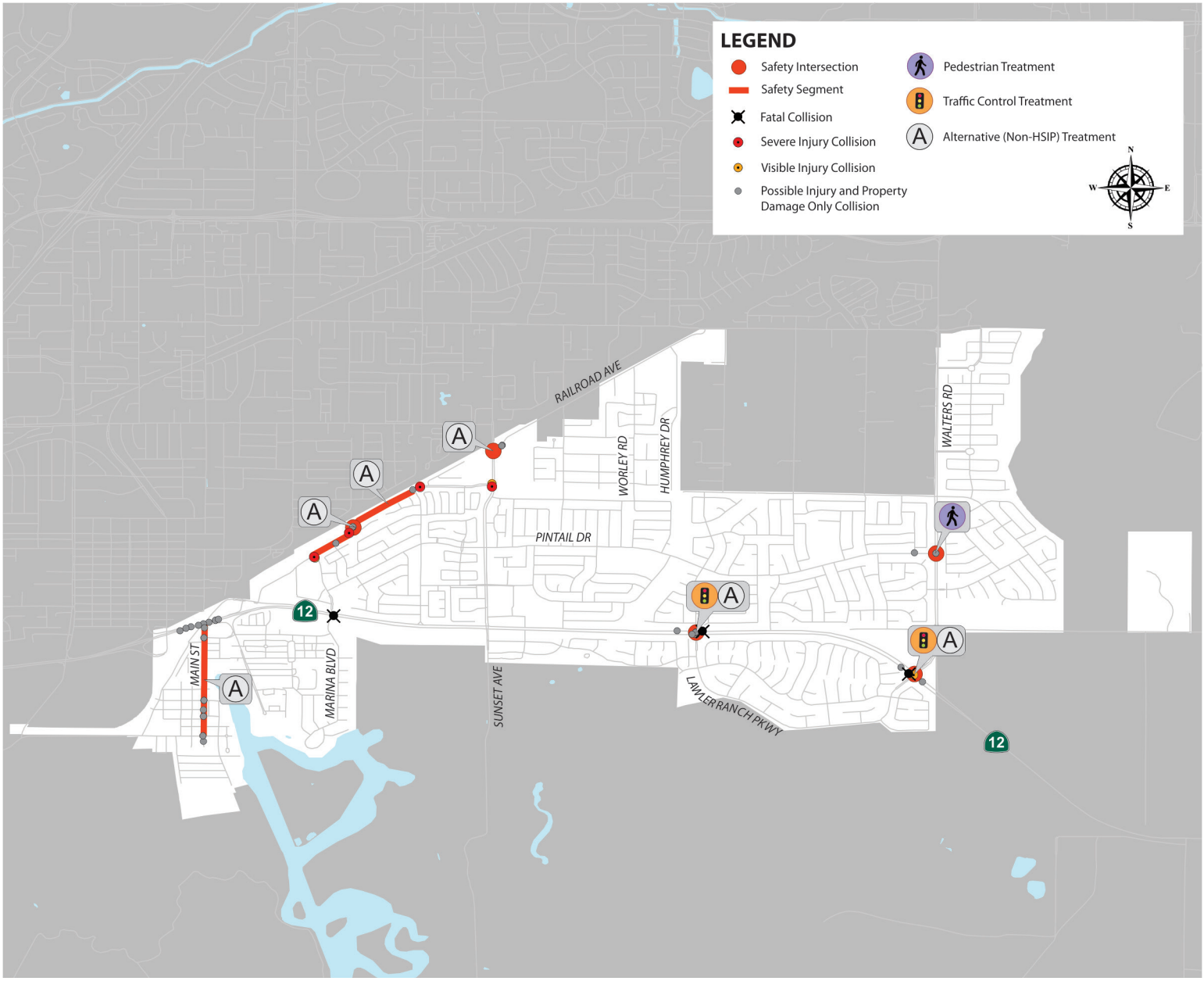
Location	CM ID	Countermeasure Description	CRF	Baseline Cost
CA-12 at Amerada Rd/Church Rd	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
CA-12 at Amerada Rd/Church Rd	NH23	Modify speed limit	8%	Varies
CA-12 at Amerada Rd/Church Rd	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
CA-12 at Amerada Rd/Church Rd	NH38	Install through-route activated warning system	20 - 30%	$70,000
CA-12 from Summerset Rd to Church Rd	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
CA-12 from Summerset Rd to Church Rd	NH23	Modify speed limit	8%	Varies
CA-12 from Summerset Rd to Church Rd	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
CA-12 at Church Rd	Realign roadway	RVS1
CA-12 at Drouin Dr	Redesign roadway	RVS2
CA-12 at Virginia Dr	Redesign intersection, part of CT CA-12 project	RVS3
Montezuma Hills Rd from Burgundy Wy to Marina Wy; 2nd St/ Beach Dr /Montezuma Hills Rd intersection (Riverview Middle School)	Design a safe route connecting school and neighborhood directly west of school.	RVS4

SUISUN CITY

The City of Suisun City experienced 465 collisions during the study period, of which 12 resulted in a fatality or severe injury. The most predominant crash types were rear-end, broadside, and sideswipe. Over 60% of the collisions in Suisun City were attributed to either unsafe speed or improper turning, while the most severe collisions were attributed to driver impairment and right-of-way violations.



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Signalized Intersections - Signal Hardware and Signal Timing						
CA-12 at Walters Rd	S2	S3	-		$120,500	
CA-12 at Emperor Dr/Lawler Ranch Pkwy					$120,500	$241,000
Treatments at Unsignalized Intersections - Install Raised Median and Pedestrian Crossing						
Pintail Dr. & Emperor Dr.	NS16	NS18	-		$62,000	$62,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

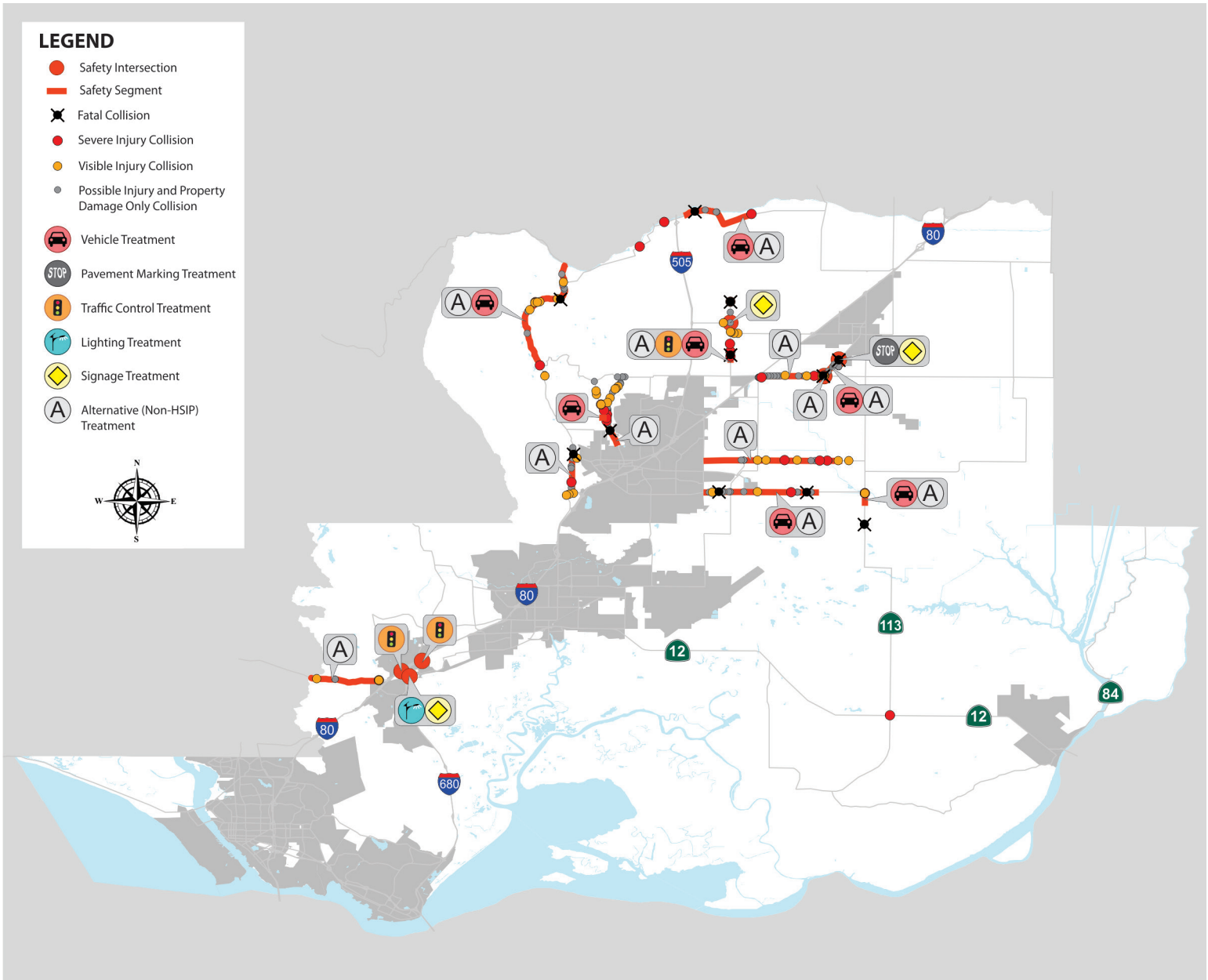
Location	CM ID	Countermeasure Description	CRF	Baseline Cost
CA-12 at Emperor Dr/Lawler Ranch Pkwy	NH15	Provide longer right-turn lanes at intersections	14 - 27%	$200,000
CA-12 at Emperor Dr/Lawler Ranch Pkwy	NH17	Provide right-turn acceleration lanes at intersections	10 - 75 %	$700,000
CA-12 at Emperor Dr/Lawler Ranch Pkwy	NH23	Modify speed limit	8%	Varies
CA-12 at Emperor Dr/Lawler Ranch Pkwy	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
CA-12 from Jackson St/Webster St Ramps to Lawler Ranch Pkwy/Walters Rd	NH17	Provide right-turn acceleration lanes at intersections	10 - 75 %	$700,000
Main St from CA-12 to Cordelia St	NH7	Install a raised intersection	N/A	Varies
Railroad Ave at Birchwood Ct	NH44	Adjust lane geometry (shift lane drop NW of intersection)	N/A	Varies
Railroad Ave from Marina Blvd to Village Dr	NH1	Install profiled thermoplastic strips for centerlines	13 - 60%	$10,000
Sunset Ave at Railroad Ave (southbound)	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
Buena Vista Avenue /Pintail Drive, from Marina Boulevard to Walters Road	Traffic calming, potentially including pedestrian countdown signals and updating signals	SUIS1

UNINCORPORATED COUNTY

The unincorporated areas of Solano County experienced 1,289 collisions during the study period, of which 90 resulted in a fatality or severe injury. Over 50% of the collisions in unincorporated Solano County were attributed to either unsafe speed or improper turning, and 13% were attributed to impaired driving. The most severe collisions were attributed to driver impairment, pedestrian violations, and vehicles on the wrong side of the roadway.



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments Along Segments – Widen Shoulders (Paved)						
Fry Rd between Leisure Town Rd and Meridian Rd	R16	-	-	-	$276,000	
Solar Hills Dr between Gibson Canyon Rd and Hillsview Dr				-	$27,600	
Porter Rd between Midway Rd and Pitt School Rd				-	$184,000	
CA-113 between Fry Rd and Maine Prairie Rd				-	$184,000	$1,039,600
Treatments Along Segments – Pave Existing Shoulder						
Fry Rd between Dally Rd and Clark Rd	R18	-	-	-	$92,000	
Meridian Rd between Bryant Rd and Elizabeth Rd				-	$220,800	
Putah Creek Rd between Boyce Rd and McNeill Ln				-	$938,400	$1,453,600
Treatments at Unsignalized Intersection – Install Additional Signs, Pavement Markings & Flashing Warning						
Porter Rd and Pitt School Rd	NS5, NS6, NS7	NS8			$26,000	$26,000
Treatments at Unsignalized Intersections - Install Warning/Regulatory Signs and Advance Beacons						
Meridian Rd at Sweeney Rd	NS5	NS8	-		$200,000	
Pitt School Rd. & Porter Rd. (Lincoln HWY)					$200,000	$ 400,000
Convert to Mini-Roundabout						
Meridian Rd and Elizabeth Rd	NS4	-	-	-	$500,000	$500,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

Location	CM ID	Countermeasure Description	CRF	Baseline Cost
CA-12 from County Line to I-80	NH23	Modify speed limit	8%	Varies
CA-12 from County Line to I-80	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
CA-12 from County Line to I-80	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
CA-12 from County Line to I-80	NH38	Install through-route activated warning system	36 - 62%	$70,000
CA-13 from Midway Rd to CA-12	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
CA-13 from Midway Rd to CA-12	NH23	Modify speed limit	8%	Varies
Fry Rd from Leisure Town Rd to CA-113	NH23	Modify speed limit	8%	Varies
Fry Rd from Leisure Town Rd to CA-113	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
Fry Rd from Leisure Town Rd to CA-113	NH38	Install through-route activated warning system	36 - 62%	$70,000
Gibson Canyon Rd from Fruitvale Rd to Cantelow Rd	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

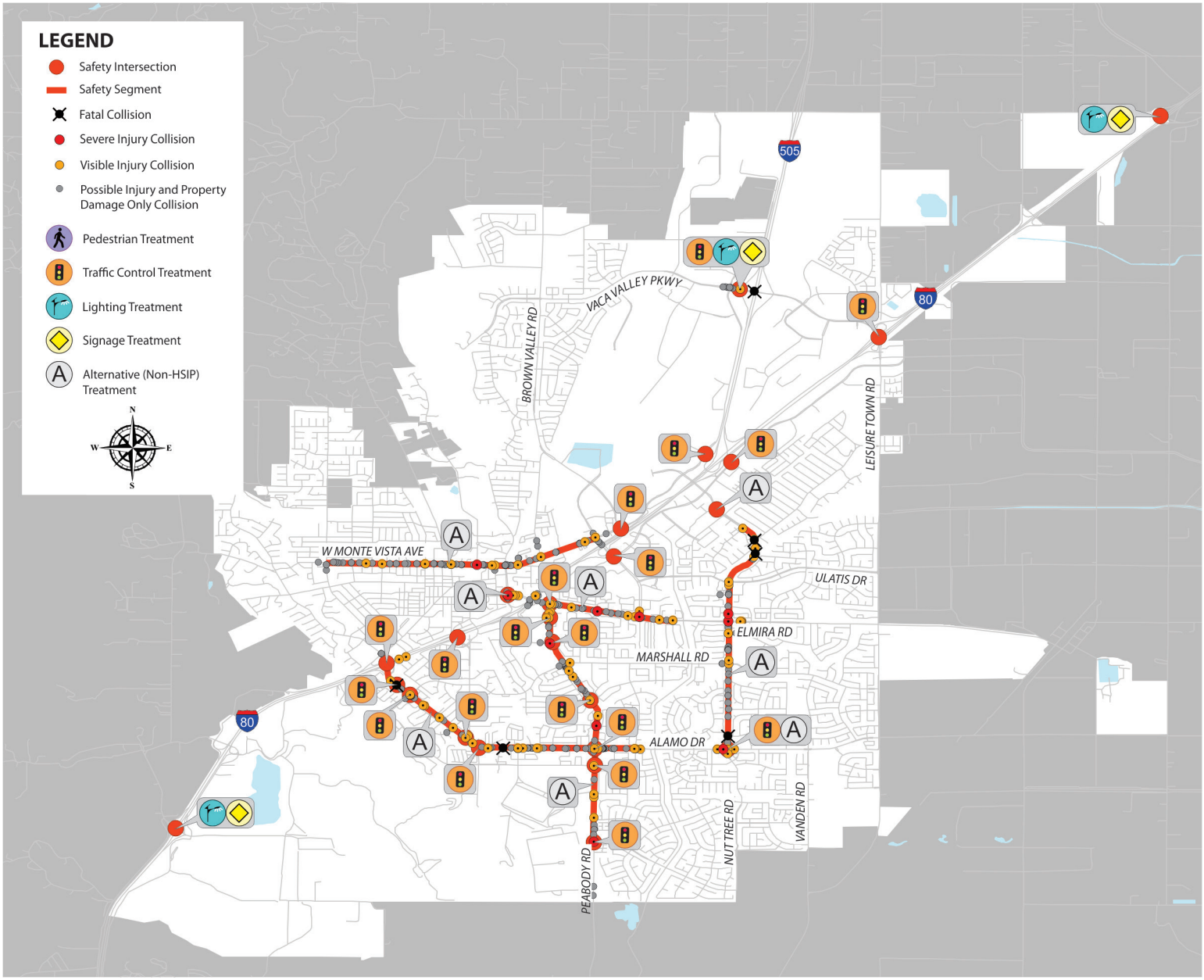
Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Gibson Canyon Rd from Fruitvale Rd to Cantelow Rd	NH23	Modify speed limit	8%	Varies
Hawkins Rd from Leisure Town Rd to CA-113	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
Hawkins Rd from Leisure Town Rd to CA-113	NH23	Modify speed limit	8%	Varies
Hawkins Rd from Leisure Town Rd to CA-113	NH28	Implement automated speed enforcement cameras	16 - 34%	$70,000
Hawkins Rd from Leisure Town Rd to CA-113	NH38	Install through-route activated warning system	36 - 62%	$70,000
Meridian Rd from Sweeney Rd to I-80	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
Meridian Rd from Sweeney Rd to I-80	NH23	Modify speed limit	8%	Varies
Midway Rd at Porter Rd	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
Midway Rd from I-80 to Rt113	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
Midway Rd from I-80 to Rt113	NH23	Modify speed limit	8%	Varies
Pleasant Valley Rd from CA-128 to Cherry Glenn Rd	NH18	Provide full-width paved shoulders in intersection areas	15 - 22 %	$50,000
Pleasant Valley Rd from CA-128 to Cherry Glenn Rd	NH23	Modify speed limit	8%	Varies
Porter Rd from Midway Rd to S Almond St	NH23	Modify speed limit	8%	Varies
Putah Creek Road from Pleasant Valley Rd to Stevenson Bridge Dr	NH23	Modify speed limit	8%	Varies

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
Putah Creek Rd between Homes Ln and Wintu Way	Pave existing shoulder	CO6
Canon Rd between Vanden Rd and Gate Rd	Widen existing shoulder	Recent county interest

VACAVILLE

The City of Vacaville experienced 2,746 collisions during the study period, of which 56 resulted in a fatality or severe injury. The most predominant crash types were rear-end, broadside, sideswipe, and hit-object. The primary contributing factors to collisions involved unsafe speed, vehicle and pedestrian right-of-way violations, and driver impairment.



