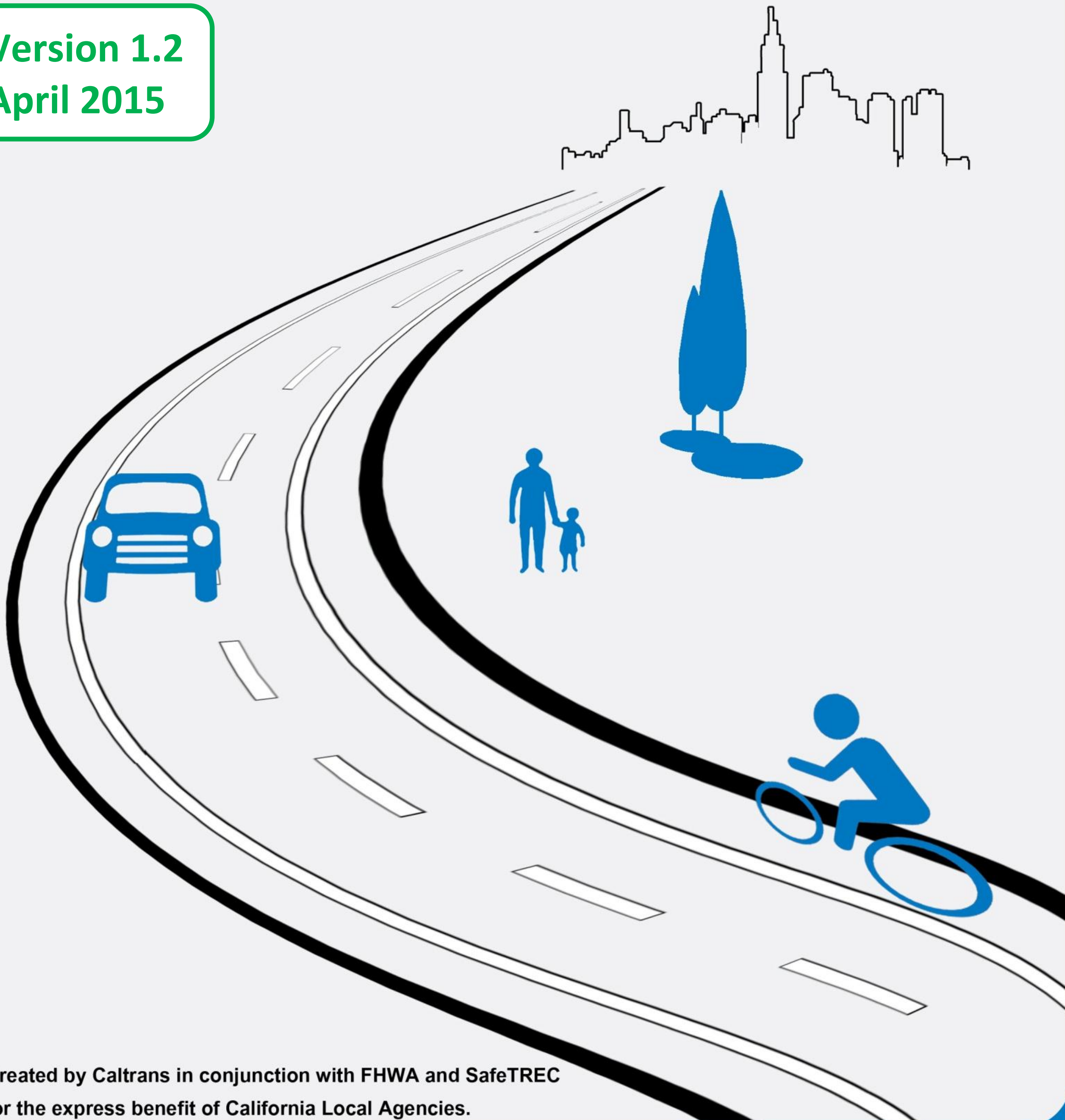
Local Roadway Safety

A Manual for California's Local Road Owners

Version 1.2
April 2015



Created by Caltrans in conjunction with FHWA and SafeTREC
for the express benefit of California Local Agencies.

Caltrans

U. S. Department of Transportation
Federal Highway Administration

Safe Transportation
Research & Education Center
SafeTREC

Document History

Version 1.0: 4/20/2012

The California Department of Transportation - Division of Local Assistance developed the first version of the Local Roadway Safety Manual (Version 1.0) in 2012 to support the Cycle 5 HSIP call-for-projects.

Version 1.1: 4/26/2013

Based on feedback and lessons learned from Cycle 5, Caltrans updated Appendix B: “Table of Countermeasures and Crash Reduction Factors” to better clarify text in “Where to use”, “Why it works”, and “General Qualities” for several of the countermeasures included in the original manual.

No other changes were made to the Local Roadway Safety Manual as part of Version 1.1

Version 1.2: 03/10/2015

Based on feedback and lessons learned from Cycle 6, Caltrans made minor updates to the text of the document as needed for achieve consistency with over Caltrans local HSIP guidance documents. The following sections were updated: 1.2, 4.2, 5.1, 6.2, and Appendix B, E, F & G.

Future Updates:

In the future, Caltrans anticipates that additional changes will be needed to keep the Local Roadway Safety Manual consistent with future Calls-for-Projects’ Guidelines and Application Instructions. In addition, new local HSIP programs, improvements to California data on local roadways, data analysis tools, and the latest safety research and methodologies may give rise to the need to make more significant changes to this manual.

Foreword

Why was this manual developed?

The California Department of Transportation - Division of Local Assistance's goal in developing this manual is to maximize the safety benefits for local roadways by encouraging all local agencies to proactively identify and analyze their safety issues and to position themselves to compete effectively in future Caltrans' statewide, data-driven call-for-projects.

This goal is complicated by California's wide variety of local agencies, roadway types, and project types, including: rural vs. urban, low-volume vs. high-volume, and intersection vs. roadway segment vs. network-wide. This variety makes it difficult to administer a single program and provide one set of guidelines that meets the needs of all California's local roadway owners and users. Many of California's local agencies are also challenged by the lack of a basic safety analysis framework and analysis tools specifically designed for local roadway managers with widely varying responsibilities and safety training. Currently, there is a vast range of safety documents, program guides, and analysis tools with a wide variety of complexity and applications. Without clear and simple safety guidance for locals, many agencies take a 'reactive' approach to safety, even when research has shown 'proactive' safety analysis of roadways is more effective in making system-wide safety improvements.