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Signalized Intersections – Signal Timing and Advanced Dilemma-Zone Detection						
Alamo and Butcher	S3	S4	-	-	$128,500	
Peabody and Cliffside				-	$128,500	
Alamo and Marshall				-	$128,500	
Peabody and Hume/Berryessa				-	$128,500	
Peabody and California				-	$128,500	
Peabody and Alamo				-	$128,500	
Peabody and Elmira				-	$128,500	
Peabody and Beelard				-	$128,500	
Peabody and Foxboro				-	$128,500	
Alamo and Alamo Ln				-	$128,500	
Alamo and Davis				-	$128,500	$1,413,500
Treatments at Signalized Intersections - Signal Hardware and Signal Timing						
Alamo Dr. & Butcher Rd.	S2	S3	-		$ 120,500	
Alamo Dr at Nut Tree Rd					$ 120,500	$ 241,000
Treatments at Signalized Ramp Intersections - Signal Hardware						
I-505 and Vaca Valley/Monte Vista	S2	-	-		$42,000	
I-80 and Browns Valley					$42,000	
I-80 and Leisure Town					$42,000	
I-80 and Alamo					$42,000	
I-80 and Davis					$42,000	
I-80 and Allison					$42,000	
I-80 and Mason/Depot/Elmira					$42,000	
I-80 and Monte Vista					$42,000	
I-80 and Orange/Lawrence					$42,000	$378,000
Treatments at Unsignalized Ramp Intersections - Install Lighting and Warning/Regulatory Signs						
I-505 and Vaca Valley	NS1	NS5	-		$58,000	
I-80 and Lagoon Valley					$58,000	
I-80 and Midway					$58,000	$174,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Alamo Dr at Nut Tree Rd	NH23	Modify speed limit	8%	Varies

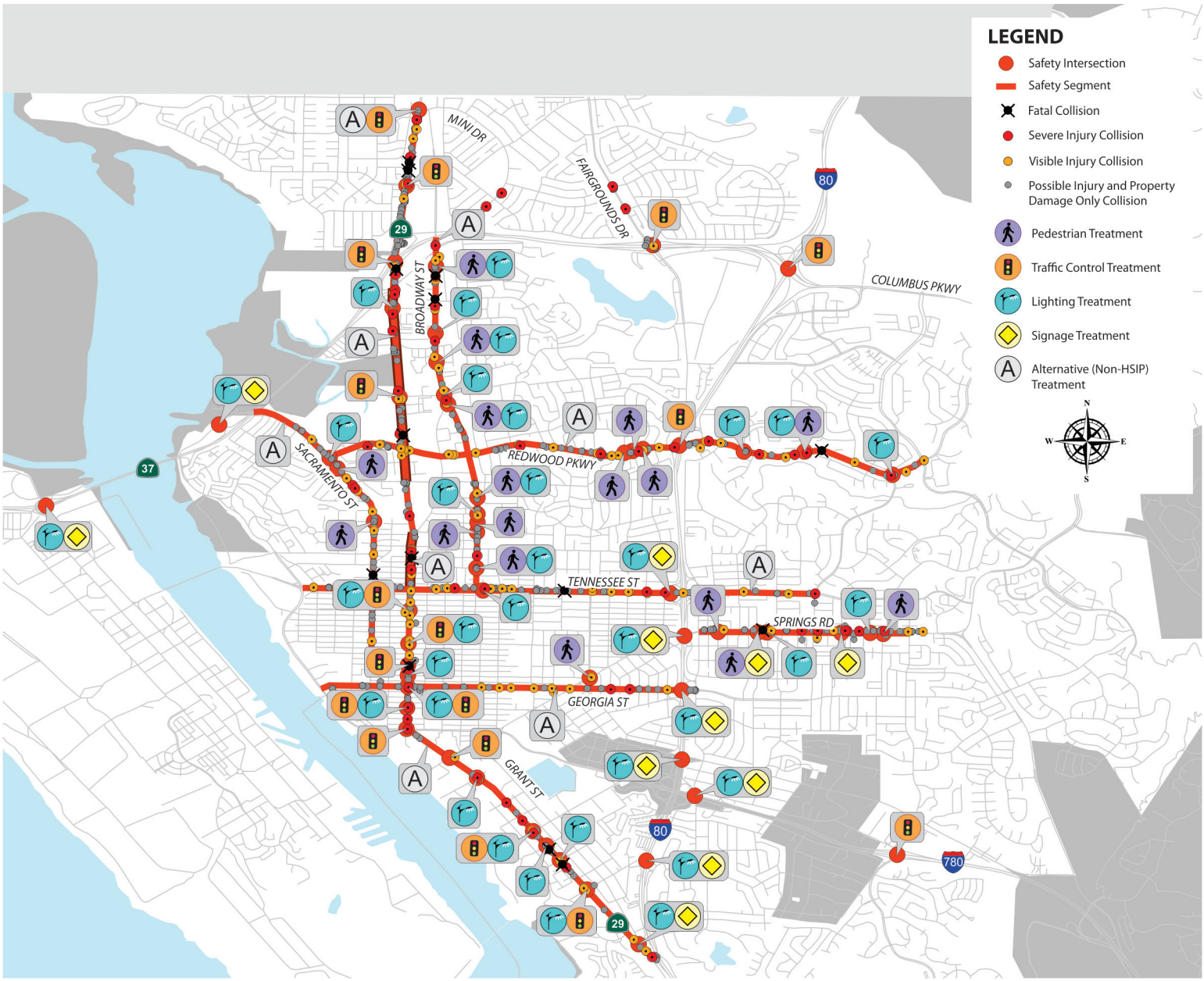
Alamo Dr from I-80 to Wildwood Dr	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Alamo Dr from Mariposa Ave to Tulare Dr	NH11	Provide longer left-turn lanes at intersections	31 - 44%	$200,000
Alamo Dr from Mariposa Ave to Tulare Dr	NH15	Provide longer right-turn lanes at intersections	14 - 27%	$200,000
Alamo Dr from Mariposa Ave to Tulare Dr	NH35	Implement access management strategies	Varies	Varies
Elmira Rd from Peabody Rd to Beelard Dr	NH11	Provide longer left-turn lanes at intersections	31 - 44%	$200,000
Mason St at Depot St/WB I-80 Ramp	NH23	Modify speed limit	8%	Varies
Monte Vista Ave from Orchard Ave to Allison Dr	NH2	Install or upgrade pedestrian signals	15 - 69%	$200,000
Monte Vista Ave from Orchard Ave to Allison Dr	NH8	Provide school route improvements	Varies	Varies
Nut Tree Rd at factory store access	NH40	Consider changes to internal site circulation	N/A	N/A
Nut Tree Rd from Arcadia Dr to Alamo Dr	NH23	Modify speed limit	8%	Varies
Peabody Rd at Marshall Rd	NH23	Modify speed limit	8%	Varies
Peabody Rd from Elmira Rd to Foxboro Pkwy	NH15	Provide longer right-turn lanes at intersections	14 - 27%	$200,000
Peabody Rd from Elmira Rd to Foxboro Pkwy	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
Crocker Drive / East Monte Vista at Vaca Valley Parkway	Install roundabout	VAC2
I-505 Southbound Off- Ramps at Vaca Valley	Install roundabout	VAC3

VALLEJO

The City of Vallejo experienced 4,250 collisions during the study period, of which 170 resulted in a fatality or severe injury. The most predominant crash types were rear-end, broadside, and hit-object. While relatively low in frequency, bicycle and pedestrian collisions comprised nearly 40% of the fatal and severe collisions in Vallejo.



HSIP-FUNDING QUALIFIED PROJECTS

State Route | Local Route

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Pedestrian Treatments at Unsignalized Intersections – Install HAWK						
Broadway and Hogan	NS19	-	-	NS18	$200,000	
Springs and Tregaskis				-	$200,000	
Broadway and Illinois				NS18	$200,000	
Broadway and Sala				NS18	$200,000	
Springs and Heartwood				NS18	$200,000	
Broadway and Couch				NS18	$200,000	
Springs and Lassen/Hilton				-	$200,000	
Broadway and Hampshire				-	$200,000	
Broadway and Oregon				-	$200,000	
Broadway and Delaware				-	$200,000	$2,000,000
Lighting Treatments at Unsignalized Intersections						
Broadway and Hogan	NS1	-	-	-	$8,000	
Broadway and Sereno				-	$8,000	
CA-29 and Georgia				-	$8,000	
CA-29 and Florida				-	$8,000	
CA-29 and Ryder				-	$8,000	
CA-29 and Ifland Way				-	$8,000	
CA-29 and Louisiana				-	$8,000	
4th and Magazine				-	$8,000	
Broadway and Couch				-	$8,000	
Broadway and Michigan				-	$8,000	
CA-29 and Maine				-	$8,000	
CA-29 and Virginia				-	$8,000	
4th and Lemon				-	$8,000	
Broadway and Illinois				-	$8,000	
4th and Winchester				-	$8,000	
Redwood and Cadloni				-	$8,000	
Redwood and Sacramento				-	$8,000	
Broadway and Oregon				-	$8,000	
4th and Cherry				-	$8,000	

HSIP-FUNDING QUALIFIED PROJECTS

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Redwood and Foothill	NS1	-	-	-	$8,000	
Redwood and Oakwood				-	$8,000	
Tennessee and Alameda				-	$8,000	
Broadway and Sala				-	$8,000	
Springs and Halabuk				-	$8,000	
Springs and Parkwood				-	$8,000	
Broadway and Winters				-	$8,000	$208,000
Mini-Roundabout at Signalized Intersections						
CA-29/Sonoma Ave at Capitol St	S4	-	-	-	$500,000	$500,000
Treatments at Signalized Intersections - Signal Hardware and Signal Timing						
Sonoma Blvd. & Solano Ave.	S2	S3	-		$120,500	
Sonoma Blvd. & Meadows Dr					$120,500	
Sonoma Blvd. & Georgia St.					$120,500	
CA-29/Sonoma Ave at Mini Dr					$120,500	
Sonoma Blvd. & Sereno Dr.					$120,500	
Sonoma Blvd. & Maine St.					$120,500	
Sonoma Blvd. & Curtola Pkwy/Coral Rd					$120,500	
Sonoma Blvd. & Lemon St.					$120,500	
Sonoma Blvd. & Louisiana St.					$120,500	
Sonoma Blvd. & Florida St.					$120,500	
Sonoma Blvd. & Magazine St.					$120,500	$ 1,325,500
Treatments at Unsignalized Intersections - Install Warning/Regulatory Signs and Advance Beacons						
Tregaskis Ave. & Springs Rd.	NS5	NS8	-		$200,000	
Lain Dr. & Springs Rd.					$200,000	$400,000
Treatments at Unsignalized Intersections - Install Raised Median and Pedestrian Crossing						
Foothill Dr. & Redwood Pkwy.	NS16	NS18	-		$62,000	
Valle Vista Ave. & Redwood St.					$62,000	
Fairview Ave. & Redwood St.					$62,000	
Howard Ave. & Redwood St.					$62,000	
Sacramento St. & Denio St.					$62,000	
Sacramento St. & Parrott St.					$62,000	
Solano Ave at Tuolumne St/Virginia St					$62,000	$434,000

HSIP-FUNDING QUALIFIED PROJECTS

Location	CM 1	CM 2	CM 3	Unused & Desired CM	Per Location	All Locations
Treatments at Signalized Ramp Intersections - Signal Hardware						
I-80 and Redwood/Fairgrounds	S2	-	-		$42,000	
I-29 and I-37					$42,000	
I-37 and Fairgrounds					$42,000	
I-780 and Glen Cove (Pkwy&Rd)					$42,000	
I-80 and Columbus					$42,000	
I-80 and Solano Blvd/29/Maritime					$42,000	$252,000
Treatments at Unsignalized Ramp Intersections - Install Lighting and Warning/Regulatory Signs						
I-80 and Benicia	NS1	NS5	-		$58,000	
I-80 and Magazine					$58,000	
I-80 and Tennessee					$58,000	
I-80 and Georgia					$58,000	
I-37 and Walnut					$58,000	
I-37 and Wilson					$58,000	
I-80 and Spring					$58,000	
I-780 and Laurel					$58,000	
I-80 and American Canyon					$58,000	$522,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Broadway St from CA-37 to Tennessee St	NH35	Implement access management strategies	Varies	Varies
CA-29/Sonoma Ave at Mini Dr	NH43	Implement education and/or enforcement campaigns (DUI, distracted driving, etc.)	None1	None1
CA-29/Sonoma Ave from Couch St to Tennessee St	NH25	Install traffic-calming	Varies	Varies
CA-29/Sonoma Ave from Couch St to Tennessee St	NH6	Install curb extensions	8 - 56%	$200,000
CA-29/Sonoma Ave from Lewis Brown Dr to Valle Vista Ave	NH35	Implement access management strategies	Varies	Varies
CA-29/Sonoma Ave from Lewis Brown Dr to Valle Vista Ave	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
CA-29/Sonoma Ave from Mini Dr to I-80	NH19	Realign intersection approaches to reduce or eliminate intersection skew	N/A	Varies
CA-29/Sonoma Ave from Mini Dr to I-80	NH35	Implement access management strategies	Varies	Varies
CA-29/Sonoma Ave from Mini Dr to I-80	NH35	Implement access management strategies	Varies	Varies
CA-29/Sonoma Ave from Mini Dr to I-80	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000

NON HSIP-FUNDING-QUALIFIED PROJECTS

Location	CM ID	Countermeasure Description	CRF	Baseline Cost
Georgia St from Mare Island Wy to Miller Ave	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Redwood Pkwy from Sacramento St to Ascot Pkwy	NH19	Realign intersection approaches to reduce or eliminate intersection skew	N/A	Varies
Redwood Pkwy from Sacramento St to Ascot Pkwy	NH35	Implement access management strategies	Varies	Varies
Redwood Pkwy from Sacramento St to Ascot Pkwy	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Sacramento St from CA-37 to Capitol St	NH43	Implement education and/or enforcement campaigns (DUI, distracted driving, etc.)	None1	None1
Springs Rd from Miller Ave to Rollingwood Dr	NH25	Install traffic-calming	Varies	Varies
Springs Rd from Miller Ave to Rollingwood Dr	NH6	Install curb extensions	8 - 56%	$200,000
Springs Rd from Miller Ave to Rollingwood Dr	NH8	Provide school route improvements	Varies	Varies
Tennessee St from Mare Island Wy to Oakwood Ave	NH9	Restrict or eliminate turning maneuvers (Including right turns on red)	51%	$75,000
Broadway and Sereno	S2, S3, S10	Signal improvements and red-light cameras	39%	$19,050
CA-29 and Georgia				$19,050
CA-29 and Meadows				$19,050
CA-29 and Sereno				$19,050
Georgia and Steffan/Miller				$19,050
Redwood and Fairgrounds				$19,050
Redwood and Tuolumne				$19,050

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
Broadway Street at Valle Vista Avenue	Install ADA-compliant curb ramps and new sidewalks	VAL2
Del Mar Avenue at Las Palmas Avenue (Copper Elementary School)	Install traffic bulb-outs at the two listed intersections; widen sidewalk	VAL7, VAL8
Fairgrounds Drive from CA-37 to City Limits	Improve lighting	VAL9
Fifth Street from Lemon Street to Magazine Street	Install Traffic Circle	VAL10
Gateway Drive, from Fairgrounds Drive to Safe Street	Install Traffic Circle	VAL11
Sacramento St from CA-37 to Capitol St	Upgrade poles and luminaries; space installations per current standards (CA-37 to Tennessee Street) Install road diet (CA-37 to Capitol Street): repave roadway.	VAL14

2016 SOLANO TRAVEL SAFETY PLAN PROJECTS

Location	Improvement Description	2016 Plan Project No.
Solano Avenue at Tuolumne/Virginia Streets	Install road diet or signalized intersection	VAL15
Tennessee St from Columbus Parkway to Oakwood Drive	Install road diet; repave roadway	VAL16
Valle Vista Avenue from Couch Street and CA-29/ Sonoma Boulevard	Relocate railroad crossing arms to enable construction of sidewalks on both sides of the street	VAL17
Citywide (intersections on Principal Arterials & Major Collector Streets)	Limited visibility due to poor lighting	VAL18

A COUNTERMEASURES TOOLBOX

SIGNALIZED INTERSECTIONS

S1. Add intersection lighting.

Applied to signalized intersections that have a disproportionate number of night-time crashes and do not currently provide lighting at the intersection or at its approaches. This countermeasure (CM) only applies to "night" crashes (all types) occurring within limits of the proposed roadway lighting 'engineered' area.

Benefit-Cost

- Implementation of this treatment reduces crashes by 40%.
- 20 years of expected life.
- Estimated $75,000.
- The provision of lighting involves both a fixed cost for lighting installation and an ongoing maintenance and power cost which results in a moderate to high cost.
- Eligible for 100% federal funding.

EXISTING CONDITION

S1 IMPLEMENTATION

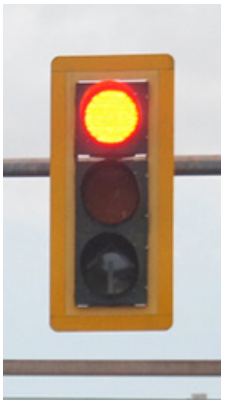
sources: CA-Local Roadway Safety Manual

S2. Improve signal hardware, may include: lenses, back-plates, mounting, size and number of heads.

Applicable at signalized intersections with a high frequency of right-angle and rear-end crashes because drivers are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. This CM does not apply to improvements like "battery backup systems", which do not provide better intersection/signal visibility or help drivers negotiate the intersection (unless applying past crashes that occurred when the signal lost power).

EXISTING CONDITIONS

S2 IMPLEMENTATION



Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $40,000 per intersection.
- Cost variation based on size/number of signal heads.
- Eligible for 100% federal funding.

Example Location(s)

- Military E and E 5th Street, Benicia
- Broadway St and Sereno Dr, Vallejo

sources: CA-Local Roadway Safety Manual

S3. Improve signal timing: coordination, phasing, clearance intervals.

Effective at locations that have a crash history at multiple signalized intersections. Signalization improvements may include adding phases, lengthening clearance intervals, eliminating or restricting higher-risk movements, and coordinating signals at multiple locations. This treatment addresses all types of crashes that occur on the approaches / influence area of the new signal timing. This treatment does not apply to projects that only 'study' the signal network and do not make physical timing changes, including corridor operational studies and improvements to Traffic Operation Centers. For projects coordination signals along a corridor, the crashes related to side-street movements should not be applied.

EXISTING CONDITIONS

S3 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $1,000 per intersection.
- Cost variation based on number of signal heads and number of movements.
- Considering that it will improve the signal operation rather than merely the safety, this countermeasure is only eligible for 50% federal funding.

Example Location(s)

- Alamo Drive and Butcher Road, Vacaville
- Redwood Street and Fairgrounds Drive, Vallejo

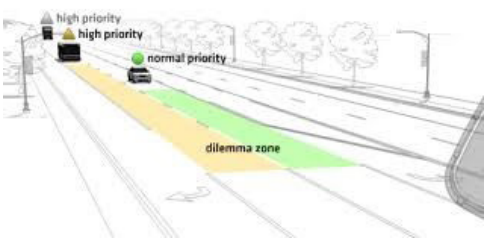
sources: CA-Local Roadway Safety Manual

S4. Provide Advance Dilemma-Zone Detection for high speed approaches.

Suitable in more rural/remote areas that have a high frequency of right-angle and rear-end crashes. The Advanced Dilemma-Zone Detection system enhances safety at signalized intersections by modifying traffic control signal timing to reduce the number of drivers that may have difficulty deciding whether to stop or proceed during a yellow phase. This CM only applies to crashes occurring on the approaches / influence area of the new detection and signal timing.

EXISTING CONDITIONS

S4 IMPLEMENTATION



Benefit-Cost

- Implementation of this treatment reduced crashes by 40%.
- 10 years of expected life.
- Estimated $50,000 for two approaches.
- Additional modification to the traffic signal controller may be necessary.
- Eligible for 100% federal funding.

Example Location(s)

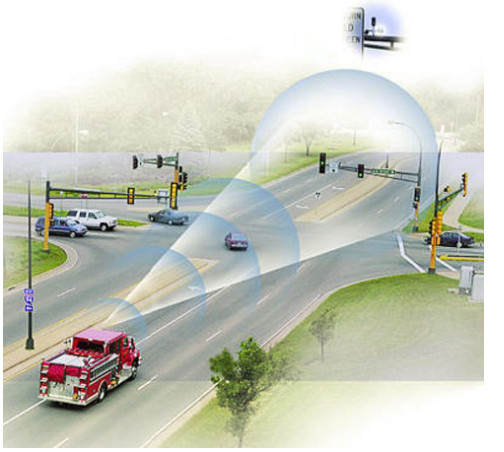
- Intersections along Peabody Road, Vacaville

sources: CA-Local Roadway Safety Manual

S5. Install emergency vehicle pre-emption systems.

Corridors that have a history of crashes involving emergency response vehicles. Sentence about when/where to use. The target of this strategy is signalized intersections where normal traffic operations impede emergency vehicles and where traffic conditions create a potential for conflicts between emergency and nonemergency vehicles. This CM addresses emergency vehicle related crashes only.

S5 IMPLEMENTATION



Benefit-Cost

- Implementation of this treatment reduces crashes by 70%.
- 10 years of expected life.
- Life cost Estimated $10,000 per installation.
- Costs for installation of a signal preemption system will vary from medium to high, based upon the number of signalized intersections at which preemption will be installed and the number of emergency vehicles to be outfitted with the technology.
- Eligible for 100% federal funding.

sources: CA-Local Roadway Safety Manual

S6. Provide Protected left turn phase (left turn lane already exits).

Used at signalized intersections (with existing left turns pockets) that currently have a permissive left-turn or no left-turn protection that have a high frequency of angle crashes involving left turning, opposing through vehicles, and non-motorized road users.

A properly timed protected left-turn phase can also help reduce rear-end, broadside, and sideswipe crashes between left-turning vehicles and the through vehicles as well as vehicles behind them. This CM only applies to crashes occurring on the approaches / influence area of the new left turn phases. This CM does NOT apply to converting a single-left into double-left turn (unless the single left is unprotected and the proposed double left will be protected).

EXISTING CONDITIONS

S6 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 20 year of expected life.
- Estimated $12,000 per intersection.
- If the existing traffic signal only requires a minor modification to allow for a protected left-turn phase, then the cost would also be low (installation is short because no actual construction). In-house signal maintainers can perform this operation once the proper signal phasing is determined so the cost is low.
- Eligible for 100% federal funding.

Example Location(s)

- Military E and E 2nd Street, Benicia

sources: CA-Local Roadway Safety Manual

S7. Covert signal to mast arm (from pedestal-mounted).

Applied to intersections currently controlled by pedestal mounted traffic signals (in medians and/or on outside shoulder) that have a high frequency of right-angle and rear-end crashes occurring because drivers are unable to see traffic signals in advance to safely negotiate the intersection. Care should be taken to place the new signal heads (with back plates) as close to directly over the center of the travel lanes as possible.

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 20 years of expected life.
- Estimated $20,000 per intersection (requires 18-4 pole, brackets, and signs).
- Mast arm cost can vary and be expensive.
- Eligible for 100% federal funding.

EXISTING CONDITIONS

S7 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S8. Install raised pavement markers and striping (through intersection).

Installed in intersections where the lane designations are not clearly visible to approaching motorists and/or intersections noted as being complex and experiencing crashes that could be attributed to a driver's unsuccessful attempt to navigate the intersection.

Benefit-Cost

- Implementation of this treatment reduces crashes by 10%.
- 10 years of expected life.
- Estimated $2,000 per installation.
- Costs of implementing this strategy will vary based on the scope and number of applications.
- Eligible for 100% federal funding.

EXISTING CONDITIONS

S8 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S9. Install flashing beacons as advance warning (S.I.).

Add the flashing beacons at signalized intersections with crashes that are a result of drivers being unaware of the intersection or are unable to see the traffic control device in time to comply. In addition, the CM 9 addresses both read end and angle crashes. Most advance warning flashing beacons can be powered by solar, thus reducing the issues relating to power source. This CM only applies to crashes occurring on the approaches / influence area of the new flashing beacons.

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 10 years of expected life.
- Estimated $70,000 for two approaches.
- Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option).
- Eligible for 100% federal funding.

S9 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S10. Install cameras to detect red-light running.

Applicable at signalized intersections with a high frequency of crashes attributed to drivers who intentionally disobey red signal indications. This type of automated enforcement refers to the use of photo and video camera systems connected to the signal controller. Such systems record vehicles proceeding through the intersection after the signal displays red. Angle crashes are the only type of crashes reduced. But, the CM also results in an increase in rear-end crashes from drivers making abrupt stops.

Benefit-Cost:

- Implementation of this treatment reduces crashes by up to 40%.
- 10 years of expected life.
- Estimated $70,000 per system.
- Studies will need to be done on where and how many cameras are needed to attack the problem intersection.
- Not eligible for federal funding.

Example Location(s)

- Broadway Street and Sereno Dr, Vallejo
- CA-29 and Georgia Street, Vallejo

EXISTING CONDITIONS

S10 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S11. Improve pavement friction (High Friction Surface Treatments).

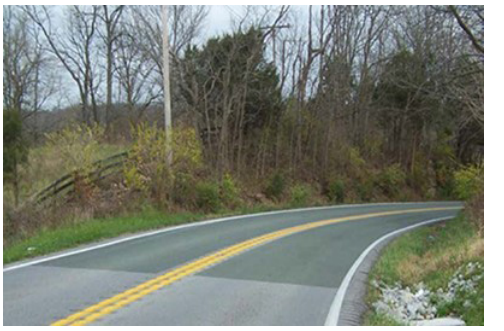
Improvement for signalized Intersections noted as having crashes on wet pavements or under dry conditions when the pavement friction available is significantly less than needed for the actual roadway approach speeds. This treatment is intended to target locations where skidding and failure to stop is determined to be a problem in wet or dry conditions and the target vehicle is unable to stop due to insufficient skid resistance. In addition, treatment also addresses night crashes all other crashes. This treatment does not apply to standard chip-seal or open-graded maintenance projects for long segments of corridors or structure repaving projects intended to fix failed pavement.

Benefit-Cost

- Implementation of this treatment reduces crashes by 40%.
- 10 years of expected life.
- Estimated $5,000 per intersection for materials and equipment.
- Cost variation based on size of intersection and material (Estimated $30/sq.yd.).
- Eligible for 100% Federal Funding.

EXISTING CONDITIONS

S11 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

S12. Install raised median on approaches.

Used at Intersections noted as having turning movement crashes near the intersection as a result of insufficient access control. Application of this CM should be based on current crash data and a clearly defined need to restrict or accommodate the movement. Angle crashes are addressed through this CM. When agencies opt to install landscaping in conjunction with new raised medians, these locations must be excluded from their federally funded HSIP application scope. This CM only applies to crashes occurring on the approaches / influence area of the new raised median. All new raised medians funded with federal HSIP funding must not include the removal of the existing roadway structural section and must be doweled into the existing roadway surface.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $200,000 per approach.
- Raised medians at intersections may be most effective in retrofit situations where high volumes of turning vehicles have degraded operations and safety, and where more extensive CMs would be too expensive because of limited right-of-way and the constraints of the built environment.
- Eligible for 90% of federal funding.

EXISTING CONDITIONS

S12 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S13. Create directional median openings to allow (or restrict) left-turns and U-turns.

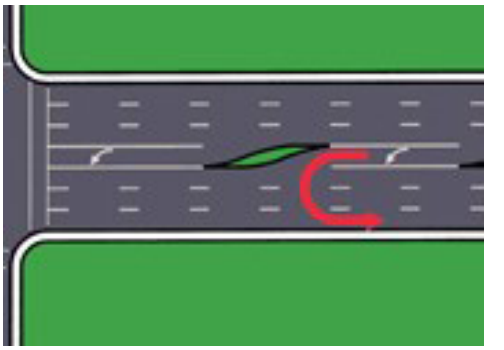
Put in medians to reduce crashes related to turning maneuvers include angle, rear-end, pedestrian, and sideswipe (involving opposing left turns) type crashes. This treatment only applies to crashes occurring in the intersection/influence area of the new directional openings.

Benefit-Cost

- Implementation of this treatment reduces crashes by 50%.
- 20 years of expected life.
- Estimated $75,000 per installation.
- The cost of this strategy will depend on the treatment.
- Eligible for 90% Federal Funding.

EXISTING CONDITIONS

S13 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

S14. Install right-turn lane.

Setting up right-turn lane may be appropriate in situations where there are an unusually high number of rear-end collisions on a single major road approach. The need for right turn lanes should be assessed on an individual approach basis. It is also important to ensure that the right-turn lanes are of sufficient length to allow vehicles to decelerate and "queue up" before turning, ideally without affecting the flow of through traffic. This treatment addresses read-end crashes. When considering new right-turn lanes, potential impacts to non-motorized user should be considered and mitigated as appropriate.

Benefit-Cost

- Implementation of this treatment reduces crashes by up to 30%.
- 20 years of expected life.
- Estimated $300,000 per right turn lane.
- Installing right turn lanes require substantial time for development and construction that can vary the cost.
- Not eligible for federal funding

EXISTING CONDITIONS

S14 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S15. Install left-turn lane (signal has no left turn phase – before and after).

Applicable to intersections that do not currently have a left turn lane and may be experiencing a large number of rear-end crashes as a result of traffic being stopped in the through lane. This treatment addresses all type of crashes particularly on high-volume and high-speed major-road approaches (including single major roads approach). Only consider installing a left turn lane at a signalized intersection 'without a separate phase' after the option of providing a turn phase has proven infeasible for the current project.

Benefit-Cost

- Implementation of this treatment reduces crashes by up to 44%.
- 20 years of expected life.
- Estimated $200,000 per intersection.
- Variation in cost depend on location, installation time based on restriping, acquisition of additional right-of-way, and extensive environmental process may be needed.
- Not eligible for federal funding.

EXISTING CONDITIONS

S15 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S16. Install left-turn lane (signal has left turn phase – before and after).

Applicable to intersections that do not currently have a left turn lane and may be experiencing a large number of rear-end crashes as a result of traffic being stopped in the through lane. This treatment addresses all type of crashes particularly on high-volume and high-speed major-road approaches (including single major roads approach). Only consider installing a left turn lane at a signalized intersection 'without a separate phase' after the option of providing a turn phase has proven infeasible for the current project.

Benefit-Cost

- Implementation of this treatment reduces crashes by up to 44%.
- 20 years of expected life.
- Estimated $200,000 per intersection.
- Variation in cost depend on location, installation time based on restriping, acquisition of additional right-of-way, and extensive environmental process may be needed.
- Not eligible for federal funding.

EXISTING CONDITIONS

S16 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S17. Install left-turn lane and add turn phase (signal has no left turn lane or phase before).

Installed at signalized intersections that have a significant crash problem and the only alternative is to change the nature of the intersection itself. This treatment addresses all type of crashes and the measure can be very effective at intersection with complex geometry and intersection with frequent left-turn movements.

Benefit-Cost

- Implementation of this treatment reduces crashes by 55%.
- 20 years of expected life.
- Estimated $700,000 per intersection.
- Variation in cost depend on location, installation time based on restriping, acquisition of additional right-of-way, and extensive environmental process may be needed.
- Eligible for 90% of federal funding.

EXISTING CONDITIONS

S17 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S18. Convert intersection to roundabout (from signal).

Change signalized intersections that have a significant crash problem and the only alternative is to change the nature of the intersection itself. This treatment addresses all type of crashes and can also be very effective at intersections with complex geometry and intersections with frequent left-turn movements. This treatment is not intended for mini-roundabouts.

Benefit-Cost

- Crash Reduction Factor (CRF) varies.
- 20 years of expected life.
- Estimated $5,000,000 per installation.
- Possible causes of variation in cost vary on project size, acquirements of right-of-way and can last for 4 years or longer.
- Eligible for 100% federal funding.

EXISTING CONDITIONS

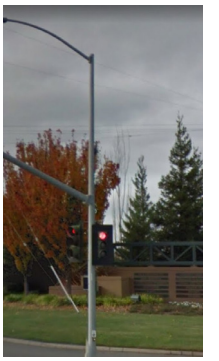
S18 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

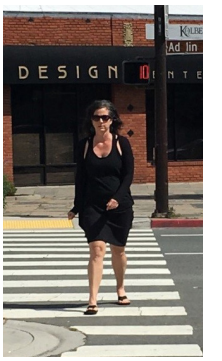
S19. Install pedestrian countdown signal heads.

Install at signals that have signalized pedestrian crossing with walk/don't walk indicators and where there have been pedestrian vs. vehicle crashes. The CM addresses both pedestrian and bicycle crashes. This CM only applies to "Ped & Bike" crashes occurring in the intersection/crossing with the new countdown heads.

EXISTING CONDITIONS



S19 IMPLEMENTATION



Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $1,500 per signal head (does not include push button or pole cost)
- Costs and time of installation will vary based on the number of intersections included in this strategy and if it requires new signal controllers capable of accommodating the enhancement. This CM can be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% federal funding.

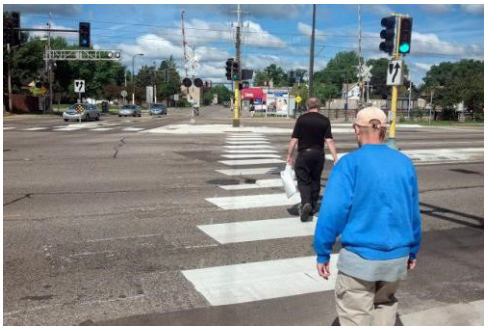
sources: CA-Local Roadway Safety Manual

S20. Install pedestrian crossing.

Should be placed at signalized Intersections with no marked crossing and pedestrian signal heads, where pedestrians are known to be crossing intersections that involve significant turning movements. They are especially important at intersections with (1) multiphase traffic signals, such as left-turn arrows and split phases, (2) school crossings, and (3) double-right or double-left turns. At signalized intersections, pedestrian crossings are often safer when the left turns have protected phases that do not overlap the pedestrian walk phase. The type of crashed address by this CM include Pedestrian and Bicycle. This CM only applies to "Ped & Bike" crashes occurring in the intersection/crossing with the new crossing. This CM is not intended to be used for high-cost aesthetic enhancements to intersection crosswalks (i.e. stamped concrete or stamped asphalt).

EXISTING CONDITIONS

S20 IMPLEMENTATION



Benefit-Cost

- Implementation of tis treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $5,000 per installation.
- When agencies opt to install aesthetic enhancement to intersection crosswalks like stamped concrete/asphalt, the project design and construction costs can significantly increase. For HSIP applications, these costs must be accounted for in the B/C calculation, but these costs (over standard crosswalk markings) must be tracked separately and are not federally reimbursable and will increase the agency's local-funding share for the project costs.
- Eligible for 100% federal funding.

sources: CA-Local Roadway Safety Manual

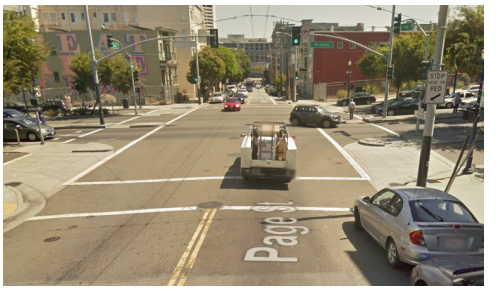
S21. Install advance stop bay before crosswalk (Bicycle Box).

Install signalized Intersections with a marked crossing, where significant bicycle and/or pedestrians volumes are known to occur. This treatment addresses pedestrian and bicycle crashes. This CM only applies to pedestrian and bike crashes occurring in the intersection-crossing with the new advanced stop bars.

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $4000 per installation.
- Costs and time of installation will vary based on the number of intersections included in this strategy and if it requires new signal controllers capable of accommodating the enhancement.
- Eligible 100% for federal funding.

EXISTING CONDITIONS



S21 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S22. Install pedestrian overpass/underpass.

Areas noted as having many pedestrian-vehicle conflicts. This treatment addresses pedestrian and bicycle crashes.

Benefit-Cost

- No information on CRF.
- No information on Life cycle.
- Estimated $1,000,000 per installation.
- Areas noted as having many pedestrian-vehicle conflicts. This CM is not eligible due to the generally high cost and high impacts associated with it and the statewide goal of maximize the safety-effectiveness of the limited HISP funding.
- Not eligible for federal funding.

EXISTING CONDITIONS

S22 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

S23. Install pedestrian median fencing on approaches.

This countermeasure applies to signalized intersections with high pedestrian-generators nearby (transit stops) the location may experience a high volume of pedestrians jaywalking across the travel lanes at mid-block locations instead of walking to the intersection. When this safety issue cannot be mitigated with signal timing and shoulder/sidewalk treatments, then installing a continuous pedestrian barrier in the median may be a viable solution. This type of CM addresses pedestrian and bicycle crashes. Impacts to transit and other land uses may need to be considered and controversy can delay the implementation. This CM only applies to "Ped & Bike" crashes occurring on the approaches/influence area of the new pedestrian median fencing.

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%.
- 20 years of expected life.
- Estimated $3,000 per installation, depending on length.
- Costs associated with this strategy will vary widely depending on the type and placement of the median fencing.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

EXISTING CONDITIONS

S23 IMPLEMENTATION

COUNTERMEASURES FOR NON-SIGNALIZED INTERSECTIONS

NS1. Add intersection lighting.

Effective at unsignalized intersections that have a disproportionate number of night time crashes and do not currently have lighting. This treatment improves the safety of the intersection during nighttime by making drivers more aware of the surroundings at the intersection, enhancing driver's available sight distances and improving the visibility of non- motorists. This CM only applies to night crashes (all types) occurring within limits of the proposed roadway lighting 'engineered' area.

EXISTING CONDITIONS

NS1 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 40%.
- 20 years of expected life.
- Estimated $8,000 per intersection.
- Cost variation based on cost for lighting installation and an ongoing maintenance and power cost.
- Eligible for 100% federal funding.

Example Location(s)

- Intersections along CA-29, Vallejo

sources: CA-Local Roadway Safety Manual

NS2. Convert to all-way STOP control (from 2-way or Yield control).

Applicable at unsignalized intersection locations with a crash history and have no controls on the major roadway approaches. The all way stop control is suitable only at intersections with moderate and relatively balanced volume levels on the intersection approaches. This treatment addresses to all type of crashes and only applies to crashes occurring in the intersection and /or influence area of the new control. CA-MUTCD warrant must be met.

EXISTING CONDITIONS

NS2 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 50%.
- 10 years of expected life.
- Estimated $5,000 per intersection.
- Cost variation based on numbers of locations.
- Eligible for 100% federal funding.

Example Location(s)

- E 5th Street and E J Street, Benicia
- E 5th Street and E L Street, Benicia

sources: CA-Local Roadway Safety Manual

NS3. Install signals.

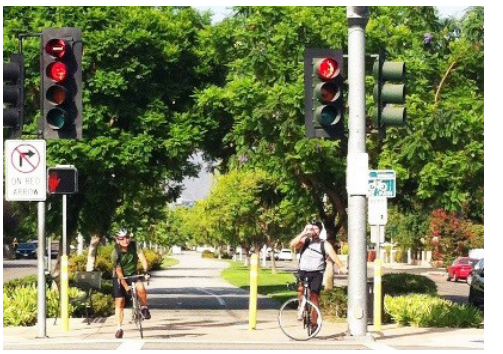
To signalized an unsignalized intersections should only be given after less restrictive forms of traffic control have been utilized as the installation of a traffic signal often leads to an increased frequency of crashes (rear-end) on major roadways and introduces congestion and signal warrants have been met. This CM only applies to crashes occurring in the intersection and/or influence area of the new signals. All new signals must meet MUTCD "safety" warrants:4,5 or 7. Given the overarching operational changes that occur when an intersection is signalized, no other intersection CMs can be applied to the intersection crashes in conjunction with this CM.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $900,000 per intersection.
- Cost variation based on application, type of signal and right-of-away considerations.
- Eligible for 100% federal funding.

EXISTING CONDITIONS

NS3 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

NS4. Convert intersection to roundabout (from 2-way STOP or Yield control).

Effective at intersections that have a high frequency of right-angle and left-turn type crashes, primarily at unsignalized intersections with moderate-volumes. This CM only applies to crashes occurring in the intersection and/or influence area of the new control and is not eligible for use at existing all-way stop intersections.

Benefit-Cost

- Implementation of this treatment, when used to reduce crashes, varies.
- 20 years of expected life.
- Estimated $750,000 per intersection.
- Cost variation based on the environmental process, right-of-way acquisition and implementation under an agency's long-term capital improvement program.
- Eligible for 100% federal funding.

Example Location(s)

- Meridian Road and Elizabeth Road, Suisun City

EXISTING CONDITIONS

NS4 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS5. Install/upgrade larger or additional stop signs or other intersection warning/regulatory signs.

Target unsignalized intersections with patterns of rear-end, right- angle, or turning collisions related to lack of driver awareness of the presence of the intersection. The ability of approaching drivers to perceive them can be enhanced by installing larger regulatory and warning signs at or prior intersections. This CM only applies to all type of crashes occurring in the intersection and/or influence area of the new signs. The influence area must be determined on a location by location basis.

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $700 per intersection.
- Cost variation based on the number of signs.
- Eligible for 100% federal funding.

Example Location(s)

- E 5th Street and E J Street, Benicia
- Porter Road and Pitt School Road, Solano County

EXISTING CONDITIONS

NS5 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS6. Upgrade intersection pavement markings.

Effective at unsignalized intersections that are not clearly visible to approaching motorists, particularly approaching motorists on the major road. This is appropriate for intersections with patterns of rear-end, right-angle or turning crashes related to lack of drivers' awareness of the presence of an intersection; and, at minor road approaches where conditions allow the stop bar to be seen by an approaching driver at a significant distance from the intersection. Improvements include "Stop Ahead" markings and the addition of Centerlines and Stop Bars. This CM applies to all type of crashes occurring on the approaches/ influence area of the new pavement markings. However, this CM is not intended to be used for general maintenance activities and must include ungraded safety features over the existing pavement markings and striping.

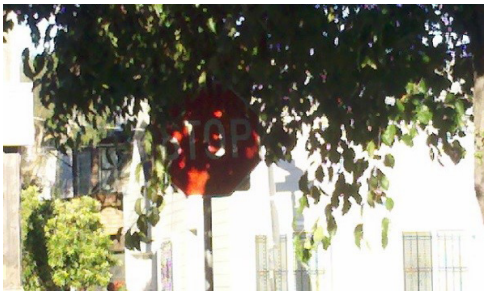
Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 10 years of expected life.
- Estimated $10,000 per intersection.
- Cost variation based on the number of markings.
- Eligible for 100% federal funding.

Example Location(s)

- Porter Road and Pitt School Road, Solano County

EXISTING CONDITIONS



NS6 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS7. Install Flashing Beacons at Stop-Controlled Intersections.

Installing Flashing beacons to reinforce driver's awareness of the non-signalized intersection control and to help mitigate patterns of right-angle crashes related to stop sign violations. This CM applies to all type of crashes occurring on the stop-controlled approaches/ influence area of the new beacons.

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $15,000 per intersection.
- Cost variation based on the design, environmental, right-of-way issues.
- Eligible for 100% federal funding.

Example Location(s)

- Porter Road and Pitt School Road, Solano County

EXISTING CONDITIONS

NS7 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS8. Install flashing beacons as advance warnings (NS.I.).

Applicable to non-signalized intersections with patterns of crashes that could be related to lack of a driver's awareness of approaching intersection or controls at a downstream intersection. This CM applies to all type of crashes occurring on the approaches / influence area of the new beacons placed in advanced of the intersection.

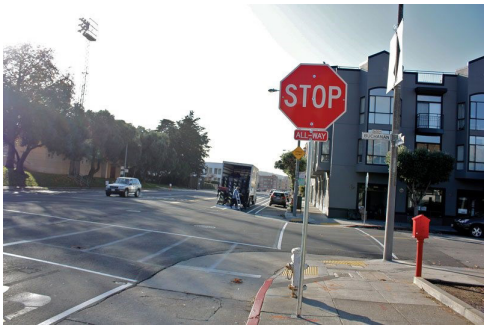
Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 10 years of expected life.
- Estimated $75,000 per intersection.
- Cost variation based on the size/number of the flashing beacons.
- Eligible for 100% federal funding.

Example Location(s)

- Porter Road and Pitt School Road, Solano County

EXISTING CONDITIONS



NS8 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS9. Install transverse rumble strips on approaches.

Transverse rumble strips are installed in the travel lane for providing an auditory and tactile sensation for each motorist approaching the intersection. They can be used at any stop or yield approach intersection, often in combination with advance signing to warn of the intersection ahead. This CM applies to all crashes occurring on the approach / influence area of the new rumble strips.

Benefit-Cost

- Implementation of this treatment reduces crashes by 20%.
- 10 years of expected life.
- Estimated $5,000 per intersection.
- Cost variation based on the length of the rumble strips.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS9 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS10. Improve sight distance to intersection (clear sight triangle).

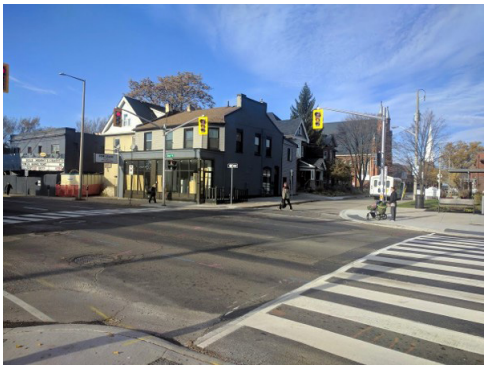
Applicable at unsignalized intersections with restricted sight distance and patterns of crashes related to lack of sight distance where the sight distance can be improved by clearing roadside obstructions without major reconstruction of the roadway. This CM applies to all crashes occurring on the approaching / influence area of the significantly improved new sight distance.