The Federal Highway Administration (FHWA) Office of Safety provides national leadership in identifying, developing, and delivering safety programs and products to local governments to improve highway safety on local and rural roads.[1] In 2010, FHWA published a set of three manuals designed specifically for rural road owners; Roadway Departure Safety, Intersection Safety, and Road Safety Information Analysis.[2] These manuals present a simple, data driven safety analysis framework for rural agencies across the nation. These manuals, in conjunction with Caltrans' ongoing short-term research and development contract with the Safe Transportation Research and Education Center (SafeTREC) at the University of California, Berkeley, provided a unique opportunity for Caltrans to pursue development of this document as a mirror of FHWA's new Manuals for Local Rural Road Owners. Much of the wording, formatting and references from these FHWA manuals have been directly incorporated into this manual for California's local road owners. Individual references to the FHWA manuals have not been included; instead these documents are intended to be referenced on a wholesale basis.

With FHWA's and SafeTREC's support and expertise, Caltrans was able to expedite the completion of this manual and can now offer California's local agencies a new tool intended to provide focused roadway safety information in one manual.

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1. Introduction and Purpose

The information in this document is geared towards local road managers and other practitioners with responsibility for operating and maintaining local roads, regardless of safety-specific highway training. The primary goal of this document is to provide an easy-to-use and comprehensive framework of the steps and analysis tools needed to identify locations with roadway safety issues and the appropriate countermeasures. For novice practitioners, the concepts and framework will be new, while experienced safety practitioners may find this manual to be mostly review. In both cases, the manual will provide the practitioners with a good understanding of how to complete a proactive safety analysis and ensure they have the best opportunity to secure federal safety funding during Caltrans calls-for-projects.

It's expected that novice and experienced practitioners will utilize this manual to help position their local agency to better compete in future Caltrans' calls-for-projects for safety programs. Inexperienced local roadway practitioners are also a target audience for this manual to gain exposure to the basic concepts that make up a proactive safety analysis of a local agency's roadway network.

The intent of this manual is to focus on key safety activities that every local agency should conduct on an annual basis (or as established by the agency) with the objective of reducing the number and severity of crashes within their jurisdiction. This manual defines this overall process as a "proactive safety analysis" approach to roadway safety. The Highway Safety Manual (HSM),[3] documents a very similar process and refers to it as the "Roadway Safety Management Process." While the process in this document is similar and suggests the same primary elements, the HSM goes into significantly more detail, focuses more on scientific and mathematical equations behind the process, and intends to provide a comprehensive understanding of the overall processes to be applied by individual agencies across the nation. In contrast, this manual attempts to streamline the discussion; and make accommodations for the more novice safety practitioners, provide an adequate understanding of the process to complete an initial safety analysis of their roadway network, and instruct them on how to prepare applications that will compete well in Caltrans' statewide calls-for-projects. In general, this manual is intended to follow the research and methodologies presented in the HSM; however, to support Caltrans' statewide calls-for-projects process, it is important to note this manual deviates from the HSM in areas related to countermeasure selection and benefit / cost calculations. The logic behind these deviations is explained at the specific topic sections.

This manual is not intended to cover many of the day-to-day basics of traffic engineering including: maintain standard signage per the Manual on Uniform Traffic Control Devices; maintain sight distance (cut vegetation, remove parking); maintain a recovery zone; work with local traffic law enforcement; monitor collisions; address complaints; and manage litigation. These activities are understood to be critical elements of a local agency's traffic engineering responsibilities, but are not within the intended scope of this document.

1.1 California Local Roadway Safety Challenges and Opportunities

California's local roads are managed by more than 600 local agencies, including: cities, counties, and tribal governments. These local roads vary from flat multi-lane urban arterials to rural gravel roads in mountainous areas. California local agencies invest extensive resources on roadway safety every year, yet many roadways operate with outdated or insufficient safety features. A portion of these roadways even lack basic signing, pavement markings, alignment, and traffic control devices. Limited funding often prevents agencies from constructing safety projects, which can be expected. At the same time, the lack of safety data, design challenges, and lack of adequate training also hinders local agencies' accurate evaluation of their roadway network safety issues, which is more preventable.

Many small California local agencies are challenged by a lack of crash data. Without data, they have no way to identify High Crash Concentration Locations (HCCLs) or high risk roadway features, which can leave them "flying blind" with respect to the safety of their overall roadway network. Without data and analysis results, local officials may overreact when a tragic crash occurs, resulting in resources being spent in areas that will not maximize the overall application of safety funds. In conjunction with the collision mapping and analysis tools developed by UC Berkeley's SafeTREC, <u>this document helps ensure all California local agencies have direct access to data on fatal and injury crashes within their jurisdictions and the analysis tools to effectively assess and prioritize future safety projects.</u>

1.2 The State's Role in Local Roadway Safety

The California Department of Transportation (Caltrans)—Division of Local Assistance is responsible for administering California's federal safety funding intended for local roadway safety improvements. This funding primarily comes to the state through two federal programs: Highway Safety Improvement Program (HSIP)—a federal-aid program focused on reducing fatalities and serious injuries on all public roads; and the Active Transportation Program (ATP)—a federal aid and state funded program focused on improving safety and the overall use of non-motorized, active transportation modes of travel. Under SAFETEA-LU, High Risk Rural Roads Program (HR3) was established to focus on addressing rural road safety needs but in MAP-21, it is now a 'special rule' under HSIP that if triggered, directs that a certain amount of HSIP funds will need to be allocated for those rural roads that meet the definition.

Caltrans' administration of these programs encompasses many responsibilities, including: establishing program guidance; reviewing applications for improvements on local roadways; ranking applications/projects on a statewide basis; selecting projects for funding based on the greatest potential for reducing fatalities and injuries; programming the selected projects in the Federal Statewide Transportation Improvement Program (FSTIP); and assisting with programming and delivery issues throughout the delivery of the local agency projects. <u>One goal for developing this document is to improve Caltrans' overall data-driven approach to statewide project selection of safety projects and to maximize the long-term safety improvements across California.</u> To show the relationship between

Caltrans' project selection process and this manual, a diagram showing the HSIP Call-for-Projects Process is provided in Appendix A.

Many State Departments are also actively engaged in California's Strategic Highway Safety Plan (SHSP). Caltrans developed the SHSP in a cooperative process with local, State, federal, and private sector safety stakeholders. The SHSP is a data-driven, comprehensive plan that established statewide goals, objectives, integrated the four E's of safety—engineering, education, enforcement and emergency medical services. This manual directly supports many of the emphasis areas of the California SHSP. Local agencies are encouraged to participate in ongoing SHSP update efforts and can find more information on the SHSP at the following website: http://www.dot.ca.gov/SHSP/

1.3 The Local Roadway Crash Problem

Approximately 3,000 people die in California traffic crashes every year, representing nearly 10% of all traffic fatalities in the United States.[4] Fifty-seven percent of these fatalities occur on local roadways, while only forty-three percent occur on the California State Highway System. A comparison of rural and urban roadways shows that local rural roadways have fatality rates 2 to 3 times higher than urban roadways per vehicle miles traveled.[5] Based on these statistics, the total annual cost of local roadway fatal crashes to California is over $6 Billion, while less than $100 Million is available annually in federal safety funds.