Benefit-Cost

- Implementation of this treatment reduces crashes by 20%.
- 10 years of expected life.
- Estimated $100,000 per intersection.
- Cost variation based on the surrounding of the intersection.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS10 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

NS11. Install splitter-islands on the minor road approaches.

Applicable for minor road approaches to unsignalized intersections where the presence of the intersection or the stop sign is not readily visible to approaching motorists. This CM is particularly appropriate for intersections where the speeds on the minor road are high. This CM allows for an additional stop sign to be placed in the median for the minor approach. All crashes occurring on the approaches / influence area of the new splitter island on the minor road approaches are reduced by the implementation of this CM.

Benefit-Cost

- Implementation of this treatment reduces crashes by 40%.
- 20 years of expected life.
- Estimated $50,000 per intersection.
- Cost variation based on the size of the splitter-islands.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS11 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS12. Install raised median on approaches.

Effective for the location where related or nearby turning movements affect the safety and operation of an intersection. The number of intersection access points coupled with the speed differential between vehicles traveling along the roadway often contributes to crashes. Any access points within 250 feet upstream and downstream of an intersection are generally undesirable. This CM applies to all crashes occurring on the approaches / influence area of the new raised median. All new raised medians funded with federal HSIP funding must not include the removal of the existing roadway structural section and must be doweled into the existing roadway surface.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $200,000 per intersection.
- Cost variation based on the size of the new median.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS12 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS13. Create directional median openings to allow (and restrict) left-turns and U-turns.

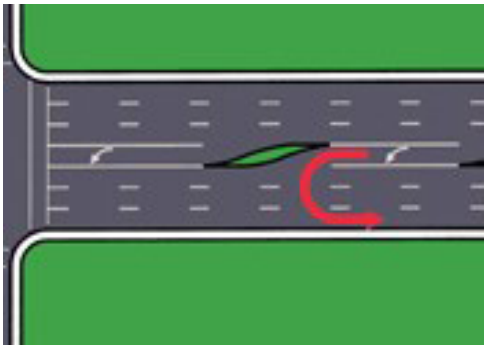
Applicable when crashes related to turning maneuvers include angle, rear-end, pedestrian and sideswipe (involving opposing left turns) type crashes. Since raised medians limit property access to right turns only, they should be used in conjunction with efforts to provide alternative access ways and promote driveway spacing objectives. This CM applies to all crashes occurring in the intersection / influence area of the new directional openings.

Benefit-Cost

- Implementation of this treatment reduces crashes by 50%.
- 20 years of expected life.
- Estimated $75,000 per intersection.
- Cost variation based on the size of the median.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS13 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

NS14. Install right-turn lane (NS.I.).

Applicable when many collisions at unsignalized intersections are related to right-turn maneuvers. This CM provides exclusive right-turn lanes, particularly on high-volume and high-speed major-road approaches to minimizing the collisions and applies to crashes occurring on the approaches / influence area of the new right-turn lanes. However, it is not eligible for use at existing all-way stop intersections.

Benefit-Cost

- Implementation of this treatment reduces crashes by 20%.
- 20 years of expected life.
- Estimated $200,000 per intersection.
- Cost variation based on how wide the new right lane.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS14 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

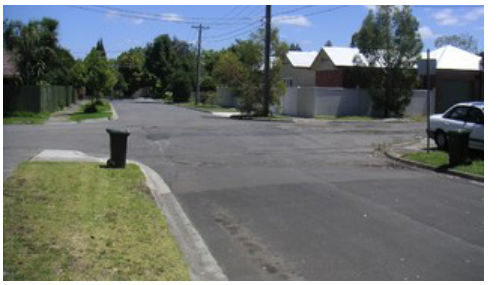
NS15. Install left-turn lane (where no left-turn lane exists).

Applicable when many collisions at unsignalized intersections are related to left-turn maneuvers. This CM provides exclusive left-turn lanes, particularly on high-volume and high-speed major-road approaches to minimizing the collisions. This CM applies to crashes occurring on the approaches / influence area of the new left- turn lanes, but is not eligible for use at existing all-way stop intersections.

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%.
- 20 years of expected life.
- Estimated $200,000 per intersection.
- Cost variation based on how wide the new left lane.
- Eligible for 90% federal funding.

EXISTING CONDITIONS



NS15 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS16. Install raised medians (refuge islands).

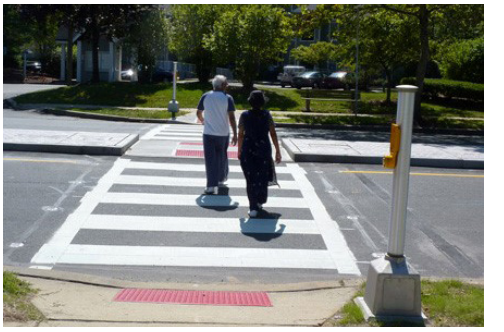
Applicable when intersections have a long pedestrian crossing distance, a higher number of pedestrians, or a crash history. Raised medians can decrease the level of exposure for pedestrians and allow pedestrians to concentrate on (or cross) only one direction of traffic at a time. Raised medians only apply to pedestrian and bicycle crashes occurring on the approaches / influence area of the new left-turn lanes. This CM does not apply to converting a single- left into double left turn, nor is it eligible for use at existing all-way stop intersections.

Benefit-Cost

- Implementation of this treatment reduces crashes by 45%.
- 20 years of expected life.
- Estimated $50,000 per intersection.
- Cost variation based on the size of the refuge islands.
- Eligible for 90% federal funding.

EXISTING CONDITIONS

NS16 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

NS17. Install pedestrian crossing at uncontrolled locations (signs and markings only).

Applicable at non-signalized intersections without marked crossings, or at intersections with significant vehicular traffic or where pedestrians are known to be crossing. They are important near schools and intersections with right and/or left turns pockets. This CM only reduces "Ped and Bike" crashes that occur in the intersection/ crossing with the new crossing. It is not intended to be used for high-cost aesthetic enhancements to intersection crosswalks (i.e. stamped concrete or stamped asphalt).

NS17 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 20%.
- 10 years of expected life.
- Estimated $5,000 per intersection.
- Cost variation based on the length of the pedestrian crossing.
- Eligible for 100% federal funding.

sources: CA-Local Roadway Safety Manual

NS18. Install pedestrian crossing at uncontrolled locations (with enhanced safety features).

Applicable at non-signalized intersections without a marked crossing, where pedestrians are known to be crossing, that involve significant vehicular traffic. They are important at school crossings and intersections with right and/or left turns pockets. Rectangular rapid flashing beacons, overhead flashing beacons, curb extensions, advanced "stop" or yield markings and other safety features should be added to complement the standard crossing elements. This CM only reduces "Ped & Bike" crashes occurring in the crossing (influence area) with the new enhanced safety features and is not intended to be used for high-cost aesthetic enhancements to intersection crosswalks (i.e. stamped concrete or stamped asphalt).

NS18 IMPLEMENTATION

Benefit-Cost:

- Implementation of this treatment reduces crashes by 35%.
- 20 years of expected life.
- Estimated $ 50,000 per intersection.
- Cost variation based on the length of the pedestrian crossing and the amount of safety signs.
- Eligible for 100% federal funding.

sources: CA-Local Roadway Safety Manual

NS19. Install pedestrian signal or HAWK.

Applicable when intersections are noted as having a history of pedestrian vs. vehicle crashes and in areas where the likelihood of a pedestrian related crash is significant. Corridors should also be assessed to determine if there are adequate safe opportunities for non- motorists to cross and if a pedestrian signal, HAWK, or hybrid beacon is needed to provide an active warning to motorists when pedestrians are in the crosswalk. This CM only reduces "Ped and Bike" crashes occurring in the intersection / crossing with the new signal.

Benefit-Cost:

- Implementation of this treatment reduces crashes by 55%.
- 20 years of expected life.
- Estimated $200,000 per intersection.
- Cost variation based on the amount of pedestrian signal or HAWK.
- Eligible for 100% federal funding

Example Location(s)

- Intersections along Broadway Street, Vallejo

EXISTING CONDITIONS

NS19 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

NS20. Improve pavement friction (High Friction Surface Treatments).

Applicable when non-signalized intersections are noted as having crashes on wet pavement, or under dry conditions when the pavement friction available is significantly less than needed for the actual roadway approach speeds. This treatment is used to target locations where skidding and/or failure to stop occur in wet or dry conditions. This CM reduces all crashes occurring within the limits of the improved friction overlay. Improved pavement friction is not intended to apply to standard chip-seal or open-graded maintenance projects for long segments of corridors or structure repaving projects intended to fix failed pavement.

Benefit-Cost:

- Implementation of this treatment reduces crashes by 40%.
- 10 years of expected life.
- Estimated $5,000 per intersection.
- Cost variation based on size of intersection and material ($30/sq.yd.).
- Eligible for 100% federal funding.

EXISTING CONDITIONS

NS20 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

COUNTERMEASURES FOR ROADWAY SEGMENTS

R1. Add Segment Lighting

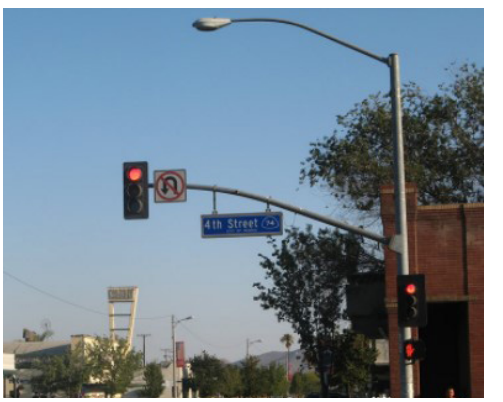
Applied to night-time crashes. In particular, patterns of rear-end, right-angle, turning or roadway departure collisions on the roadways may indicate that night-time drivers can be unaware of the roadway characteristics. This treatment addresses only to all night type crashes.

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%
- 20 years of estimated life.
- Estimated $8,000 per installation.
- Cost variation depending if lighting connected to signal box. If yes, then no additional pullbox.
- Eligible for 100% federal funding.

EXISTING CONDITIONS

R1 IMPLEMENTATION



sources: CA-Local Roadway Safety Manual

R2. Remove or relocate fixed objects outside of Clear Recovery Zone.

Applicable to known locations or roadway segments prone to collisions with fixed objects such as utility poles, drainage structures, trees, and other fixed objects, such as the outside of a curve, end of lane drops, and in traffic islands. This treatment addresses fixed object crashes that occur within the limits of the new clear recovery zone.

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%.
- 20 years of expected life.
- Estimated $50,000 per employment.
- Costs will generally be low, assuming that in most cases the objects to be removed are within the right-of-way.
- Eligible for 90% of federal funding.

EXISTING CONDITIONS

R2 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R3. Install Median Barrier.

Put in areas where crash history indicates drivers are unintentionally crossing the median and the cross-overs are resulting in high severity crashes. This treatment addressed only head-on crashes. This treatment is only applied to crashes occurring within the limits of the new barrier.

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 20 years of expected life.
- Estimated $150,000 varies.
- Costs will vary depending on the type of median barrier selected and whether the strategy is implemented as a stand-alone project or incorporated as part of a reconstruction or resurfacing effort.
- Eligible for 100% of federal funding.

EXISTING CONDITIONS

R3 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R4. Install Guardrail.

Guardrail is installed to reduce the severity of lane departure crashes. This treatment addresses fixed object and run-off road crashes. This treatment and corresponding CRF should only be applied to locations where past crash data or engineering judgement applied to existing attenuator conditions suggests the upgrade attenuators may result in a few or less severe crashes.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $50,000 per installment.
- Strategies range from relatively inexpensive too costly.
- Eligible for 100% of federal funding.

EXISTING CONDITIONS

R4 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

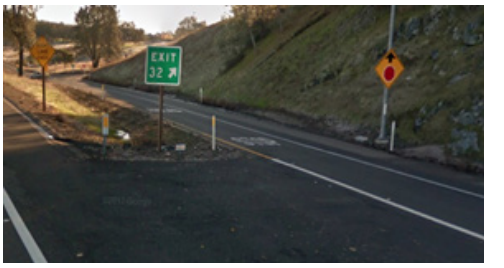
R5. Install impact attenuators.

Impact attenuators are typically used to shield rigid roadside objects such as concrete barrier ends, steel guardrail ends and bridge pillars from oncoming automobiles. This treatment addresses fixed object and run-off road that occur with the limits of the new attenuators. This CM and corresponding CRF should only be applied to locations where past crash data or engineering judgement applied to existing attenuator conditions suggests the upgrade attenuators may result in a few or less severe crashes.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 10 years of expected life.
- Estimated $5000 for steel railing, $2500 for traffic barrels.
- Costs depending on the scope of the project, type(s) used, and associated ongoing maintenance costs.
- Eligible for 100% of federal funding.

EXISTING CONDITIONS



R5 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R6. Flatten side slopes.

Consider adding to roadways experiencing frequent lane departure crashes that result in roll-over type crashes as a result of the roadway slope being so severe as to not accommodate a reasonable degree of driver correction. This treatment addresses fixed object and run-off road crashes. This treatment only applies to crashes occurring within the limits of the new side slope. Minor/incidental flattening of side slopes would not likely result in the CRF shown below and may not be appropriate for use in Caltrans B/C calculations.

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 20 years of expected life.
- Estimated cost varies significantly based on shoulder conditions.
- Strategies that include creating safer side slopes where none exists can be moderately expensive based on the scope of the project and the associated clearing, grading, etc.
- Eligible for 90% federal funding.

Example Location(s)

- CA-113 between E C Street and W E Street, Dixon

EXISTING CONDITIONS

R6 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R7. Flatten side slopes and remove guardrail.

Put in locations where high number of crashes originate as a lane departure and result in collision with guardrail or a fixed object located on the side slope shielded by guardrail. This treatment addresses roll over and fixed object crashes; but, can still result in severe crashes in some locations. This treatment only applies to crashes occurring within the limits of both the removed guardrail and the new side slopes.

Benefit-Cost

- Implementation of this treatment reduces crashes by 40%.
- 20 years of expected life.
- Estimated $100,000 per implementation.
- Strategies that include creating safer side slopes where none exists can be moderately expensive based on the scope of the project and the associated clearing, grading, etc.
- Eligible for 90% of federal funding.

EXISTING CONDITIONS

R7 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R8 . Upgrade bridge railing.

Installed on open-faced railings that can present a snagging hazard, which may produce high deceleration forces leading to occupant injuries. Consider curbs or walkways between the driving lane and the bridge railing are another common hazard of older railing systems. This treatment addresses all types of crashes and possibility impact vehicles to go over the railing.

Benefit-Cost

- No information on CRF.
- No information on Life cycle.
- Estimated $80,000 (or higher).
- Cost depends on the scope of the project.
- Not eligible for funding due to the generally high cost and high impacts associated with it and the statewide goal to maximize the safety-effectiveness of the limited HISP funding.

R8 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R9. Install raised median.

Installed in areas experiencing head-on collisions that may be affected by both the number of vehicles that cross the centerline and by the speed of oncoming vehicles. This address only head-on crashes and only applies to crashes occurring within the limits of the new raised median. Application of raised medians on roadways with higher speeds is not advised and documentation of impacts of additional turning movements at nearby intersection should be considered.

R9 IMPLEMENTATION

Benefit-Cost

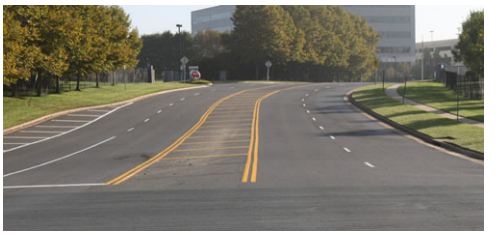
- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $200,000+ (depends on length, right-of-way, and surface treatment).
- Choosing to install landscaping can exclude agencies from their federally funded HSIP application scope.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R10. Install median (flush).

Installed in areas experiencing head-on collisions that may be affected by both the number of vehicles that cross the centerline and by the speed of oncoming vehicles. This treatment addresses all types of crashes occurring within the limits of the new flush media.

R10 IMPLEMENTATION



Benefit-Cost

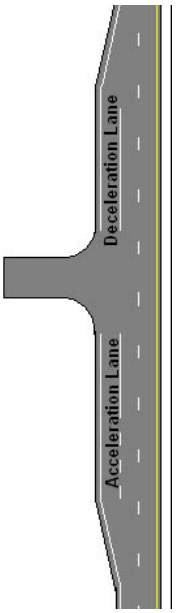
- Implementation of this treatment measure reduces crashes by 15%.
- 20 years of expected life.
- Estimated $25,000 per segment (approximately 1,000 linear feet).
- Costs and time to implement could significantly increase if the paved area is not sufficient to include a median. This measure is only eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R11. Install acceleration/deceleration lanes.

Applicable in areas proven to have crashes that are the result of drivers not being able to turn onto a high speed roadway to accelerate until the desired roadway speed is reached and areas that do not provide the opportunity to safety decelerate to negotiate a turning movement. This CM can also be used to improve the safety of merging vehicles at a lane-drop location. This type of CM addresses sideswipe and read-end. This CM only applies to crashes occurring within the limits of the new acceleration/deceleration lanes on high speed roadways.

R11 IMPLEMENTATION



Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $700,000 (cost are highly variable).
- Where the roadway must be widened and additional right-of-way must be acquired, higher costs and a lengthy time-to-construct are likely.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R12. Install climbing lane (where large difference between car and truck speed).

Install where truck traffic is above average and there is an existing grade which are believed to have resulted in a known crash history between vehicles and slower trucks. This treatment addresses all types of crashes that occur on separation between slower vehicles. This treatment is not eligible due to the generally high costs and high impacts associated with it and the statewide goal to maximize the safety-effectiveness of the limited HSIP funding.

Benefit-Cost

- No information on CRF.
- 20 years of expected life.
- Estimated $600,000 per installation.
- Variation of cost is associated with road widening, additional right-of-way, and a lengthy time-to-construct.
- Not eligible for federal funding.

sources: CA-Local Roadway Safety Manual

R13. Widen lane (initially less than 10ft).

Use on horizontal curves or tangents and low speed or high speed roadways identified as having lane departure crashes, sideswipe or head-on crashes that can be attributed to an existing pavement width less than 10 feet. This treatment addresses all types of crashes that occur with increasing pavement width. This treatment only applies to crashes occurring within the limits of the widened lanes (widening must be a minimum of 1 foot).

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $75,000.
- Horizontal curves or tangents and low speed or high speed roadways identified as having lane departure crashes, sideswipe or head-on crashes that can be attributed to an existing pavement width less than 10 feet.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R14. Add two-way left-turn lane (without reducing travel lanes).

Install on roadways having a high frequency of drivers being rear-ended while attempting to make a left turn across oncoming traffic. Also can be effective for drivers crossing the centerline of an undivided multilane roadway inadvertently. This treatment address all types of crashes by having two-way left turn lanes that provides a buffer between opposing directions of travel and separate left turning traffic from through traffic. This treatment only applies to crashes occurring within the limits of the new lane, where an existing median did not already exist.

Benefit-Cost

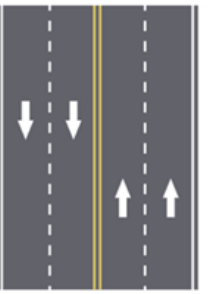
- Implementation of this treatment reduces crashes by 30%.
- 20 years of expected life.
- Estimated $800,000 (varies).
- Costs and time to implement could significantly increase if the paved area is not sufficient to include a median, requiring new right-of-way, and having significant environmental impacts.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

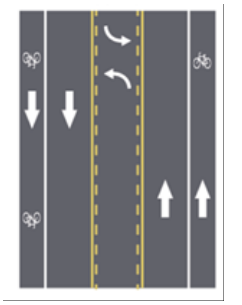
R15. Road Diet (reduce travel lanes from 4 to 3 and add a two way left-turn and bike lanes).

Applicable to areas noted as having a higher frequency of head-on, left-turn, and rear-end crashes with traffic volumes that can be handled by only 2 free flowing lanes. This treatment addresses all types of crashes that occur by reducing the roadway segment speeds and serious head-on crashes. This treatment only applies to crashes occurring within the limits of the new lane striping. "Intersection" crashes can only be applied when they resulted from turning movements that had no designated turn lanes/phases in the existing condition and the Road Diet will provide turn lanes/phases for these movements.

EXISTING CONDITIONS



R15 IMPLEMENTATION



This treatment does not apply to roadway sections that already included left turn lanes or two way left turn lanes before the lane reductions. New bike lanes are also expected to be part of these projects. Pre-approval from the HSIP program manager is needed for: 1) the use of this treatment without removing a travel lane in each direction and/or without adding new bike lanes; and/or 2) if any pavement is planned to be removed for the purpose of adding landscaping, planter-boxes, or other non-roadway user features.

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 20 years of expected life.
- Estimated $750,000 (varies).
- Projects that only require new lane markings and minor signalization modifications will have relatively low cost and can be very effective and can be considered on a systematic approach.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R16. Widen shoulder (paved).