These statistics demonstrate the large and complex safety issues facing California. Through the development of this document, Caltrans is striving to help local agencies proactively identify high risk roadway features, roadway network locations/corridors with the highest safety needs, and encourage them to select effective low-cost improvements, whenever appropriate.

1.4 Reactive vs. Proactive Safety Issue Identification

Safety issues are identified on local roadways through a wide range of approaches. Although no single approach works best for all local agencies, some are far more effective at improving long-term roadway safety. Many agencies, often larger ones, have staff whose full-time job is dedicated to roadway safety; allowing them to focus on safety initiatives, be trained in the latest safety research, and have access to safety analysis data, tools and procedures. These agencies often utilize a 'proactive' approach to analyze their roadway network and identify safety issues.

At the same time many agencies, often the smaller ones, lack the financial ability to dedicate large portions of their staff resources to analyze safety issues and their staff has limited access to roadway safety training, safety expertise, and the latest safety analysis tools and procedures. Unfortunately, this can often result in identifying their safety issues in 'reaction' to tragic events.

The following is a basic outline of the differences in proactive vs. reactive identification approaches used by local agencies:

Reactive Approach

For this document, an agency is considered to be utilizing a reactive approach to roadway safety if they primarily identify safety improvements in reaction to:

- Recent crashes triggering safety investigations
- Specific crash concentrations triggering safety investigations
- Stakeholder identification of locations with safety issues and requests for improvements
- New funding becoming available

Crash concentrations and crash trends may be missed if local agencies rely exclusively on these identifiers for their roadway safety effort. They may also miss many opportunities to effectively utilize low-cost, systemic type improvements. This document encourages local agencies to adopt a more proactive approach to their roadway safety.

Proactive Approach

An agency is considered to be using a proactive approach to roadway safety if they go beyond the elements of a reactive approach and identify safety improvements by analyzing the safety of their entire roadway network, in one of the following ways:

- One-time, network-wide safety analysis of their roadways driven by new source of funding.
- Routine safety analyses of the roadway network (Preferred Approach!)

Agencies with a proactive approach utilize both systemic and spot location improvements (as defined in section 1.5 below). Applying improvements systemically across an entire corridor or network allows an agency to proactively address locations that have not had crash concentrations in the past, but have similar features as those currently experiencing high levels of crashes. In addition, even though a spot location improvement may be based on 'past' crashes, agencies making improvements based on countermeasures with proven crash reduction factors at their highest crash locations often have the best chance of proactively reducing future crashes.

This document encourages safety practitioners to pursue a proactive approach and routinely analyze the safety of their roadway networks to yield the best overall safety results.

1.5 Implementation Approaches

When an agency proactively identifies their safety issues throughout their roadway network, it is likely they will find high crash concentrations at intersections, roadway segments, and corridors. The safety practitioner should consider which implementation approach to utilize. Typical approaches include:

- Systemic Approach

- Spot Location Approach
- Comprehensive Approach incorporating human behavior issues

Each of these approaches has benefits and drawbacks. As Local agency practitioners identify their safety issues and analyze the data for crash patterns, they should be open to implementing a combination of these approaches, as documented in Sections 2 and 3 of this manual.

Systemic Approach

The Systemic Approach is primarily based on application of proven safety countermeasures at multiple crash locations, corridors, or geographic areas. Implementation of the Systemic Approach is generally based on 'system-wide' crash data with the estimates of the impacts being made in terms of benefits measured in traffic crash reduction and deployment cost. Identified locations experiencing high levels of crashes and locations with similar geometric features can be treated systemically with low-cost, proven safety countermeasures. *Note: The term "Systemic" used throughout in this manual is often exchanged with the term "Systematic" in many national safety documents and research studies. In general, safety practitioners will find these terms interchangeable. This manual uses "Systemic" to match the new HSM and the FHWA CMF Clearinghouse.*

Benefits of the Systemic Approach may include:

- <u>Widespread effect.</u> The Systemic Approach addresses safety issues at a large number of locations or on an entire local roadway network. It can also generate projects that combine HCCLs and locations with the potential for crashes and still have high Benefit to Cost (B/C) ratios. An example of this type of project could be upgrading pavement delineation and warning signs along a rural corridor: crashes may not have occurred on every curve or segment along the corridor, but all of the corridor's pavement delineation and warning signs can be upgraded at one time. For urban applications, an example could be protecting the left-turn phase of signalized intersections with existing left-turn pockets: severe crashes may not have occurred at each of the left-turn movements, but with minor changes to the signal hardware and signing, all or many of a city's unprotected left-turn phases can be protected with one safety project.
- <u>Crash type prevention.</u> By focusing on a predominant crash type, an agency can address locations that have not experienced significant numbers of these types of crashes, but have similar characteristics or conditions as existing HCCLs. The resulting B/C ratios for these types of projects will be less than if only HCCLs are included; but by using low-cost countermeasures and including as many high crash locations as possible, the resulting B/C ratios should still be high enough to allow agencies to proactively address locations that have not experienced high numbers of these types of crashes. For urban areas, projects improving pedestrian crossings can be good examples of the Systemic Approach. By applying the countermeasures systemically, the agency can often justify these projects based on relatively high B/C ratios, even though some of the improvement locations have not experienced enough crashes to yield moderate-to-high B/C ratios on their own.

- Cost-effectiveness. Implementing low-cost solutions across an entire system or corridor can be a more cost-effective approach to addressing system-wide safety issues. Even though this approach does not address all (or total) safety issues for a given location, the deployment of low-cost countermeasures often result in the highest overall safety benefit for an agency with limited safety funding. An example of this would be an agency choosing to install rumble stripes along an entire corridor for equal or less money than realigning a small portion the roadway to fix a single curve.
- Reduced data needs. The Systemic Approach can be used without a detailed crash history for specific locations, thereby reducing data needs. For example, consider a long rural corridor, which includes a section that passes through an Indian Reservation: Even if there is no documented crash data for the portion of the corridor that passes through the reservation, the entire limits can be treated with the same low-cost improvements. As long as there are sufficient past crashes documented for the entire corridor, the project will still have a reasonably high B/C ratio.

Drawbacks of the Systemic Approach may include:

- Justifying improvements can be difficult. Because this approach does not always address locations with a history of crashes and active stakeholders, it can be difficult to justify the improvements. The Systemic Approach will rarely include a recommendation for a large-scale safety improvement at a single location. Since large-scale projects usually garner attention from decision makers, the media, elected officials, and the general public, safety practitioners often need to make additional efforts to explain the Systemic Approach and its benefits to those groups. Safety practitioners can utilize the high B/C ratios of these systemic projects to convey their benefits compared to high-profile, single location projects with lower B/C ratios.

Spot Location Approach

The Spot Location Approach is typically based on an analysis of crash history to identify locations that have significantly higher crashes and treat them accordingly. It is important to practitioners to understand that for many locations, safety issues can be complicated and sometimes the most appropriate fixes are not quick, easy or cheap.

Benefits of the Spot Location Approach may include:

- Focus on demonstrated needs. The Spot Location Approach focuses directly on locations with a history of crashes and specifically addresses those crashes. Intersection improvements are some of the most common spot location projects. Intersections tend to have higher concentrations of crashes resulting from opposing traffic movements. These high crash concentrations often require stand-alone improvements to adequately resolve the safety issues.
- Justifying improvements can be easy. Because this approach addresses locations with a history of crashes, it is usually easy to justify improvements. For urban areas, reconfiguring/ reconstructing an entire intersection can be a good example of an effective Spot Location Approach. Large urban intersections can have extremely high crash concentrations, making major changes to the

intersection the only way to significantly reduce future crashes. With these types of scenarios, even the highest cost countermeasures can be cost effective.

- If low-cost countermeasures are used, this approach can prove very cost effective. The Spot Location Approach does not always have to include moderate or high cost improvements. It is often appropriate for local agencies to make low-cost improvements at one location at a time. Ongoing maintenance and development projects offer great opportunities for these low-cost improvements to be constructed with no additional expense to local agencies.

Drawbacks of the Spot Location Approach may include:

- Assumption that the past equals the future. This approach assumes locations with a history of crashes will continue to experience the same number and type of crashes in the future. When agencies do not account for the random nature of roadway crashes (i.e., Regression to the Mean), moderate to high cost projects can be erroneously justified. Practitioners can easily mitigate this by using 5 or more years of crash data when analyzing their roadways. In addition, significant changes to land use or roadway characteristics in or around proposed projects can either increase or decrease the expected number of future crashes.
- Minimal overall benefit to the roadway network. Some local agencies use this approach with medium and high cost improvements at locations which do not represent their worst high crash concentration locations. The result can be projects with low B/C ratios and overall safety benefits that are not as high as if they utilized a Systemic Approach. This drawback can be minimized by safety practitioners who analyze their entire roadway network, propose spot location fixes only at their highest crash locations, and utilize lower cost countermeasures wherever appropriate.

The Spot Location Approach to traffic safety is ideally implemented along with the Systemic Approach to provide the best combination of safety treatments. For instance, the Spot Location Approach can be applied at locations where low-cost countermeasures are not expected to be effective in significantly reducing future crashes or at those locations that have had low-cost countermeasures previously installed systemically but, after an assessment, continue to show a higher-than-average crash rate.

Comprehensive Approach

The Comprehensive Approach introduces the concept of the “4 E’s of Safety”: Engineering, Enforcement, Education, and Emergency Medical Services (EMS). This approach recognizes that not all locations can be addressed solely by infrastructure improvements. Incorporating the “4 E’s of Safety” is often required to achieve marked improvement in roadway safety. For instance, some roadway segments will be identified for which targeted enforcement is an appropriate countermeasure. Some of the most common violations are speeding, failure-to-yield, red light running, aggressive driving, failure to wear safety belts, distracted driving, and driving while impaired. When locations are identified as having these type violations, coordination with the appropriate law enforcement agencies is needed to deploy visible targeted enforcement to reduce the potential for future driving violations and related crashes. To improve safety, education and outreach efforts can also be used to supplement enforcement efforts.

Enforcement and/or education can also be effectively utilized as short-term ways to address high crash locations, until the recommended infrastructure project can be implemented.

1.6 Our "Safety Challenge" for Local Agencies

Caltrans, FHWA and Safe Transportation Research and Education Center (SafeTREC) "challenge" local agencies to initially commit one or more days to understanding and applying the concepts and tools outlined in this manual. Experienced safety practitioners working in agencies currently using a proactive approach can quickly review the topics in the manual and consider/test some of the new tools (e.g., TIMS) identified within it. In contrast, novice safety practitioners may need several days to better understand the underlying concepts in this manual to be able to complete the basic elements of a proactive safety analysis of their roadway network. In these situations, the room for knowledge growth, internal process improvements, and expected safety benefits will be even greater, which should more than offset the additional time invested.

By utilizing this simple framework for identifying, analyzing and implementing a proactive approach for improving safety on their roadways, practitioners will have a better understanding of their agencies' unique safety issues, the proven low-cost countermeasures that can reduce crashes, and the existing and future funding to implement the projects. This small investment of time will help local agencies achieve significant reductions in future fatalities, injuries and overall crashes. We believe these local agencies may also gain the added unexpected benefit of improved job satisfaction of those involved, as there are few more rewarding tasks than knowing that your efforts will result in future roadway users arriving safely at their destination instead of becoming statistics.