Installed in roadways that have a frequent incidence of vehicles leaving the travel lane resulting in an unsuccessful attempt to reenter the roadway. The probability of a safe recovery is increased if an errant vehicle is provided with an increased paved area in which to initiate such a recovery. This type of CM addresses Fixed Object, Run-off Road, and Sideswipe.

Benefit-Cost

- Implementation on this treatment reduces crashes by 30%.
- 20 years of expected life.
- Estimated $150,000 (cost depends on need for right-of-way or if roadside modification is needed).
- Shoulder widening costs would depend on whether new right-of-way is required and whether extensive roadside modification is needed. Since shoulder widening can be a relatively expensive treatment, one of the keys to creating a cost effective project with at least a medium B/C ratio is targeting higher-hazard roadways.
- Eligible for 90% of federal funding.

Example Location(s)

- Fry Road between Leisure Town Road and Meridian Road, Solano County

EXISTING CONDITIONS

R16 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R17. Widen shoulder (unpaved).

Appropriate to roadways with a frequent incidence of vehicles leaving the travel lane resulting in an unsuccessful attempt to reenter the roadway. This CM addressed all types of crashes. Unless shoulder widening requires additional right-of-way and environmental impacts, these treatments can be implemented in a relatively short timeframe. This CM only applies to crashes occurring within the limits of the new shoulder. A minimum of 2-4 feet width must be added and the new traversable shoulders must be a minimum of 4 feet wide.

Benefit-Cost

- Implementation on this treatment reduces crashes by 20%.
- 20 years of expected life.
- Estimated $50,000 (varies).
- The cost of adding a navigable non-paved shoulder would depend whether extensive roadside modification and shoulder stabilization are required.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R18. Pave existing shoulder.

Applied to roadways with an unpaved existing shoulder - exhibiting a frequent incidence of vehicles leaving the travel lane resulting in an unsuccessful attempt to reenter the roadway. This type of CM addresses all crashes. This CM only applies to crashes occurring within the limits of the new paved shoulder. The new paved shoulders must be a minimum of 4 feet wide.

R18 IMPLEMENTATION

Benefit-Cost

- Implementation on this treatment reduces crashes by 15%.
- 20 years of expected life.
- Estimated $50,000 (varies).
- Shoulder pavement costs should be similar to lane pavement costs, but will depend on how much shoulder stabilization is required.
- Eligible for 90% of federal funding.

Example Location(s)

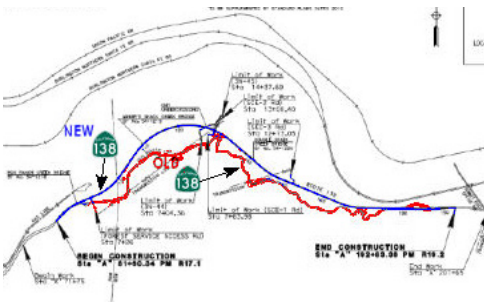
- CA-113 between E C Street and W E Street, Dixon

sources: CA-Local Roadway Safety Manual

R19. Improve Horizontal Alignment (flatten curves).

Applicable to roadways with horizontal curves that have experienced lane departure crashes as a result of a roadway segment having compound curves or a severe radius. This treatment addresses all types and is very effective in improving the safety performance of the curve. This strategy should generally be considered only when less expensive strategies involving clearing of specific sight obstructions or modifying traffic control devices have been tried and have failed to ameliorate the crash patterns. This treatment only applies to crashes occurring within the limits (or influence area) of the improved alignment.

R19 IMPLEMENTATION



This treatment is not eligible unless it is done as the last step of an "incremental approach", including: the agency documents that: 1) they have already pursued and installed lower cost and lower impact CMs (i.e. signing/striping upgrades to MUTCD standards/recommendations, rumble strips, etc.), 2) they have already monitored the crash occurrences after these improvements were installed, and 3) the 'after' crash rate is still unacceptably high. This 'incremental approach' (or a special exception from the HSIP program manager) must be documented in the Narrative Questions in the application and a summary of the agency's 'before' and 'after' crash analysis must be attached to the application.

Benefit-Cost

- Implementation on this treatment reduces crashes by 50%.
- 20 years of expected life.
- Estimated $1,000,000 higher-cost varies on location.
- Cost revolved around additional right-of-way, environmental review, and total reconstruction of the roadway.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R20. Flatten crest vertical curve.

The target for this strategy is usually unsignalized intersections with restricted sight distance due to vertical geometry and with patterns of crashes related to that lack of sight distance that cannot be ameliorated by less expensive methods. This strategy should generally be considered only when less expensive strategies involving clearing of specific sight obstructions or modifying traffic control devices have been tried and have failed to ameliorate the crash patterns. This treatment addresses all types of crashes by having acceptable sight distance for drivers at stopped approaches in an intersection. This treatment only applies to crashes occurring within the limits (or influence area) of the improved alignment. This treatment must follow the "incremental approach" discussed in treatment R19.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 20 years of expected life.
- Estimated $750,000 per installation
- Varies based on slope and improvement can take several years.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R21. Improve horizontal and vertical alignments.

Applicable to roadways that have compound issues with curves (horizontal and vertical) and are experiencing lane departure and sight distance related crashes. This treatment addresses all types of crashes by reducing the likelihood of a vehicle leaving its lane, crossing the roadways centerline, and helps in providing adequate sight distance. This treatment only applies to crashes occurring within the limits (or influence area) of the improve alignment. This treatment must follow the "incremental approach" discussed in treatment R19 & R20.

Benefit-Cost

- Implementation of this treatment reduces crashes by 60%.
- 20 years of expected life.
- Estimated $1,000,000 (varies and improvement can take several years).
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R22. Improve curve super elevation.

Applicable for roadways noted as having frequent lane departure crashes and inadequate or no superelevation. This treatment addresses specifically run-off road crashes but also all other crashes by improving the superelevation or restoring along curves where the actual superelevation is less than the optimal. This CM only applies to crashes occurring within the limits (or influence area) of the improved superelevation. This CM does not apply to sections of roadways where the horizontal or vertical alignments are changing via another CM.

Benefit-Cost:

- Implementation of this treatment reduces crashes by 45%.
- 20 years of expected life.
- Estimated $700,000 (varies).
- Higher-cost alternative for improving the safety of a curve because it involves reconstruction to some degree. Other projects may be able to be constructed by simple overlays and minimal reconstruction of roadway features.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R23. Convert from two-way to one-way traffic.

One-way streets can offer improved signal timing and accommodate odd-spaced signals. One-way streets can simplify crossings for pedestrians, who must look for traffic in only one direction. This countermeasure addresses all types of crashes.

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%.
- 20 years of expected life.
- Estimated $50,000 per conversion.
- Costs may vary depending on length of treatment and if the conversion requires modification to signals.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R24. Improve Pavement friction (high friction surface treatments).

Areas as noted having crashes on wet pavements or under dry conditions when the pavement friction available is significantly less than actual roadway speeds; including but not limited to curves, loop ramps, intersections, and areas with short stopping or weaving distances. This treatment addresses all types of crashes including wet and rear-end crashes. This CM only applies to crashes occurring within the limits of the improved friction overlay. This CM is not intended to apply to standard chip-seal or open-graded maintenance projects for long segments of corridors or structure repaving projects intended to fix failed pavement.

Benefit-Cost

- Implementation of this treatment reduces crashes by 40%.
- 10 years of expected life.
- Estimated $25,000
- Eligible for 100% of federal funding

sources: CA-Local Roadway Safety Manual

R25. Provide Tapered Edge for Pavement Edge Drop–off.

This treatment is designed to be a standard policy for any overlay project. Instead of an overlay project ending with a 90-degree asphalt or concrete face at the edge of pavement, the tapered edge provides a 30-degree angle at the edge. The type of treatment addressed Run-off Road crashes. This treatment primarily applies to new structural overlay projects, which are not eligible in California's federal safety funding programs.

Benefit-Cost

- No crash reduction rate available.
- No Life cycle information.
- Estimated $25,000.
- Not eligible for federal funding.

EXISTING CONDITIONS

R25 IMPLEMENTATION

sources: CA-Local Roadway Safety Manual

R26. Install/Upgrade signs with new fluorescent sheeting (regulatory or warning).

The target for this strategy should be on roadway segments with patterns of head on, nighttime, non-intersection, run-off road, and sideswipe crashes related to lack of driver awareness of the presence of a specific roadway feature or regulatory requirement. This CM only applies to crashes occurring within the influence area of the new/upgraded signs. This CM is not intended for maintenance upgrades of street-name, parking, guide, or any other signs without a primary focus on roadway safety.

This CM is not eligible unless it is done as part of a larger sign audit project, including the study of: 1) the existing signs' locations, sizes and information per MUTCD standards, 2) missing signs per MUTCD standards, and 3) sign retroreflectivity. The overall sign audit scope (or a special exception from the HSIP program manager) must be documented in the Narrative Questions in the application. Based on the scope of the project/audit, it may be appropriate to combine other CMs in the B/C calculation.

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $1,000 per sign.
- Costs for implementing this strategy are nominal and depend on the number of signs. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, This treatment can be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R27. Install chevron signs on horizontal curves.

Set up on roadways that have an unacceptable level of crashes on relatively sharp curves during periods of light and darkness. Ideally this type of safety CM would be combined with other sign evaluations and upgrades (install warning signs, delineators, markers, beacons, and relocation of existing signs per MUTCD standards). This treatment can address all types of crashes; but, specifically, run-off road crashes occurring near curves. This treatment only applies to crashes occurring within the influence area of the new signs (i.e. only through the curve).

R27 IMPLEMENTATION

Benefit-Cost:

- Implementation of this treatment reduces crashes by 40%.
- 10 years of expected life.
- Estimated $1,000 per curve
- Costs for implementing this strategy are nominal and depend on the number of signs. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, this treatment can be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R28. Install curve advance warning signs.

Roadways that have an unacceptable level of crashes on relatively sharp curves during periods of light and darkness. This treatment may also include horizontal alignment and/or advisory speed warning signs. Ideally this type of safety CM would be combined with other sign evaluations and upgrades (install warning signs, chevrons, delineators, markers, beacons, and relocation of existing signs per MUTCD standards). This treatment addresses all types of crashes; but, particularly helps reduce run-off road crashes that occur when there is no advance warning of unexpected or sharp curves. This CM only applies to crashes occurring within the influence area of the new signs. (i.e. only through the curve).

R28 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 10 years of expected life.
- Estimated $1,000 per curve.
- Costs for implementing this strategy are nominal and depend on the number of signs. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, this treatment can be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R29. Install curve advance warning signs (flashing beacon).

Installed on roadways that have an unacceptable level of crashes on relatively sharp curves. Flashing beacons in conjunction with warning signs should only be used on horizontal curves that have an established severe crash history to help maintain their effectiveness. This treatment addresses all types of crashes due to unexpected or sharp curve. This treatment only applies to crashes occurring within the influence area of the new signs. (i.e. only through the curve).

R29 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 10 years of expected life.
- Estimated $25,000 per approach, depending on access to utilities.
- Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option).
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R30. Install dynamic/variable speed warnings signs.

Curvilinear roadways that have an unacceptable level of crashes due to excessive speeds on relatively sharp curves. This type of treatment addresses all crashes caused by motorist traveling too fast around shape curves. Before choosing this treatment, the agency needs to confirm the ability to provide power to the site (solar may be an option). This treatment does not apply to dynamic regulatory speed warning signs.

R30 IMPLEMENTATION

Benefit-Cost

- Implementation on this treatment reduces crashes by 30%.
- 10 years of expected life.
- Estimated $100,000 (varies).
- Cost varies on type of implementation.
- Eligible for 100% federal funding.

Example Location(s)

- Locations along W Texas Street, Fairfield

sources: CA-Local Roadway Safety Manual

R31. Install delineators, reflectors and/or object markers.

Set up on roadways that have an unacceptable level of crashes on curves (relatively flat to sharp) during periods of light and darkness. This treatment addresses all types of crashes occurring when drivers approaching curve or a fixed object cannot easily be removed. This treatment only applies to crashes occurring within the limits / influence area of the new features. Also, this is not a striping-related treatment.

R31 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $2,000 (depends on number and length of locations).
- Costs for implementing this strategy are nominal and depend on the number of locations. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, this treatment can be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in low to moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R32. Install edge-lines and centerlines.

Applicable on any road with a history of run-off-road right, head-on, opposite-direction-sideswipe, or run-off-road-left crashes is a candidate for this treatment – should be installed where the existing lane delineation is not sufficient to assist the motorist in understanding the existing limits of the roadway. This treatment addresses all types; but, specifically impacts head-on and run-off road crashes. This treatment only applies to crashes occurring within the limits of the new centerlines and/or edge-lines. The treatment is not intended to be used for general maintenance activities (i.e. the replacement of existing striping and RPMs in-kind) and must include upgraded safety features over the existing striping. For two lane roadways allowing passing, a striping audit must be done to ensure the passing limits meeting the MUTCD standards. Both the centerline and edge-lines are expected to be upgraded, unless prior approval is granted by Caltrans staff in writing and attached to application.

Benefit-Cost

- Implementation of this treatment reduces crashes by 25%.
- 10 years of expected life.
- Estimated $4,000 (depends on number and length of segment, as well as striping material).
- Costs for implementing this strategy are nominal and depend on the number and length of segment as well as the striping material (paint, thermoplastic, etc.). This CM can be effectively and efficiently implemented using a systematic approach with numerous and long locations, resulting in low to moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R33. Install no-passing line.

Installed on roadways that have a high percentage of head-on crashes suggesting that many head-on crashes may relate to failed passing maneuvers. No-passing lines should be installed where drivers "passing sight distance" is not available due to horizontal or vertical obstructions. This treatment addresses all types of crashes that occur when drivers cannot differentiate the centerline markings between passing and no-passing area. This treatment only applies to crashes occurring within the limits of the new or extended no-passing zones.

R33 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 45%.
- 10 years of expected life.
- Estimated $2,000 (varies).
- When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, This treatment can be effectively and efficiently implemented using a systematic approach with numerous and long locations, resulting in low to moderate cost projects that are more appropriate to seek state or federal funding.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R34. Install centerline rumble strips/stripes.

Set up on center Line rumble strips/stripes can be used on virtually any roadway – especially those with a history of head-on crashes. This treatment addresses all types of crashes; but, specifically, it addresses head-on and side-swipe crashes by alerting drivers (using rumble strips) that occur while driving outside the travel lane. This treatment only applies to crashes occurring within the limits of the new rumble strips/stripes.

R34 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 20%.
- 10 years of expected life.
- Estimated $3,000 per mile.
- Costs for implementing this strategy are nominal and depend on the number and length of locations.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R35. Install edgeline rumble strips/stripes.

Shoulder and edge line milled rumble strips/stripes should be used on roads with a history of roadway departure crashes. This treatment address run-off road crashes by providing an auditory indication (through a rumble strip) and tactile rumble when driver on, alerting drivers drifting out of their travel lanes. This treatment only applies to crashes occurring within the limits of the new rumble strips/stripes.

Benefit-Cost

- Implementation of this treatment reduces crashes by 15%.
- 10 years of expected life.
- Estimated $3,000 per mile.
- Costs for implementing this strategy are nominal and depend on the number and length of locations.
- Eligible for 100% of federal funding.

sources: CA-Local Roadway Safety Manual

R35 IMPLEMENTATION

R36. Install bike lanes.

Roadway segments noted as having crashes between bicycles and vehicles or crashes that may be preventable with a buffer/shoulder. This type of CM addresses both pedestrian and bicycle crashes and only applicable to "Ped & Bike" crashes occurring within the limits of the class II (not class III) bike lanes. When an off-street bike-path is proposed that is not adjacent to the roadway, the applicant must document the engineering judgment used to determine which "Ped & Bike" crashes to apply.

Benefit-Cost

- Implementation on this treatment reduces crashes by 35%.
- 10 years of expected life.
- Estimated $100,000 (varies).
- It is most cost efficient to create bike lanes during street reconstruction, street resurfacing, or at the time of original construction.
- Eligible for 90% of federal funding.

Example Location(s)

- Military E and E 5th Street, Benicia

sources: CA-Local Roadway Safety Manual

EXISTING CONDITIONS

R36 IMPLEMENTATION

R37. Install sidewalk/pathway (to avoid walking along roadway).

Suitable for areas noted as not having adequate or no sidewalks and a history of walking along roadway pedestrian crashes. In rural areas asphalt curbs and/or separated walkways may be appropriate. This treatment addresses pedestrian and bicycle crashes by providing sidewalk and walkway people to travel within the public right-of-way that is separated from roadway vehicle. This treatment only applies to "Ped & Bike" crashes occurring within the limits of the new walkway. Also this treatment is not intended to be used where an existing sidewalk is being replaced with a wider one, unless prior Caltrans approval is included in the application. Lastly, when an off-street multi-use path is proposed that is not adjacent to the roadway, the applicant must document the engineering judgement used to determine which "Ped & Bike" crashes to apply.

Benefit-Cost

- Implementation of this treatment reduces crashes by 80%.
- 10 years of expected life.
- Estimated $200,000 (varies type of project).
- Costs for sidewalks will vary, depending upon factors such as width, materials, and existing of curb, gutter and drainage.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R38. Installed pedestrian crossing (with enhanced safety features).

Set up on roadway segments with no controlled crossing for a significant distance in high-use mid-block crossing areas and/or multilane roads locations. This treatment addresses both pedestrian and bicycle by adding the following: curb extensions, raised medians, beacons, and lighting, combined with pavement markings delineating a portion of the roadway that is designated for pedestrian crossing. This treatment is not intended to be combined with the "install raised pedestrian crossing" when calculating the improvement's B/C ratio. Also, this treatment is not intended to be used for high-cost aesthetic enhancements to intersection crosswalk (i.e. stamped concrete or stamped asphalt). Lastly, this treatment only applies to "Ped & Bike" crashes occurring in the influence area (expected to be a maximum of within 250') of the new crossing which includes new enhanced safety features.

Benefit-Cost

- Implementation of this treatment reduces crashes by 30%.
- 10 years of expected life.
- Estimated $200,000 varies on extent of treatment.
- Costs associated with this strategy will vary widely, depending on the extent of the curb extensions, raised medians, flashing beacons, and other pedestrian safety elements that are needed with the crossing. When considered at a single location, these improvements can sometimes be low cost and funded through local funding by local crews.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R39. Installed raised pedestrian crossing.

Install on lower-speed roadways, where pedestrians are known to be crossing roadways that involve significant vehicular traffic. This treatment addresses pedestrian and bicycle crashes by enhancing pedestrian safety at locations noted as being especially problematic. Special requirements may apply and extra care should be taken when considering installing raised crossings to ensure unintended safety issues are not created, such as: emergency vehicle access or truck route issues.

R39 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%.
- 10 years of expected life.
- Estimated $50,000 (varies).
- Cost varies on elements of the raised crossing and the need for a new curb ramps and sidewalk modifications.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R40. Install Animal Fencing.

Installed at locations with high percent of vehicular/animal crashes (reactive) or where there is a known high percent of animals crossing due to migratory patterns (proactive). This treatment addresses animal type related crashes by adding fencing that channelize animals to a natural or man-made crossing. This treatment only applies to "animals" crashes occurring within the limits of the new fencing.

R40 IMPLEMENTATION

Benefit-Cost

- Implementation of this treatment reduces crashes by 80%.
- 20 years of expected life.
- Estimated $3,000 per installation.
- Costs will be fairly low but can increase greatly for longer segment lengths.
- Eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

R41. Install Truck Escape Ramp.

Roadways as identified as having a combination of heavy trucks and highway downgrades that present potentially dangerous conditions for truck drivers, other drivers on the road, and occupants of roadside property. This treatment addresses run-off and rear-end crashes that occur when runaway trucks generally result from brake failures which can arise for many different reasons. This treatment is not eligible due to the generally high costs and high impacts associated with it and the statewide goal to maximize the safety-effectiveness of the limited HSIP funding.

R41 IMPLEMENTATION

Benefit-Cost

- No information on CRF.
- 10 years of expected life.
- Estimated $500,000 per installation.
- Costs could be high given the constraints of the areas in which they would likely be constructed. Much is dependent on the scope of the project, available resources (right-of-way, etc.), and the determined specific parameters of the project.
- Not eligible for federal funding.

sources: CA-Local Roadway Safety Manual

R42. Installed pedestrian median fencing.

Put in roadway segments with high pedestrian-generators and pedestrian-destinations nearby (e.g. transit stops) may experience a high volume of pedestrians J-walking across the travel lanes at mid-block locations instead of walking to the nearest intersection or designated mid-block crossing. This type of treatment addresses bike and pedestrian crashes by adding pedestrian medians fencing that enhances pedestrian safety. This treatment only applies to Ped & Bike crashes occurring on the approaches/influence area of the new pedestrian median fencing.