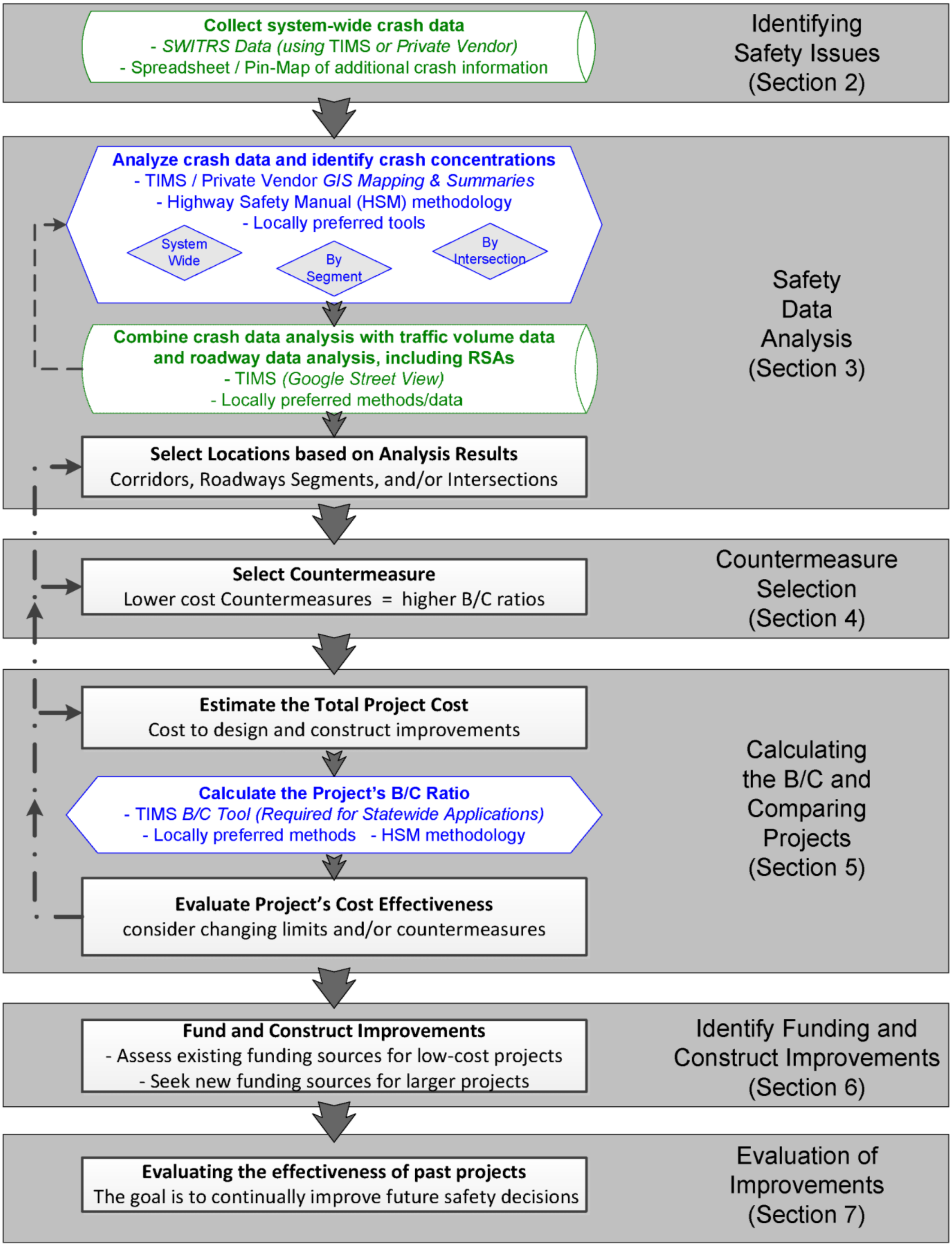
1.7 Summary of information in this Document

This document provides information on effectively identifying California's local roadway safety issues and the countermeasures that address them, ultimately leading to the effective implementation of safety projects that improve safety on local roadways. The document is not intended to be a comprehensive guide for roadway design and improvement or the only guide local agencies utilize for their safety analysis of their roadways.

Caltrans also expects this document will directly support its efforts in selecting local agency safety projects. The expectation is that as local agencies throughout the state utilize the proactive safety analysis approach outlined in this document, their applications for HSIP, SRTS and ATP projects will include lower cost improvements at locations with the highest safety needs. This will improve Caltrans' data-driven approach to statewide project selection of safety projects and maximize the safety benefits across California.
The proactive safety analysis framework incorporated in this document is summarized in Figure 1.

Figure 1

Local Roadway Safety: Proactive Safety Analysis Approach



The above flowchart illustrates how each of the individual sections of this document work together to make up a proactive safety analysis approach. These sections are briefly outlined below:

Section 2 of this manual provides an overview of the types of data to collect for the identification of roadway safety issues. It discusses sources of crash data and how they can be used.

Section 3 summarizes the types of analyses that can be conducted to determine what roadway countermeasures should be implemented. This section is the link between the data (Section 2) and the selection of appropriate countermeasures (Section 4). It provides definitions and examples of the qualitative and quantitative factors that should be considered when evaluating roadway safety issues.

Section 4 provides a description of selected countermeasures that have been shown to improve safety on local roads. It includes a basic set of strategies to implement at locations experiencing a history of crashes and their corresponding crash modification factors (CMF). The interrelationship between CMFs and Crash Reduction Factors (CRFs) are defined and used interchangeably throughout this document.

Section 5 defines a methodology for calculating a B/C ratio for a potential safety project. It includes sources for estimating projected costs and benefits and the specific values/formulas Caltrans uses for its statewide evaluations of HSIP projects. This section also discusses the potential value in reevaluating projects' overall cost effectiveness at this point in the safety analysis, including; refining the project's costs and/or changing the mix of countermeasures and locations.

Section 6 identifies existing and new funding opportunities for safety projects that local agencies should be considering. This section also briefly discusses some unique project development issues and strategies for safety projects as they proceed through design and construction.

Section 7 presents the process to complete an evaluation of installed treatments. After the countermeasures are installed, assessing their effectiveness will provide valuable information and can help determine which countermeasures should continue to be installed on other roadways to make them safer as well as those that should be limited or discontinued.

Appendix A presents a flowchart of the HSIP call-for-projects process. This flowchart demonstrates how this document interacts with these Caltrans calls-for-projects.

Appendix B contains the Table of countermeasures and CRFs discussed in Section 4. This table includes detailed information about each countermeasure, including: where to use, why it works, general qualities (time, cost and effectiveness), crash type(s) addressed, crash reduction factor, and specific values for use in Caltrans HSIP calls-for-projects.

Appendix C includes a summary of "recommended actions" involved in a proactive safety analysis.

Appendix D contains the formulas to calculate the B/C ratio included in SafeTREC's TIMS and required to be included in HSIP applications. Screenshots from TIMS are also included to provide additional details on the B/C calculation process.

Appendix E contains references to examples of attachments for Caltrans calls-for-projects and presents TIMS tutorials that are available to assist local agencies in completing Caltrans call-for-projects application requirements and attachments. The tutorials include examples for Spot Location projects and systemic projects.

Appendix F contains references to case studies in FHWA manuals for Local Rural Road Owners and lessons learned from the first generation of Caltrans' B/C ratio calculator used in the 2010 4th cycle of HSIP call-for-projects.

Appendix G presents a list of the abbreviations used in this document.

Appendix H presents a list of references.

2. Identifying Safety Issues

This document encourages local agency safety practitioners to proactively analyze their roadway networks with the intention of yielding the best overall safety benefits. When utilizing a proactive safety analysis approach, practitioners need to consider a wide range of data sources to get an overall picture of the safety needs.