Benefit-Cost

- Implementation of this treatment reduces crashes by 35%.
- 20 years of expected life.
- Estimated $3,000 (varies on placement of median).
- Costs associated with this strategy will vary widely depending on the type and placement of the median fencing.
- Only eligible for 90% of federal funding.

sources: CA-Local Roadway Safety Manual

Figure Links

S1a *https://www.aaroads.com/california/ca-238.html*
S1b *https://www.aaroads.com/california/ca-262.html*
S2a *http://santaclaritacitybriefs.com/2016/02/26/new-blue-light-traffic-enforcement-tool-installed-at-seven-intersections-throughout-santa-clarita/*
S2b *http://wishtv.com/2016/02/16/new-traffic-signals-aim-to-reduce-crashes/*
S3a *http://www.k-state.edu/roundabouts/ada/news/USNews.htm*
S3b *https://parade.com/19072/marilynvossavant/what-would-traffic-light-synchronization-cost/*
S4a *https://www.aaroads.com/forum/index.php?topic=1824.0*
S4b *http://www.advancedtraffic.com/products/wavetronix/smartsensor-advance/*
S5a *https://ops.fhwa.dot.gov/publications/fhwahop08024/chapter9.htm*
S6a *https://www.fhwa.dot.gov/publications/research/safety/09036/index.cfm*
S6b *http://www.madriverunion.com/samoa-boulevard-traffic-light-system-changed-up/*
S7a *http://www.mantecabulletin.com/archives/77790/*
S7b *http://www.trafficsignals.net/west.htm*
S8a *https://dohanews.co/qatars-civil-defense-junction-is-now-a-proper-intersection/*
S8b *http://www.gulf-times.com/story/461946/Ashghal-opens-signal-controlled-intersection-on-New-Rayyan-Road*
S9b *http://elteccorp.com/warning_systems/solar-powered-lighting-systems/*
S10a *http://www.health.com/weight-loss/traffic-light-calorie-label*
S10b *https://www.ticketsnipers.com/article/red-light-cameras-may-increase-traffic-tickets-at-local-intersection*
S11a *http://www.cochraneeagle.com/article/Cochrane-familes-celebrate-cultural-diversity-20170803*
S11b *https://rspcb.safety.fhwa.dot.gov/noteworthy/html/edccasestudy_ky.aspx*
S12a *http://www.jurist.org/hotline/2014/03/zachary-heiden-maine-panhandling.php*
S12b *https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec42.cfm*
S13a *https://bouldercolorado.gov/transportation/median-maintenance*
S13b *Unknown*
S14a *Unknown*
S14b *https://nacto.org/publication/urban-bikeway-design-guide/intersection-treatments/through-bike-lanes/*
S15a *Google Streetview*
S15b *Google Streetview*
S16a *Google Streetview*
S16b *https://www.flickr.com/photos/raymondyue/7130680785/sizes/l/*
S17a *https://www.flickr.com/photos/raymondyue/8299071442*
S17b *https://www.flickr.com/photos/raymondyue/7130680785/sizes/l/*
S18a *Unknown*
S18b *Google Streetview*
S19a *Google Streetview*
S19b *Unknown*
S20a *Unknown*
S20b *https://www.minnpost.com/cityscape/2014/07/everything-youve-always-wanted-know-about-crosswalks*
S21a *Google Streetview*
S21b *Google Streetview*
S22a *https://www.videoblocks.com/video/pedestrians-rushing-to-cross-the-road-in-front-of-a-driving-car-traffic-rules-stnhugi7ioq3cl48/*
S22b *https://psomas.com/services/pch-traffic-congestion-relief/*
S23a *http://sfcitizen.com/blog/2015/12/09/abbey-road-vs-post-street-even-the-long-haired-beatles-didnt-bring-along-chilrens-is-jaywalking-a-general-motors-conspiracy/*
S23b *http://erectionswa.com.au/products/ingal-pedestrian-barrier/*
NS1a *Google Streetview*
NS1b *Unknown*
NS2a *Google Streetview*
NS2b *http://www.ite.org/uiig/types.asp*
NS3a *http://www.ite.org/uiig/problems.asp*
NS3b *Unknown*
NS4a *https://www.flickr.com/photos/repowers/2933707788/*
NS4b *Unknown*

NS5a https://alchemistsdiary.wordpress.com/2017/07/22/
NS5b http://www.xwalk.com/pages/TS40-R5-1-Do-Not-Enter.htm
NS6a Unknown
NS6b http://www.pinsdaddy.com/signal-ahead-pavement-markings_pmmyKaBIkhEBxPhrBiiWMkFlQQFWhfqxyj3AuCoWiME/
NS7a http://www.ite.org/uiig/types.asp
NS7b http://www.renewa.es/renewa31/index.php/balizamiento/trafico/115-trafico/zonas-escolares/194-r829-semaforo-solar-zona-escolar
NS8a http://www.sfexaminer.com/stop-signs-installed-at-marina-intersection-where-driver-struck-boys/
NS8b Unknown
NS9a http://www.cleveland.com/berea/index.ssf/2012/11/berea_changes_stop_sign_parkin.html
NS9b https://radiobintangsembilan.com/2016/03/07/hindari-kecelakaan-anak-sekolah-warga-minta-garis-kejut/
NS10a https://www.strongtowns.org/journal/2017/4/18/are-one-way-streets-really-that-bad
NS10b Unknown
NS11a https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec43.cfm
NS11b https://safety.fhwa.dot.gov/intersection/other_topics/fhwasa08008/ue3.cfm
NS12a http://www.jurist.org/hotline/2014/03/zachary-heiden-maine-panhandling.php
NS12b https://www.edmonton.ca/transportation/on_your_streets/neighbourhood-traffic-concerns.aspx
NS13a https://bouldercolorado.gov/transportation/median-maintenance
NS13b Unknown
NS14a Google Streetview
NS14b https://ux.stackexchange.com/questions/42867/how-does-the-projection-angle-of-road-arrows-change-drivers-expectations-of-the
NS15a https://en.wikipedia.org/wiki/Uncontrolled_intersection
NS15b http://www.mikeontraffic.com/left-turn-lane-design-factors/
NS16a https://www.vosizneias.com/36699/2009/08/13/new-jersey-undercover-police-to-enforce-pedestrian-crosswalks-rules/
NS16b http://njbikeped.org/helping-to-tame-multi-lane-crossings/
NS17b https://michigancompletestreets.wordpress.com/2014/01/21/mid-block-pedestrian-crossings-explained/
NS18b https://nacto.org/publication/urban-bikeway-design-guide/bicycle-boulevards/major-street-crossing/
NS19a http://www.ite.org/uiig/ada.asp
NS19b https://www.fhwa.dot.gov/publications/research/safety/10045/index.cfm
NS20a http://www.cochraneeagle.com/article/Cochrane-familes-celebrate-cultural-diversity-20170803
NS20b https://rspcb.safety.fhwa.dot.gov/noteworthy/html/edccasestudy_ky.aspx
R1a https://www.aaroads.com/california/ca-238.html
R1b https://www.aaroads.com/california/ca-074.html
R2a Unknown
R2b Unknown
R3a Google Streetview
R3b Unknown
R4a Google Streetview
R4b https://www.reddit.com/r/funny/comments/4zcplq/a_local_plumbers_truck_decal/
R5a Unknown
R5b http://lslee.com/attenuators/Impact-Attenuators
R6a http://toolkit.irap.org/default.asp?page=treatment&id=57
R6b http://www.engr.uconn.edu/~garrick/ce371/l12-14.htm
R7a https://www.roadsbridges.com/lindsay-transportation-solutions
R7b https://www.fhwa.dot.gov/publications/publicroads/09mar/05.cfm
R8b https://www.hennepin.us/brownroadbridge
R9b https://safety.fhwa.dot.gov/intersection/other_topics/corridor/cam_tech/sa1500505.cfm
R10b https://safety.fhwa.dot.gov/intersection/other_topics/corridor/cam_tech/sa1500504.cfm
R11b http://modot.mo.gov/northeast/programs/generalintersectionetiquette.htm
R15 https://www.littlerock.gov/for-residents/bikeped-little-rock/projects/road-diets/road-diets-and-safety/
R16a Unknown
R16b http://ruraldesignguide.com/gallery
R18b http://gobiking.ca/ontario-rides/cycling-around-thunder-bay/

R19b *http://www.cahighways.org/137-144.html*
R25a *Unknown*
R25b *http://theasphaltpro.com/heres-how-to-build-a-safety-edge/*
R27b *https://www.fhwa.dot.gov/publications/research/safety/15030/009.cfm*
R28b *http://countyprogress.com/road-safety-101/*
R29b *https://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa15084/ch4.cfm*
R30b *https://www.fhwa.dot.gov/publications/publicroads/16marapr/04.cfm*
R31b *https://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/ch2.cfm*
R33b *https://content.govdelivery.com/accounts/ORDOT/bulletins/119b591*
R34b *http://www.ct.gov/dot/cwp/view.asp?a=3199&q=526532*
R35b *https://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/bike_ig/*
R36a *http://www.latimes.com/politics/la-pol-sac-enviro-bike-lanes-20160407-story.html*
R36b *http://moderntransit.org/expy/pa.html*
R39b *https://www.arrivealive.co.za/Traffic-Calming-Speed-Calming-and-Road-Safety*
R40b *http://www.henrycoate.co.uk/RCsite/HIGHWAYS%20AND%20RAILWAY%20FENCE%20SYSTEM.html*
R41b *https://www.autoevolution.com/news/runaway-truck-ramps-the-speed-killers-20432.html*

B METHODOLOGY

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MEMORANDUM

DATE: October 4, 2017

TO: Anthony Adams, Solano Transportation Authority

FROM: Josh Pilachowski, DKS Associates
Benjamin Rady, DKS Associates
Bobby Sidhu, DKS Associates

SUBJECT: STA Travel Safety Plan - Systemic Project Grouping Methodology

The purpose of this memorandum is to describe the methodology used to compile a list of projects for a countywide treatment package. Treatment packages are based on funding available from the Highway Safety Improvement Program (HSIP). As per the *HSIP Guidelines*, it is the intent of the HSIP program that federal funds be expended on safety projects that can be designed and constructed expeditiously. As long as a specific safety problem is identified and the proposed countermeasure addresses that condition, projects are eligible to receive funding. All proposed projects must lead to and complete the construction of safety improvements. The maximum federal HSIP reimbursement about for a single HSIP project is $10 million; if a project exceeds this limit, the remaining costs are to be covered by the project sponsor.

Locations identified to be included in treatment packages are at hot-spot intersections, ramps, or along corridors that have crash trends determined to be common throughout the system. Improvements include countermeasures to crash trends divided into the following treatment packages: improve visibility and operations of signals, improve visibility at stop-controlled intersections, improve pedestrian facilities at unsignalized intersections, improve visibility at signalized ramps, and improve visibility at unsignalized ramps. Not all locations selected to be included in a treatment package have a high individual benefit-cost ratio, this is due to the averaging of all location benefit-cost ratios for a given package. Using this methodology, a higher benefit-cost ratio at one location raises the average such to include an intersection with a ratio below the threshold.

INTERSECTION CHARACTERISTICS

To best determine the intersections that would most benefit from treatments, all intersections that define the “safety segments” were identified. Each intersection was analyzed to determine a series of characteristics intended to aid in the determination of potential treatments. Characteristics noted include, but are not limited to: control type, type of crosswalk, number of lanes on minor and major streets, left turn phasing, the presence of medians and bicycle

facilities. Characteristics were then used to classify all intersections into archetypes to be used later in the process in determining treatments for additional intersections with a high number of crashes, or “hot-spots”.

TREATMENTS

A series of five treatment packages were determined by organizing similar treatments (countermeasures) into groups associated with applicable funding sources:

Improve Visibility and Operations of Signals

- **Countermeasure ID S2** – Improve signal hardware: lenses, back-plates, mounting, size and number of heads. Applicable at signalized intersections with a high frequency of right-angle and rear-end crashes because drivers are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. Providing better visibility of intersection signals aid the drivers’ advance perception of the upcoming intersection. Installation costs and time should be minimal as these improvements often do not require the approval process normally associated with more complex projects.
- **Countermeasure ID S3** – Improve signal timing: coordination, phasing, clearance intervals. Signalized improvements may include adding phases, lengthening clearance intervals, eliminating or restricting higher-risk movements, and coordinating signals at multiple locations. Typically, these are low-cost improvements to multiple signalized intersections that can be implemented in a short period of time.

See *Appendix A* for a sample conceptual treatment.

Improve Visibility at Stop-Controlled Intersections

- **Countermeasure ID NS5** – Install/upgrade larger or additional stop signs or other intersection warning signs. The target for this strategy are approaches to unsignalized intersections with patterns of rear-end, right-angle, or turning collisions. The visibility of intersections can be enhanced by installing larger regulatory and warning signs at or prior to intersections. Signing improvements do not require a long development process and can be implemented quickly.
- **Countermeasure ID NS8** – Install flashing beacons as advanced warning at unsignalized intersections. This strategy is effective at non-signalized intersections with patterns of crashes that could be related to lack of a driver's awareness of approaching intersection or controls at a downstream intersection. Advance flashing beacons can be used to supplement and call driver attention to intersection control signs. They require minimal development process, allowing them to be installed within a short time period.

See *Appendix B* for a sample conceptual treatment.

Improve Pedestrian Facilities at Unsignalized Intersections

- **Countermeasure ID NS16** - Install raised medians (refuge islands). Raised medians decrease pedestrian level of exposure and allow them to concentrate on crossing one direction of traffic

at a time. They are effective at intersections that have long pedestrian crossing distance, a higher number of pedestrians, or a crash history.

- **Countermeasure ID NS18** - Install enhanced pedestrian crossing. Unsignalized intersections with or without a marked crossing and significant vehicular traffic are ideal locations for this strategy. Incorporating advanced "yield" markings provide an extra safety buffer and can be effective in reducing danger to pedestrians.

See *Appendix C* for a sample conceptual treatment.

Improve Visibility at Signalized Ramps

- **Countermeasure ID S2** – Improve signal hardware: lenses, back-plates, mounting, size and number of heads. As described above.

See *Appendix D* for a sample conceptual treatment.

Improve Visibility at Unsignalized Ramps

- **Countermeasure ID NS1** – Add intersection lighting. Use this treatment at locations that have a disproportionate number of night-time crashes and do not currently provide lighting at the intersection or at its approaches. Providing lighting at an intersection, its approach, or both improves the safety of an intersection during night-time conditions by making drivers more aware, enhancing drivers' sight distance, and improving the visibility of non-motorists. Lighting projects can usually be completed relatively quickly, but usually require more than a year to implement due to the required provision of electrical power.
- **Countermeasure ID NS5** – Install/upgrade larger or additional stop signs or other intersection warning signs. As described above.

See *Appendix E* for a sample conceptual treatment.

All intersections identified in the previous step were revisited to determine the potential application of the treatments listed above. If all countermeasures in a funding source were determined to be feasible to implement at an intersection, that location was included in the benefit-cost analysis.

Benefit-Cost Ratios

The goal of this step was to compile a list of projects for countywide treatment packages with a B/C ratio (B/C) of 6.0 or higher.

Cost

The first step to determine a B/C ratio was to organize locations where a treatment package would apply. Treatments were assigned a high level planning cost per installation by considering Caltrans unit costs and projects with similar improvements. Annual costs for each treatment are calculated by dividing the treatment cost by a Caltrans provided life-cycle. For

example, the cost estimate to apply countermeasure NS8 (install flashing beacons as advance warnings) is $150,000 with a 10 year life-cycle; therefore, the annual cost is $15,000.

Benefit

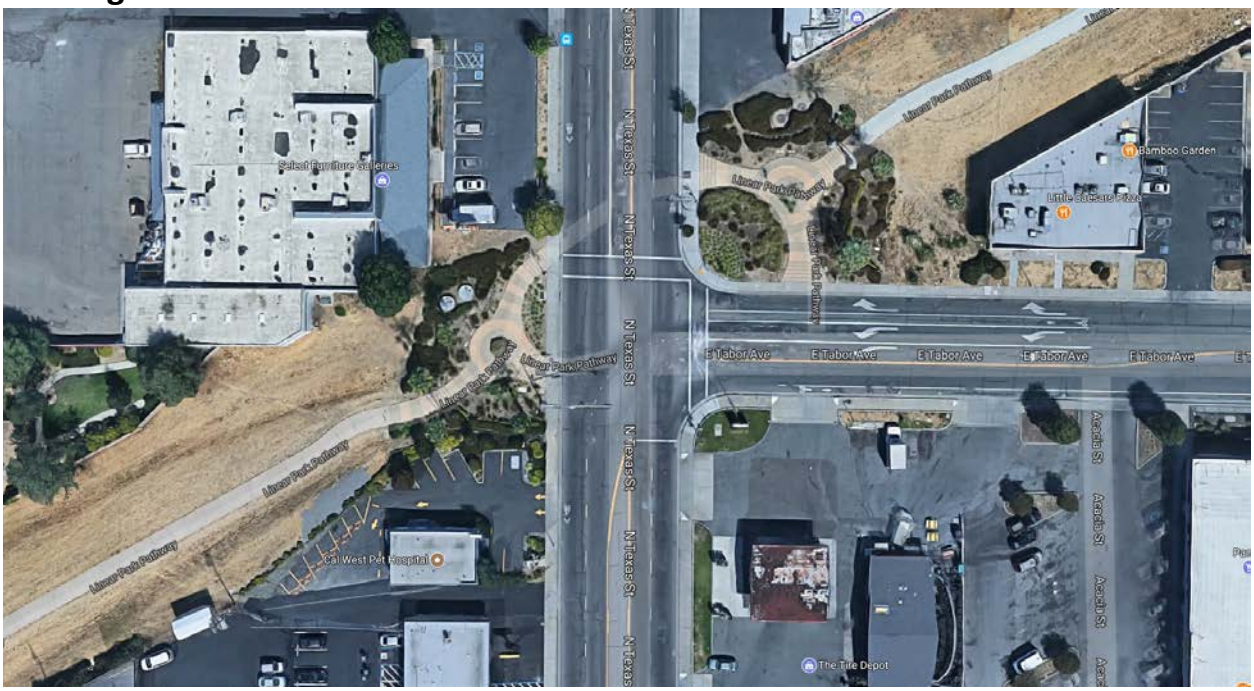
Each set of improvements identified as a treatment package has an expected crash reduction associated with it. Crash reduction factors (CRFs) are defined by Caltrans to describe a reduction in the expected number of crashes, based upon observed crash rates, that can be expected from the implementation of a set of safety based improvements. In this case, the total expected crash reduction is not the sum of the reduction expected from each improvement applied independently, but instead crash reduction factors are applied on top of each other, leading to a reduced effect for each one. A total cost for each location was calculated by taking the number of crashes reported over the past five years and applying a defined dollar amount to the number of crashes at each severity level. Benefit is then calculated as the dollar amount associated with the expected crash reduction. The total cost was then divided by the five years of crash data used to give an annual benefit.

B/C Ratios

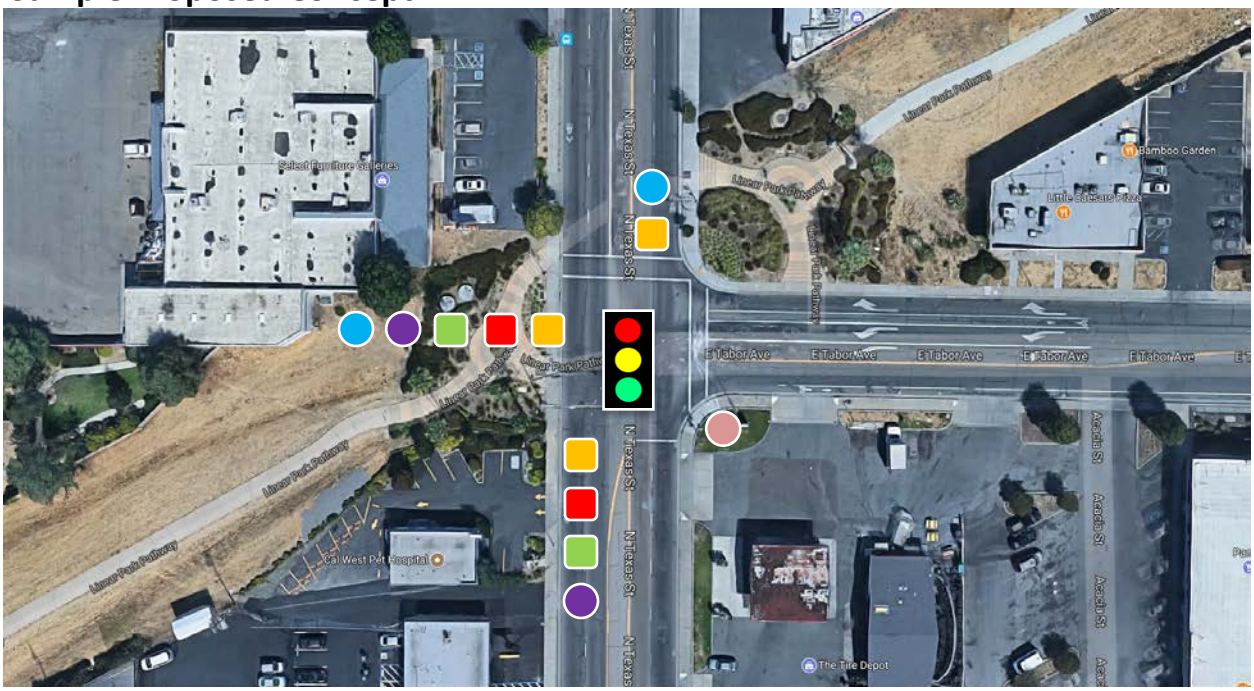
The B/C ratios for each treatment package are the location specific products of annual benefit divided by annual cost. The higher the B/C ratio for a location, the more cost effective it is to apply the treatment package. Effectively, higher B/C ratios are associated with a reduction in sever crashes and/or with low cost but effective improvements. The benefit from a systemic approach, is that we can group together several locations with the same treatment package and calculate the total benefit and total cost over many locations. Since HSIP funding is entirely dependent on B/C ratio, and awards are given to all applications that show a B/C ratio over a relatively consistent threshold, projects with B/C ratios significantly higher than that threshold represent wasted benefit. By combining many locations together with a range of B/C ratios, the locations with higher B/C ratios can essentially fund those with lower ones. To effectively maximize the potential funding, the locations are sorted by B/C ratio from largest to smallest and a cumulative B/C ratio calculated for the entire list so that the final B/C ratio remains above the threshold, but includes the maximum number of locations while doing so.