There are a number of information sources that can be accessed to get a clearer picture of the roadway safety issues on the roadway network. These can be formal or informal sources, including:

Formal sources:

- State and local crash databases
- SafeTREC's TIMS website (or locally preferred mapping software)
- Law enforcement crash reports and citations
- Field assessments

Informal sources:

- Observational information from road maintenance crews, law enforcement, and first responders
- Citizen notification of safety concerns

Examining crash history will help practitioners identify locations with an existing roadway safety problem, and also identify locations that are susceptible to future roadway crashes. In addition to location identification, this data can provide information regarding crash causation that ultimately provides insight into identifying potentially effective countermeasures.

Emphasis on data-driven decisions is indicative of reliability and efficiency. The more reliable the data, the more likely the decisions regarding safety improvements will be effective. However, detailed, reliable crash data are not available in all areas. Under this circumstance, the practitioner should use the best available information and engineering judgment to make the best decisions. In an effort to mitigate these situations, UC Berkeley, SafeTREC has developed the TIMS website, which includes GIS mapping tools to access fatal and injury crashes statewide. This site is now available to all California local agencies. See Section 2.2 for more details on TIMS.

It is generally accepted that at least 3 years, or preferably 5 or more years, of crash data be used for an analysis; additional years of crash data can provide better information. For low volume roadways and/or when only severe crashes are analyzed, even more years of crash data may be necessary for an effective evaluation. Due to the randomness of crashes in a given year, a multi-year average of safety data will smooth outlier years of relatively high or low roadway crash rates. This concept is commonly referred to as "regression to the mean" and is critical in helping safety practitioners avoid making wrong inferences as they analyze their roadway network data. An example of this is an agency making a high-cost improvement at a location in response to one or two tragic crashes. The Highway Safety Manual (HSM) includes more details on regression to the mean and methods to reduce the random nature of crashes.

There are some circumstances where additional years of crash data may not always be advantageous. First, it's important for practitioners to recognize that as more years of crash data are used, they need to consider changes in traffic patterns, physical infrastructure, land use, and demographics that may affect their projection of future crashes. Second, if practitioners only focus on many years of past crash data, they could miss emerging safety issues and crash trends. For these reasons, if practitioners sense one or more factors affecting crashes have changed or may be changing, they should consider looking at the crash data for the specific area on a yearly or 3-year moving average to expose any changes and crash trends that are occurring.

2.1 State and Local Crash Databases

California has a central repository for storing crash data called SWITRS, which stands for Statewide Integrated Traffic Records System. SWITRS is a comprehensive data source for doing roadway safety analysis that includes almost all public roads in the database except tribal roads which are currently not included. SWITRS information is available to California's local agencies, although many agencies have had difficulty identifying, extracting and utilizing their crash records from SWITRS. All California local agencies, especially those that currently have difficulty accessing and mapping crash data, are encouraged to utilize the SafeTREC TIMS website to access and map SWITRS data.

This document focuses on the SafeTREC TIMS website as a tool to access and map SWITRS data because TIMS is free to local agencies and the general public. At the same time, this document also acknowledges that TIMS currently does not offer some of the features currently available in some of the commercially available crash analysis software packages. For this reason, local agencies are encouraged to try TIMS, but they should not feel obligated to make a switch if they prefer using their vendor supplied crash analysis software. See section 2.2 for more details on TIMS.

Many agencies utilize one of several crash analysis software packages (e.g., Crossroads) to manage and access their crash records. Their use can be costly, but allows local road practitioners to identify locations with multiple roadway crashes, conduct an analysis that can produce predominant crash types, and identify associated roadway features that may have contributed. One drawback to agencies managing and updating their own individual databases is that the statewide database may become outdated and may not include the updated crash details like geo-coded locations. Agencies that manage and update their own individual databases are encouraged to share all updates, including any geo-coding information, with the SWITRS data managers at the California Highway Patrol. This will allow updated geo-coding and other crash features to be available on a statewide basis.

Recommended Action: Obtain at least 5 years of network-wide crash data to identify local roads that have a history of roadway crashes. This data will be used to identify predominant roadway crash locations, crash types and other common characteristics.

As practitioners gather formal and informal information relating to the safety of their roadway network, they are encouraged to develop one or more separate spreadsheets and/or pin-maps to help track and manage this data. (These spreadsheets/pin-maps should capture much of the data gathered in each of Sections 2.1 through 2.8). A spreadsheet and/or pin-map can serve as a database to help an agency identify locations and crash characteristics representing their greatest safety issues and guide them in identifying appropriate countermeasures.

The following spreadsheet is offered as an example, but each agency's spreadsheet should be reformatted to include data to meet their needs. Agencies should consider printing their spreadsheets on 'legal' or '11 x 17' paper for easy review of their data.

Location & Date	General Information		Crash Information			Evaluation / Action		
	Source/Type of information	Safety Issue/Problem	Nature of Crashes	Time of Day	Weather/Traffic Conditions	Staff Evaluation	Recommend Action	Resolution
1) Intersection "X"								
1) Feb 7, 2010	Input from law enforcement	Clearance Intervals need adjustment	V1-WB V2-SB Side-swipe	21:30	Dry, Night, Free-flowing	R. Jones 2/26/10	Increase all-red interval	Completed 2/26/10
1) Mar 9, 2010	Citizen Complaint	Ped Crossing unsafe due to RT turns	N/A	N/A	N/A	R. Jones 3/12/10	No RT on Red (Need study)	
2) Intersection "Y"								
2)								
3) Roadway Segment (PM 5.3 to PM 7.8)								
PM 6.4 to 6.8 Sep 29, 2011	Maintenance data	Extensive skid marks. Speed of Travel?	General WB: ROR	N/A	Dry Free-flowing	J. Smith 10/1/11	High Friction Overlay	Preparing HSIP App.
PM 7.1 Jan 5, 2011	Input from law enforcement	Stop Sign missing	N/A	N/A	N/A	J. Smith 1/5/11	Informed Maintenance	New sign 1/5/11

An example of a pin-map, which could be modified to capture much of the data gathered in Section 2, is shown in the following section as part of the TIMS output.

2.2 Transportation Injury Mapping System (TIMS)

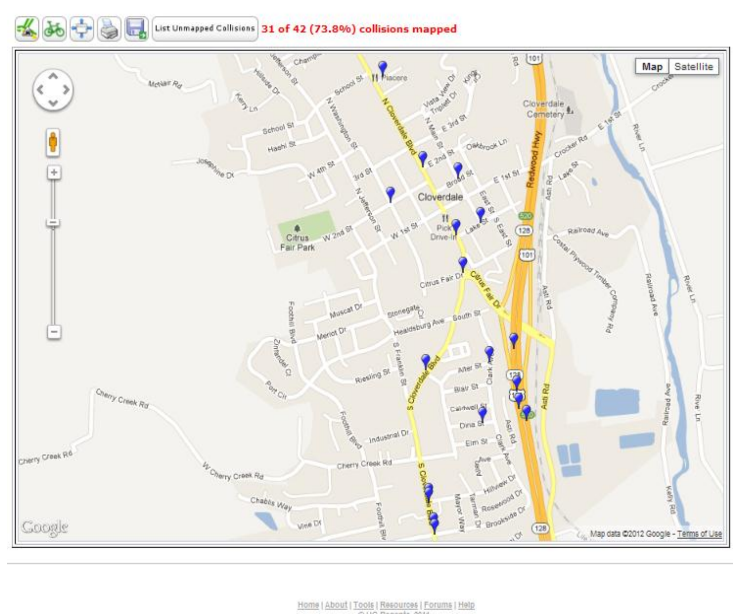
The Safe Transportation Research and Education Center (SafeTREC) at the University of California, Berkeley, has recently developed a powerful website with tools for California's local agencies to gather data for their safety analyses. Their Transportation Injury Mapping System (TIMS) website provides safety practitioners with California crash data (SWITRS) and collision mapping and analysis tools. California local agencies are encouraged to utilize TIMS at: http://tims.berkeley.edu/

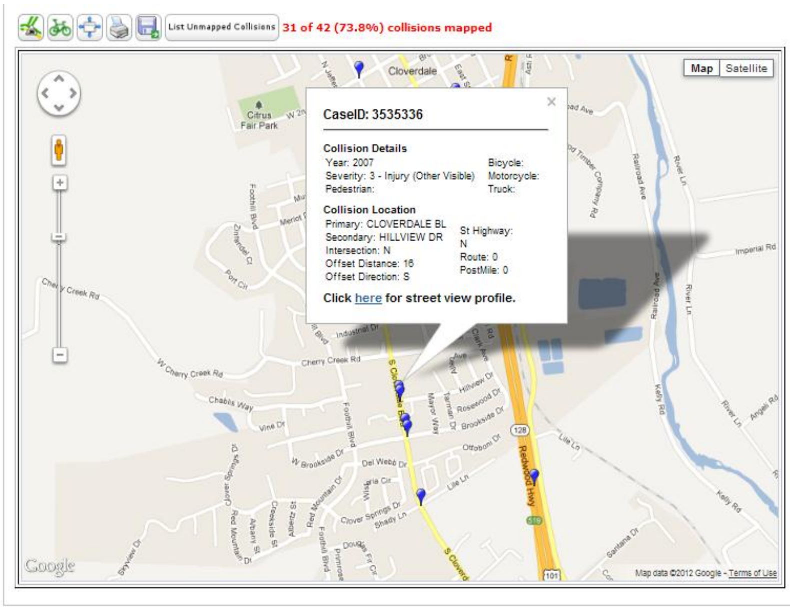
Site Features:

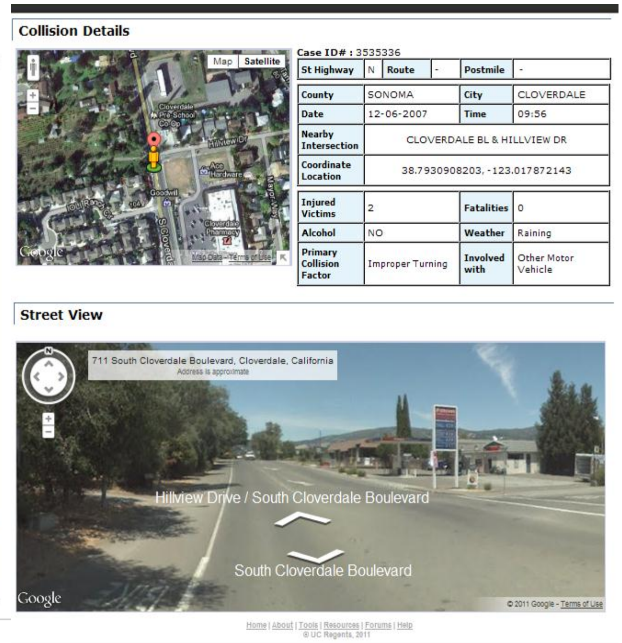
- Applications to query map and download geo-referenced SWITRS data.
- Summary tables based on data included in SWITRS individual crash reports. These summary tables can be generated based on specified data fields or spatial limits.
- Virtual field review by connecting the crash location to Google maps and Google Street View, allowing the examination of the existing roadway infrastructure and dimensions.
- Benefit/Cost Calculator tool for the HSIP online application process.
- A 'Help Tab' that provides step-by-step instructions.

At this time, there are two limitations of TIMS worth mentioning: First, some of the mapping applications in TIMS do not work from Internet Explorer Browser version 7 or 8. Full functionality is available from Internet Explorer 9 (Windows 7). Practitioners may also download a free version of Mozilla Firefox or Google Chrome before using TIMS. Secondly, SafeTREC is not able to incorporate all SWITRS crashes into TIMS due to poor crash location descriptions in the crash reports. Currently, TIMS only includes approximately 85% of California fatal and injury crashes and does not include Property Damage Only collisions.

Recommended Action: Consider augmenting your local agency's data collection approach with information available using the suite of TIMS tools. The TIMS tools (and/or purchased software applications) can help the safety practitioner complete or assist with each of the actions in Sections 2.1 through 2.8. This website includes several tutorials specifically designed to support the individual sections of this document. Local practitioners may find the TIMS output files as a great starting point to build their tracking spreadsheet discussed in the recommendation of Section 2.1. The following images are examples of TIMS functionality and outputs:







2.3 Law Enforcement Crash Reports

Both State and local law enforcement officials can be an important source of roadway crash data. The actual law enforcement crash reports can be valuable in identifying the location and contributing circumstances to roadway crashes (e.g., did the highway hardware and features operate as intended: end treatment worked, no barrier in the passenger compartment, pavement not slippery when wet, signs visible, signal timing, etc.). The following variables can and should be extracted and compiled from the crash reports:

- Location
- Date and time
- Crash type
- Crash severity
- Weather conditions
- Lighting conditions
- Sequence of events and most harmful events
- Contributing circumstances
- Driver Variables: age of driver, DUIs, use of seat belt, etc.

Similar to the crash database, the information in the crash reports can be used to assist in the identification of potential infrastructure and non-infrastructure safety treatments and the deployment approach.

<u>Recommended Action:</u> Develop a working relationship with law enforcement officials responsible for enforcement and crash investigations. This could foster a partnership where sharing crash reports and safety information on problem roadway segments becomes an everyday occurrence. Practitioners with limited access to crash data are encouraged to use TIMS to assess the local crash report data.