Appendix A: Improve Visibility and Operations of Signals

Existing



Sample Proposed Concept



Improvements

- CM ID S2
- CM ID S3
- Upgrade/replace signal lenses
- Replace signal back-plate
- Add signal head
- Modify phasing
- Increase clearance interval
- Upgrade controller cabinet

Appendix B: Improve Visibility at Stop-Controlled Intersections

Existing

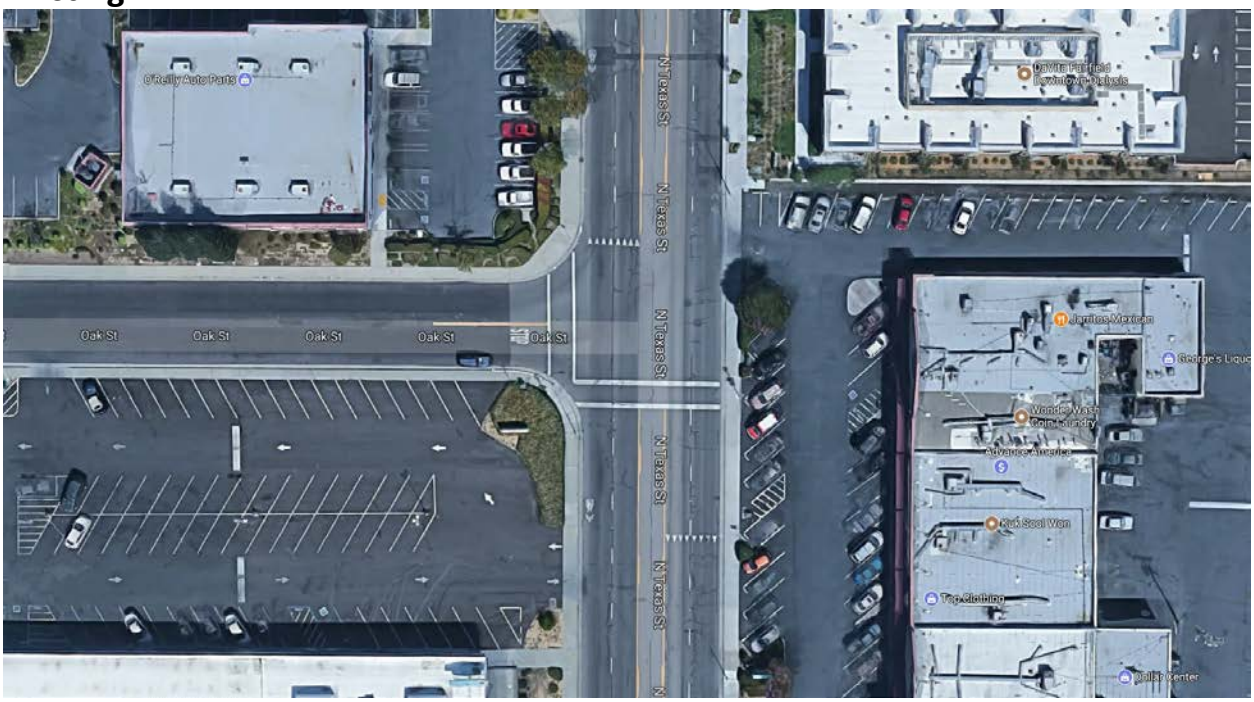
Sample Proposed Concept

Improvements

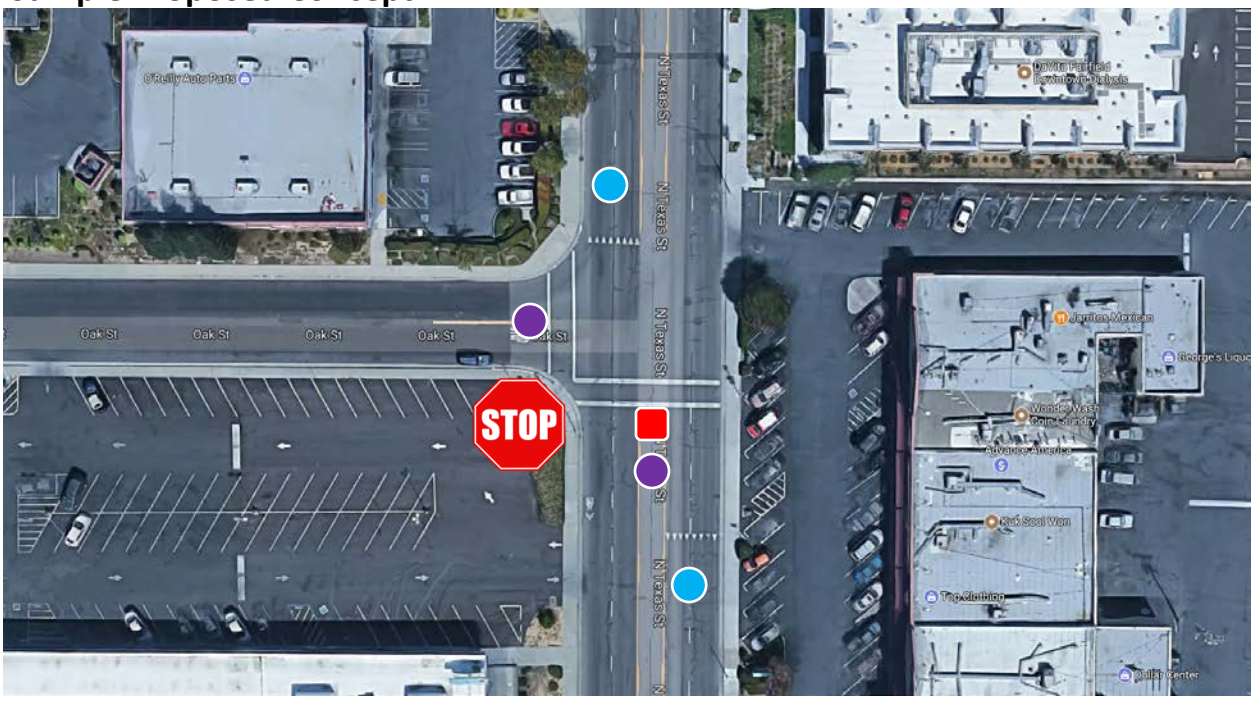
- CM ID NS5
- CM ID NS8
- Install larger stop sign
- Install intersection warning sign
- Install flashing beacon

Appendix C: Improve Pedestrian Facilities at Unsignalized Intersections

Existing



Sample Proposed Concept



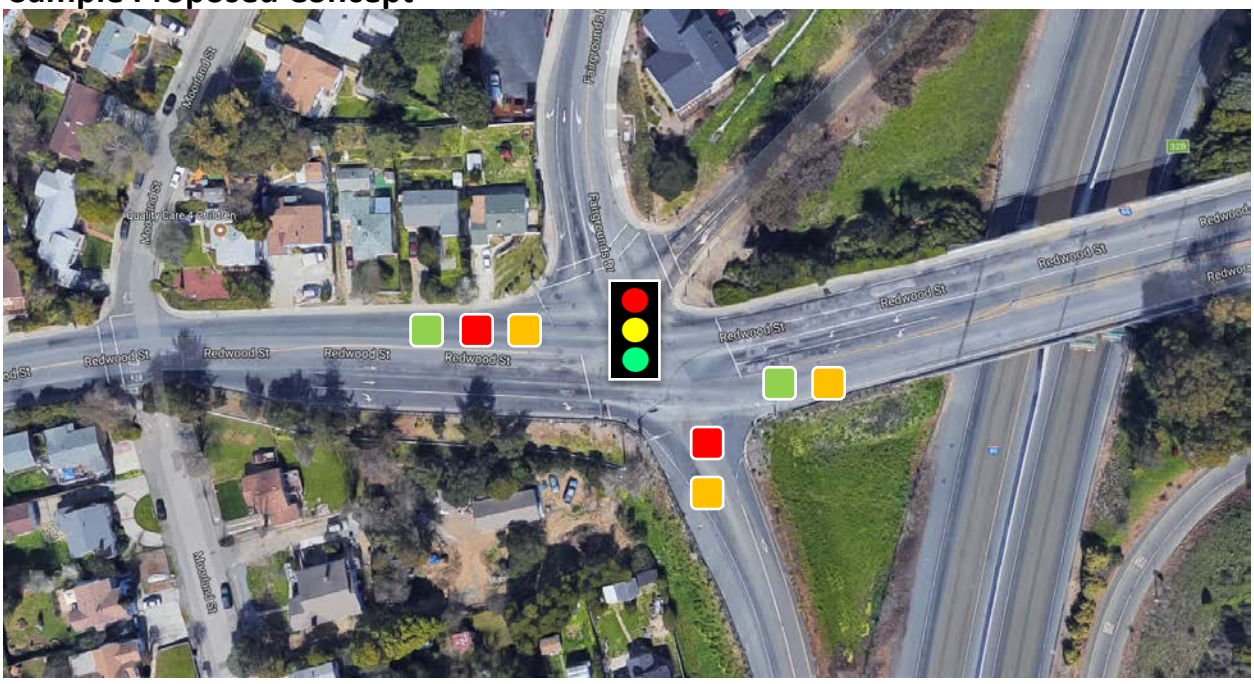
Improvements

- CM ID NS16
- CM ID NS18
- Install a raised median
- Install enhanced pedestrian crossing
- Install advanced yield markings

Appendix D: Improve Visibility at Signalized Ramps

Existing

Sample Proposed Concept



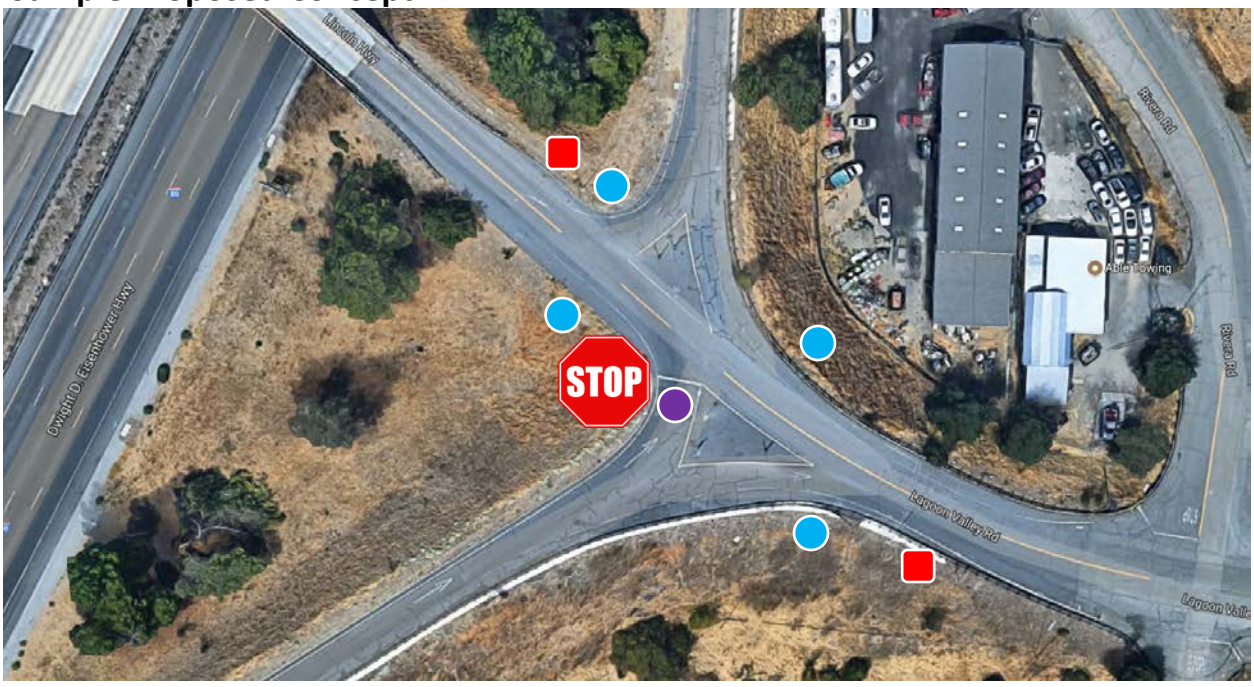
Improvements

- ☐ CM ID S2
- Upgrade/replace signal lenses
- Replace signal back-plate
- Modify Phasing

Appendix E: Improve Visibility at Unsignalized Ramps

Existing

Sample Proposed Concept



Improvements

- CM ID NS1
- CM ID NS2
- Add lighting
- Install larger stop sign
- Install intersection warning sign

C LITERATURE REVIEW

LITERATURE REVIEW

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DATE: June 13, 2017

TO: Anthony Adams | Solano Transportation Authority

FROM: Josh Pilachowski | DKS Associates
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Jean Senechal Biggs | DKS Associates

SUBJECT: 2017 Solano Travel Safety Plan: Background Information and Literature Review

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Background and Motivation

This memorandum provides a review of the current safety literature for standards of practice at the regional and local level, for current data collection and analysis methodology, and for presentation of materials. This review included the 2016 Solano Travel Safety Plan as well as Vision Zero plans, the California Strategic Highway Safety (SHSP) Plan, Highway Safety Improvement Program (HSIP) studies, and published research.

In addition to a review of the current literature, this memorandum also compares current data collection and analysis methodology best practices to the capabilities of Solano County and city agencies within Solano County. This comparison has been done to identify the steps that Solano County would need to take to be able to conduct safety research that is in alignment with the current state of practice and to identify existing opportunities to meet those needs through either the 2017 Solano Travel Safety Plan or through setting future goals and policies for Solano County.

2016 Solano Travel Safety Plan

The 2016 Solano Travel Safety Plan was a continuation of an ongoing effort to document crash rates, recently completed and funded roadway improvements and enforcement programs, and potential funding sources for future safety projects. Previous plans were prepared in 1998 and 2005.

The 2016 plan, lacking comprehensive volume data, did not report crash rates and relied instead on the judgement and experience of local agency staff and local crash reports to identify priority locations and potential improvements. The 2016 plan did not include potential funding sources.

The 2016 plan did present fatality and injury rates, the effect of crashes in economic and societal (monetary) cost, vehicle hours of delay and greenhouse gas emissions. The plan was automobile-oriented and covered the differences between automobile collisions and collisions with cyclists and pedestrians. It then presented a list of completed projects by jurisdiction and location in a table as well as with regional and local maps.

The majority of the 2016 plan was organized by jurisdiction and presented a list of 76 priority locations and proposed improvements supported by a description of the safety issue identified, a broad estimation of cost, and a map of the identified locations. Each of the seven cities and unincorporated county area provided the procedure for identifying priority locations, which included resident input, committees and collision/volume data where available.

Literature Review

The following sections summarize relevant findings of published literature related to data-driven, systemic safety analysis methods including the Highway Safety Manual (HSM), national guidance documents, example projects, and other useful resources.

What is Systemic Safety Analysis?

The Federal Highway Administration (FHWA) describes systemic safety analysis as a three-step approach to reducing the frequency and severity of crashes on the nation's roadways. The first step is to identify the crash types and characteristics that are contributing to the occurrence of fatal and serious injury crashes. The goal of this step is to identify the underlying characteristics, or "risk factors", that are related to high severity crashes across the network. The second step is to identify appropriate countermeasures for mitigating the prevalent risk factors. These countermeasures are typically low-cost strategies that have been proven to reduce the risk of specific types of crashes. The final step is to develop a list of locations that have one or more of the identified risk factors and deploy the most cost-effective countermeasures at those locations. (1)

There are multiple benefits to taking a systemic approach to safety analysis (2).

- More effective at improving system-wide safety performance than addressing a small number of hot-spot locations in isolation.
- A proactive approach that aims to prevent future crashes from occurring rather than waiting to treat locations based on a history of serious crashes.
- Can be tailored to address agency-specific priorities (e.g., rural two-lane highways or mid-block pedestrian crashes).
- Data-driven and can be applied with a broad range of data availability.

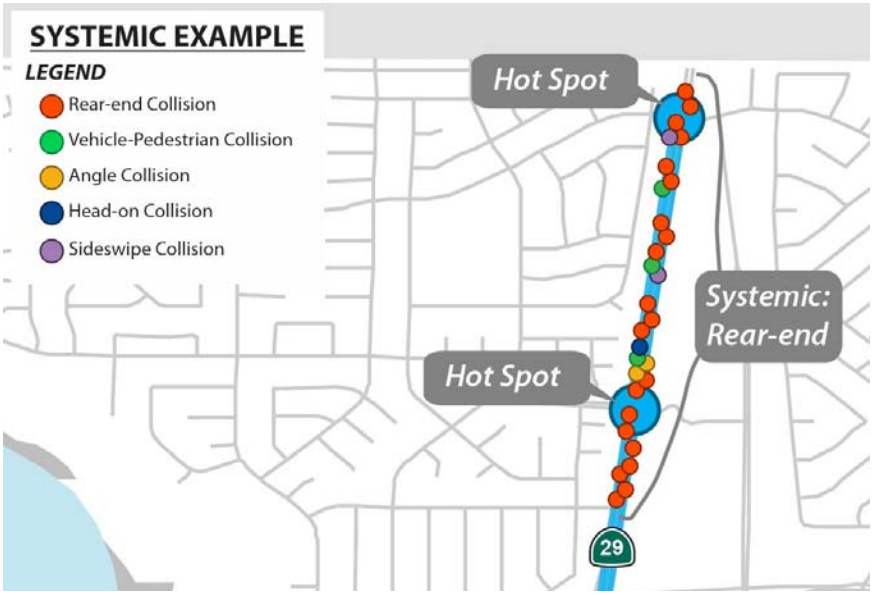

Figure 1. Example of Systemic vs. Hot-Spot Location Identification

Demonstrated Benefits

Missouri DOT used the concepts in the Systemic Safety Project Selection Tool to evaluate a systemic project they developed and implemented (3). They observed that implementing edge-line markings along 570 miles of rural highway proved effective according to a "before vs. after" evaluation. The evaluation results showed a 15-percent reduction in total expected crashes and a 19-percent reduction in severe expected crashes. Crash data collected after the project provided proof that implementing low-cost countermeasures on low-volume roads with low-crash frequency and density yields a reduction in crashes.

Many other jurisdictions have used a systemic approach to identify crash types and countermeasures to prepare grant applications, but the effectiveness of those projects have not yet been quantified or published. However, there are also benefits to the systemic approach outside of crash reductions. In Thurston County, Washington, the experience of working with Washington State DOT to apply to the systemic tools provided

County staff an opportunity for greater involvement in Strategic Highway Safety Planning (SHSP) activities (4). The New York State DOT found the systemic tools to be flexible enough to be applied by NYSDOT staff in a central location and disseminated to region staff or to be applied by region staff at the local level, allowing for flexibility and efficiency in staffing (5). Analysis Methods and Data Needs

Local, state, and federal agencies have been evaluating the safety performance of roadways for decades. Analysis methods have evolved drastically over the years as the availability and accuracy of crash data has improved and as the industry's knowledge of crash patterns, human behavior, and statistical applications have expanded.

The HSM, published in 2010, is the first national guidance document that outlines recommendations for comprehensive and quantitative safety analysis procedures (6). Table 1 summarizes the data needs for a variety of safety performance measures that can be applied to systemic and hot-spot safety projects.

Table 1. Safety Performance Measures and Data Needs (Adapted from Table 4-1 of the Highway Safety Manual)

Performance Measure	Data Needs and Inputs				
	Crash Data	*Roadway Information for Categorization*	*Traffic Volume*	*Calibrated SPF*	*Other*
Average Crash Frequency	x	x			
Crash Rate	x	x	x		
Equivalent Property Damage Only (EPDO) Average Crash Frequency	x	x			x
Relative Severity Index	x	x			x
Critical Rate	x	x	x		
Excess Predicted Average Crash Frequency Using Method of Moments	x	x	x		
Level of Service of Safety	x	x	x	x	
Excess Predicted Average Crash Frequency Using Safety Performance Functions	x	x	x	x	
Probability of Specific Crash Types Exceeding Threshold Proportion	x	x			
Excess Proportion of Specific Crash Types	x	x			
Expected Average Crash Frequency with EB Adjustment	x	x	x	x	
Equivalent Property Damage Only (EPDO) Average Crash Frequency with EB Adjustment	x	x	x	x	x
Excess Expected Average Crash Frequency with EB Adjustment	x	x	x	x	

As shown in Table 1, there are five performance measures that can be evaluated using only basic crash and roadway information and without the need for the traffic volume data that is often unavailable and costly to obtain on local roadways. The strengths and limitations of each of those performance measures, as outlined in the HSM (6), are summarized below.

Crash Frequency: This is the simplest performance measure and accounts for only the number of crashes at a site. It does not account for exposure (traffic volume) or regression to the mean (RTM) bias, cannot identify sites with more or less crashes than similar sites, and will fail to identify low-volume, high-severity sites that would benefit from low-cost treatments. *Takeaway: Suitable for systemic safety analysis, with limitations.*

EPDO Average Crash Frequency: This performance measure combines crash frequency and severity through a weighting factor (typically based on relative societal crash costs). This evaluation process is simple and accounts for both crash frequency and severity. However, it does not account for exposure (traffic volume) or RTM bias, may exaggerate the significance of sites with a low frequency of high severity crashes, and cannot identify sites with more or fewer crashes than similar sites. *Takeaway: Suitable for systemic safety analysis, with limitations.*

Relative Safety Index (RSI): This performance measure uses jurisdiction-specific costs that are assigned to crashes based on type and location. The resulting relative safety indices are used to rank individual sites against the population RSI. The evaluation process is simple and considers both crash type and crash severity. It does not account for exposure (traffic volume) or RTM bias, can exaggerate the significance of sites with a low frequency of high severity crashes, and can mistakenly prioritize low-volume sites with low crash frequency. *Takeaway: Suitable for systemic safety analysis only if all RSI costs are consistent across locations and if the greater population RSI scores are known.*

Probability of Specific Crash Types Exceeding Threshold Populations: This performance measure prioritizes locations based on the probability that the true proportion of a crash type or severity is greater than the threshold proportion. It can be used as a diagnostic tool, accounts for data variance, and is not affected by RTM bias. However, it does not account for exposure (traffic volume), the analysis results can be skewed by unusually low crash type frequencies, and it requires detailed statistical analysis of a reference population larger than the study population. *Takeaway: Not suitable for systemic safety analysis without first determining true population crash type and severity distributions.*

Excess Proportions of Specific Crash Types: This performance measure is very similar to the previous performance measure (Probability of Specific Crash Types Exceeding Threshold Populations) with identical data inputs, strengths, and limitations. *Takeaway: Not suitable for systemic safety analysis without first determining true population crash type and severity distributions.*

While a systemic safety analysis can be conducted with all levels of data availability – from aggregated (non-geocoded) crash data only to a comprehensive data set of crash records, roadway inventory, land use, traffic volumes, and more – using additional data will result in a more accurate and complete assessment of crash risk factors (7). A complete list of crash risk factors can only be developed if the available data set includes all possible contributing factors (environment, roadway, vehicle, and participant). However, simply having the necessary data on-hand may not be sufficient. Depending on the size of the jurisdiction or system being evaluated, even with a variety of data types it may not be feasible to conduct a thorough analysis if the information is not in a compatible format and level of detail. For example, a GIS database of detailed roadway inventories will not be useful if the crash data excludes geo-location information and cannot be spatially tied to precise roadway characteristics. Gaps in the availability and usability of crash data, roadway data, and non-traditional data sets are a roadblock to a holistic view and approach to safety (8).Resources for Conducting Systemic Safety Projects

Highway Safety Manual

The HSM provides comprehensive guidance on the standard of practice for safety analysis methodologies and their applications. The HSM describes the life-cycle safety management process in six steps, all of which correspond directly to standard systemic and hot-spot safety analyses, as summarized below.

Step 1 – Network Screening (HSM Chapter 4): Uses one or more performance measure(s) and screening method(s) to identify sites that are best suited for safety improvements.

Step 2 – Diagnosis (HSM Chapter 5): Provides guidance on identifying the factors that contribute to common crash patterns.

Step 3 – Countermeasure Selection (HSM Chapter 6): Contains useful information for identifying the treatments that are most likely to improve safety performance based on the crash patterns diagnosed in Step 2.

Step 4 – Economic Appraisal (HSM Chapter 7): Provides guidance on the proper methods for evaluating the cost effectiveness of implementing a given safety improvement.

Step 5 – Project Prioritization (HSM Chapter 8): Outlines the recommended procedures for prioritizing projects through one of three methods; economic effectiveness measures, benefit-cost rankings, or optimization.

Step 6 – Safety Effectiveness Evaluation (HSM Chapter 9): Provides guidance for evaluating the true effectiveness of a countermeasure after it has been implemented, including both observational and experimental studies.

CMF Clearinghouse

The HSM includes detailed discussions of a variety of the most commonly applied countermeasures and their associated crash modification factors (CMFs) and crash reduction factors (CRFs) which represent the expected change reduction in crash frequency after implementation of a given countermeasure. A companion resource to the HSM is the CMF Clearinghouse, a free online database of countermeasures, CMFs, CRFs, and details of the supporting research studies. The CMF Clearinghouse database is updated regularly and currently includes over 6,000 CMFs (9).

NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

In response to AASHTO's Strategic Highway Safety Plan, the National Cooperative Highway Research Program (NCHRP) developed a series of guidance documents aimed at helping local and state agencies improve the safety performance of their roadways (10). Each guide serves as a comprehensive resource for addressing specific crash patterns or emphasis areas (including speeding, younger drivers, older drivers, work zones, bicyclists and pedestrians, roadway departure, signalized intersections, driving under the influence, and many others).

NCHRP Report 500 also includes a guidance document focused on safety data and analysis techniques. It outlines different methodologies for implementing strategic safety plans depending on the level of crash data and roadway data that is available.

Caltrans Local Road Safety Manual

The Caltrans Local Road Safety Manual (LRSM) provides information and support to local agencies who wish to proactively address safety performance issues and compete for funding as part of statewide, data-driven calls for projects (11). The Proactive Safety Analysis process outlined in the LRSM is based on the six-step safety management process outlined in the HSM (summarized previously). While the underlying methodologies are the same, the LRSM presents the process in a less-technical manner that is geared toward implementation of a streamlined, consistent HSIP application process without explanation of the underlying theory. It presents detailed requirements for each stage of the process, including data sources, analysis techniques, countermeasure selection, benefit-cost evaluations, and project prioritization.

The LRSM includes a list of 77 pre-approved countermeasures that should be used through the Caltrans HSIP call for projects. Although applications for HSIP funding must utilize only the listed countermeasures, agencies are encouraged to consider other treatments with documented safety benefits (e.g., those in the CMF Clearinghouse) for projects with non-HSIP funding sources.

Transportation Safety Planning: State of the Practice

The goal of eliminating or reducing death and serious injuries on roadways is becoming more common in transportation safety planning at both the state and local level. Vision Zero, Towards Zero Deaths, and Road to Zero are some of the names that transportation agencies are using to describe this goal. Approaches typically include multi-modal, system wide, collaborative, data-driven approaches to decision-making.

Safety plans are now more often using data to identify high crash corridors and intersections. Rich, geo-coded data can analyze roadway, environmental and land use conditions that contribute to crashes. With data, planners can find patterns and trends that contribute to crashes, identify needs, prioritize projects, and predict outcomes. (See San Francisco's *High Injury Network* maps (12) and *Vision Zero Priority Projects* maps (13).)

Performance measures, specific targets, and feedback loops are often included in safety plans as data availability and analysis tools are more available to evaluate outcomes of infrastructure, education and enforcement efforts. New online tools with esri's ArcGIS make live maps a resource for decision-makers, staff, and the public to view and analyze crash data. (See Portland's Vision Zero story map on *Esri's "Maps We Love" website* (14).)

Outside of Vision Zero efforts, safety planning is often included in other planning efforts such as modal plans (bicycle, pedestrian, transit, freight), Safe Routes to Schools plans, complete streets plans, road diets, and traffic calming plans. As HSIP funding has become widely available to state, county and local jurisdictions, the application of systemic approaches to identifying countermeasures to reduce crashes and calculating their potential effectiveness more widespread.

FHWA's *Roadway Safety Noteworthy Practices* database (15) is an online resource that features reports from across the country on a variety of safety topics including transportation safety planning, data collection and analysis, HSIP funding, Strategic Highway Safety Plans and Systemic Safety Improvements.

FHWA's *Transportation Safety Planning* website (16) also has resources and tools, including a 2016 guide on how to improve safety through coordination between planning and safety practitioners and a 2009 primer on safety performance measures for the transportation planning process.

FHWA and the Roadway Safety Foundation recognize roadway safety achievements that help reduce fatalities and serious injuries through the *National Roadway Safety Awards* (17). The awards acknowledge successful engineering solutions that agencies have integrated into their roadway safety programs.

California’s HSIP Application and Evaluation Tool for Local Roadways won a National Roadway Safety Award in 2011. With the goal of making the local roadway HSIP entirely data driven, CalTrans, in partnership with University of California Berkeley’s Safe Transportation Research and Education Center and members of California’s Strategic Highway Safety Planning team, developed a user-friendly HSIP Tool that makes fair and reliable statewide project selections following Federal guidelines for proven safety countermeasures.

Other nationally-recognized winners of the awards program include:

- Minnesota County Road Safety Plans (2011)
- California’s HSIP Application and Evaluation Tool for Local Roadways (2011)
- Idaho: Highway Safety Corridor Analysis Project (2013)
- New Jersey: Road Safety Audits – Engineering Guidance for Fatality Reduction (2013)
- Louisiana: South Central Regional Transportation Safety Plan (2013)
- Michigan: usRAP Safety Improvement Plan for County Roads in Genesee County (2013)
- Deployment of HSIP Projects Using Virginia-Specific Safety Performance Functions (2015)

Information about each of these winning projects can be found in the Noteworthy Practice Guides published online by FHWA in 2011 (18), 2013 (19) and 2015 (20).

Examples of Systemic Safety Projects

Systemic safety studies have been completed around the world on both large (nation-wide) and small (corridor-level) scales. The following sections summarize two of the most well-known systemic safety approaches in the United States: Vision Zero and Strategic Highway Safety Plans.

Vision Zero

The term “Vision Zero” was first used by the Swedish parliament in 1997 to describe their nationwide goal of eliminating (i.e. reducing to zero) crashes that result in fatal or severe injuries by the year 2020 (21). Since then, numerous countries have followed suit and implemented their own Vision Zero plans, including the Netherlands, the United Kingdom, Canada, and the United States, among others. Within the US alone, over 40 cities have a Vision Zero strategy in place or are considering developing a Vision Zero plan, as shown on Figure 2.

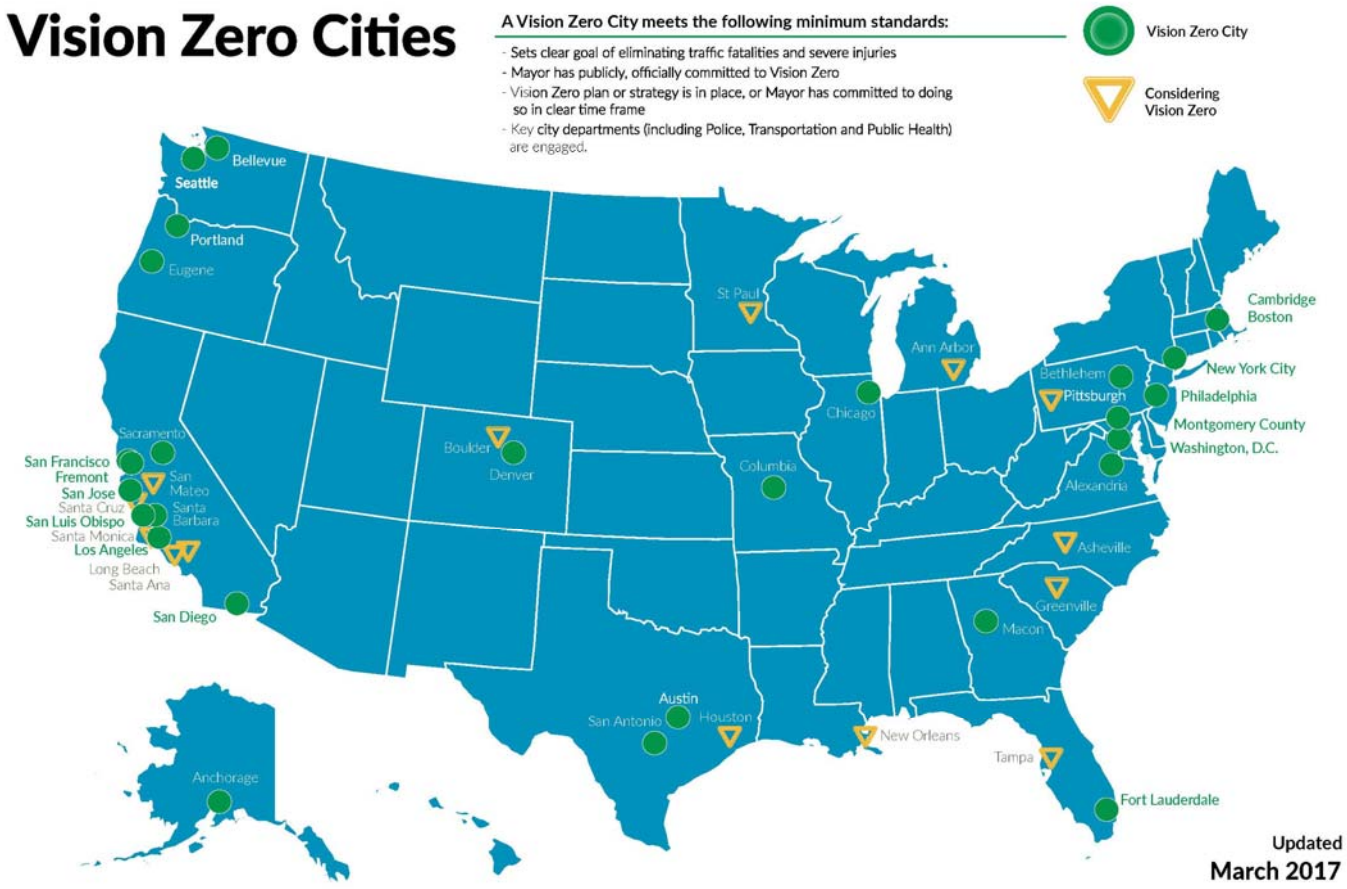

Figure 2. Map of US cities that are considering or have implemented a Vision Zero Plan (21)

The Vision Zero concept is one of the most familiar and widely-implemented systemic safety approaches in the United States. It provides a framework for cities to make a commitment to eliminating roadway fatalities and serious injuries. The approach uses a ten-year timeline and institutes a collaborative process that brings stakeholders including elected officials, public agencies, and non-profit community partners together to reach the goal. The key elements that distinguish a Vision Zero strategy from traditional traffic safety techniques (21) are presented below.

- Reframing traffic deaths as preventable
- Focusing on system failure
- Reducing the impact of collisions
- Adopting a Safe System approach
- Data-driven decision making
- Road safety as a social equity issue

The Vision Zero concept is a commitment to data-driven, systemic safety analysis as the basis for developing strategies and action plans. It should be noted that "system" in a Vision Zero context is quite broad and encompasses all aspects of traffic safety, from local infrastructure to national policies.

New York City's Vision Zero Action Plan (22) was released in 2014 and outlines 63 separate initiatives by city agencies to reduce death and serious injuries on city streets. More initiatives have been added since then. Initiatives are focused in five areas: street design, outreach, enforcement, legislation, and campaigns. The latest Vision Zero statistics for 2017 show a 12 percent decline in traffic fatalities (69 compared to 78 by this date in 2016) and a 17 percent decrease in pedestrian deaths (46 in 2016 compared to 38 in 2017). New York City is using GIS to track and monitor crash data city-wide, alongside maps that show where street design efforts are underway. *Vision Zero View maps* (23) allow users to access live maps that show injury and fatality crashes by mode for each year, going back to 2009. New York City plans to invest a total of $1.6 billion in Vision Zero over the next five years.

Queens Boulevard is an example of Vision Zero's success. Queens Boulevard, which had 22 traffic fatalities as recently as 1997, has not had a single traffic fatality in two and a half years, the same time DOT began the street's conversion into a Vision Zero Priority Corridor (24). In May 2017, Mayor Bill de Blasio announced further redesign and improvements to the street to improve safety.

The City of San Francisco, California adopted a Vision Zero policy in 2014 and in March 2017 released their latest two-year action plan (25) that identifies key projects and policy changes needed to meet the City's goal of eliminating fatal and severe injury crashes by 2024 (26). The two-year strategy, with the goal of creating measurable progress by the end of 2018, includes action items related to infrastructure design and improvements, improving driver safety training, developing safe routes to school programming, and promoting safer vehicle designs. Vision Zero SF has not had as strong results as New York City. Annual traffic fatalities remain at about 30 people per year since 2014 (27).

The City of Portland, Oregon adopted a Vision Zero policy and action plan in 2016, with the goal of eliminating fatal and serious injuries on the city's roadways by 2026 (28). The City's strategy focuses on providing safe streets for everyone, protecting the most vulnerable users, teaching Portlanders to live and travel together, and enforcing safe behavior on City streets. The action plan includes two-year and five-year actions and focuses on five main areas – street design, impairment, speed, dangerous behaviors, and education and accountability. The Portland Bureau of Transportation issues quarterly progress report with updates on the actions. (29) Annual reports will include data on traffic deaths and serious injuries. It's too soon since the launch of the plan to evaluate its effectiveness and progress.

Strategic Highway Safety Plans

In 1997, AASHTO published a Strategic Highway Safety Plan (SHSP) with the goal of significantly reducing deaths, injuries, and health care costs associated with crashes on the nation's highways (30). Through coordination with state and local agencies, national coalitions, research institutions, and members of the industry, AASHTO developed a plan that focuses on 22 specific safety emphasis areas. The SHSP provides background on each of the emphasis areas as well as strategies for addressing safety concerns.

Since the enactment of SAFETEA-LU legislation in 2005, all states are required to develop their own SHSP in order to qualify for HSIP funding. MAP-21, the federal transportation bill that followed SATETEA-LU continued both the HSIP program and the SHSP mandate. Additional requirements were added to strengthen the SHSP program such as increased stakeholder involvement, consideration of other safety factors, integration with other plans, use of effective safety strategies and countermeasures, and evaluation methods (31).

Nearly all states have taken a data-driven, systemic approach to identifying the unique safety concerns in their state. Caltrans' plan was most recently updated in 2015 and includes the following challenge (emphasis) areas to reduce fatalities and serious injuries on California roadways (31)

- Roadway Departure and Head-On Collisions
- Intersections, Interchanges, and other Roadway Access
- Work Zones
- Alcohol and Drug Impairment
- Occupant Protection
- Speeding and Aggressive Driving
- Distracted Driving
- Driver Licensing Competency
- Pedestrians
- Bicyclists
- Young Drivers
- Aging Road Users
- Motorcycles
- Emergency Medical Services

Comparing Approaches

There are subtle nuances between Vision Zero and SHSPs, although they share many of the same planning elements, including the following.

- Data-driven approaches to decision-making
- Coordination with other plans
- Outreach and involvement with other state and local agencies, and tribal governments across transportation, health, and public safety
- Performance measures, evaluation and reporting

Highway safety plans are also embracing the core tenets of Vision Zero. California's 2015-2019 Strategic Highway Safety Plan (32) is a statewide, coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and severe injuries on all public roads. In developing the plan, members of the Executive Leadership Team and the Steering Committee "felt strongly that Toward Zero Deaths (TZD) as the ultimate aspirational goal for the plan and that realistic and achievable steps should be set for California to move closer to zero deaths." (31) The plan sets goals for a three percent per year reduction in fatalities and a 1.5 percent per year reduction in serious injuries.

Implementing Systemic Approaches in California's Local Jurisdictions

The Caltrans Division of Local Assistance (DLA) manages California's local agency share of HSIP funds (33). California's Local HSIP focuses on infrastructure projects with nationally recognized crash reduction factors (CRFs). Local HSIP projects must be identified on the basis of crash experience, crash potential, crash rate, or other data-supported means.

HSIP Program Funding

Normally an HSIP call-for-projects (34) is made at an interval of one to two years. The applicant must be a city, a county, or a tribal government federally recognized within the State of California. The timing and size of the call is determined by the program apportionments, HSIP FTIP capacity and the delivery of the existing HSIP projects. HSIP Cycle 8, the most recent call for projects, was closed on August 12, 2016.

In 2016, Solano County was successful in their grant application for $2.029 million of federal HSIP funds to upgrade existing painted edge lines and centerlines to thermoplastic with raised pavement markers (RPMs) and thermoplastic markings for stop signs (35). The new pavement markings will be applied at various locations on public roadways throughout unincorporated Solano County. The project is focused on systemic improvements to address roadway departure and head-on collisions on 139 miles of roadways. Locations were identified after staff reviewed Traffic Collision Reports from the California Highway Patrol (CHP) and generated a report of all severity crashes. Staff found that many of the crashes that occurred between 2009 and 2013 involved cars running off the road and then striking roadside objects and ditches. Staff then evaluated the benefit of installing edge lines and centerlines on roadways using a Caltrans calculator, which confirmed the viability of the project and the potential for the County to have a winning HSIP grant application.

SSARP Funding

For smaller jurisdictions without the staff or data analysis resources to identify projects and prepare a grant application, the HSIP funds are out of reach. In 2016, to expand the reach of the program, Caltrans set aside $10 million from the HSIP program and exchanged for state funds to implement a new safety analysis program, the Systemic Safety Analysis Report Program (SSARP) (36). The intent of the program is to assist local agencies with funding to develop future HSIP and other safety program applications.

Jurisdictions applying for SSARP funds are encouraged to use the concepts in the Systemic Safety Project Selection Tool to identify projects. Grant funds can be used to perform collision analysis, identify safety issues on the roadway network, and develop a list of systemic low-cost countermeasures that can be used to prepare future HSIP and other safety program applications. The SSARP guidelines (36) describe a systemic approach that focuses on evaluating the entire roadway network and acknowledge that crashes alone are not always sufficient to prioritize countermeasures across a system.

Caltrans made SSARP calls for applications in two phases in February 2016 and April 2016. 108 applications were received requesting $17.6 million of state funds. After prioritization, 61 projects with a total of $10 million of SSARP state funds were selected for implementation. In January 2017, another $7.7 million of state funds was allocated by the California Transportation Commission (CTC) to fund the SSARP applications that were initially submitted in the 2016 SSARP calls for applications but were unfunded at that time due to funding limitations.

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