2.4 Observational Information

Law enforcement officers, local agency maintenance crews, and Emergency Medical Services personnel can serve as valuable resources to identify problem areas. Since they travel extensively on local roads, they can continuously monitor roads for actual or potential problems (e.g., poor delineation, fixed objects near the roadway, missing signs, signs of vehicles leaving the road). Law enforcement observations of driver behavior and roadway elements can provide valuable information to the local road agency. Additionally, law enforcement officers are sometimes aware of problem areas based on citations written, even if crashes related to the violations have not yet occurred. Road maintenance crews may keep logs of their work, including sign and guardrail replacements, debris removal, and edge drop-off repairs. These logs can provide supplemental information about crashes and HCCLs that may not have been reported to law enforcement. Finally, Emergency Medical Service Crash Reports can provide an entirely different perspectives and set of observations relating to crash occurrences.

Information obtained from road maintenance crews, law enforcement officers, and Emergency Medical Services personnel can help support all three methods of implementation approaches: Spot Location treatments, systemic deployments, and the Comprehensive Approach. Often, traffic violations such as speeding and impaired driving lend themselves to education and enforcement solutions to address these behaviors and supplement the intended infrastructure countermeasures.

Recommended Action: Add information received from law enforcement, road maintenance crew, and Emergency Medical Service observations to the agency's tracking spreadsheet and/or pin-maps. Develop a system for maintenance crews to report and record observed roadway safety issues and a mechanism to address them.

2.5 Public Notifications

Occasionally, when unsafe situations are observed, local citizens may notify the local government by email, letter, telephone, or at a public meeting. Information identifying safety issues on local roads may also come from community or regional newspapers, newsletters, correspondence, and from local homeowner and neighborhood associations. These sources can serve as indicators that a safety issue may exist and may warrant further review and analysis to determine the extent of the issues. Citizen reports can be tracked along with official crash data; however, safety practitioners should not regard these reports as factual, unless proven by other methods. Local safety databases should only contain objective and verifiable data.

Recommended Action: Review and summarize information received from these sources, identifying segments or corridors with multiple notifications and record the locations, dates, and nature of the problem that are cited. Add information received from public notifications to tracking spreadsheets and/or pin-maps once confirmed.

2.6 Roadway Data and Devices

It is also valuable to obtain information about the existing roadway infrastructure. Currently, many local agencies have few of their roadway characteristics in a database. For these agencies, the establishment of a roadway database could be a long-term goal. The following roadway characteristics are often used to assist practitioners in safety analyses of roadway segments:

- Roadway surface (dirt, aggregate, asphalt, concrete)
- Roadway geometry (horizontal, vertical, flat)
- Lane information (number, width)
- Shoulder information (width, type)
- Median (type, width)
- Traffic control devices present (signs, pavement marking, signals, rumble stripes etc.)
- Roadside safety hardware (e.g., guardrail, crash cushions, drainage structures)

The new TIMS site, described in Section 2.2, can provide safety practitioners with much of this roadway data virtually by using Google Maps and Google Street View. By utilizing TIMS (and/or private for-profit vendors), safety practitioners can save hours and even days of driving during the initial steps in the safety analysis of their network. Once agencies start to define individual safety projects for funding and future construction, actual field reviews are needed to ensure a complete understanding of the project location and context.

As local practitioners gather information about their existing roadway infrastructure, they need to determine whether it complies with the minimum standards for signs, breakaway supports, signals, pavement markings, protective barriers, etc. Practitioners should use the most current *California - Manual on Uniform Traffic Control Devices* (CA-MUTCD), which provides the minimum standard requirements for traffic control devices on all public streets, highways, bikeways, and private roads open to public travel.[6] In addition to ensuring compliance with the MUTCD, geometric standards for sight distance, curve radius, and intersection skew angle and roadway standards for lane width, shoulder width, clear recovery zone, and super-elevation should also be evaluated.

Roadway information can be combined with crash data to help local practitioners identify appropriate locations and treatments to improve safety. For example, if a local rural segment is experiencing a high number of horizontal curve-related crashes, analysis of the inventory of roadway elements could reveal that the roadway does not have sufficient signage installed in advance of many of those curves to give motorists warning of the pending change in roadway geometry.

Recommended Action: Identify and track roadway characteristics for the intersections, roadway segments, and corridors, including compliance with the minimum standards. At a minimum, this should be done for locations being considered for safety improvements, but ideally agencies would establish an extensive database of roadway data to help them proactively identify high risk roadway features.

2.7 Exposure Data

The number of crashes can sometimes provide misleading information about the most appropriate locations for treatment. Introducing exposure data helps to create a more effective comparison of locations. Exposure data provides a common metric to the crash data so roadway segments and intersections can be compared more appropriately, helping local agencies prioritize their potential safety improvements.

The most common type of exposure data used on roadway segments is traffic volume. Ideally, volume would be broken down by pedestrians, bicycles, cars, motorcycles, and large trucks. A count of the number of vehicles and non-motorized users can provide information for comparison. For example, if two roadway segments have the same number of crashes but different traffic volumes, the segment with fewer vehicles (i.e., less exposure) will have a higher crash rate, meaning that vehicles were more likely to experience a crash along that roadway segment. In situations where traffic volume is not available, segment length or population can serve as an effective exposure element for comparison.

Recommended Action: Consider the availability of exposure data and track it along with the other crash data to help prioritize potential locations for safety improvements.

2.8 Field Assessments and Road Safety Audits

Local road practitioners should always consider conducting field assessments in conjunction with their collection of crash data to help identify problem locations. An assessment can be as informal as driving, walking or virtually viewing the road network looking for evidence of roadway crashes. Ideally, informal field assessments are to be performed by multidisciplinary teams that include a traffic safety expert, law enforcement personnel, and others. The team can visit several sites and document evidence of crashes or deficiencies on the roadway or roadside, including: damaged trees or fences, skid marks, ruts on the shoulder, car parts on the shoulder, and/or pavement drop-offs. This information, along with observations of actual driver-behavior, can be used to develop recommendations for improvement.

Field reviews can also be more formalized such as in conducting a Road Safety Audit (RSA). A RSA is a formal safety performance examination of an existing or future road by an independent, multidisciplinary team. The team examines and reports on existing or potential road safety issues and identifies opportunities for safety improvements for all road users. Agencies considering RSAs for the first time are encouraged to consider requesting support from FHWA. For more information on FHWA's free RSA support, go to their website at: http://safety.fhwa.dot.gov/rsa/. Another great source for agencies considering RSAs is the UC Berkeley Institute of Transportation Studies and their free service to California local agencies in completing Traffic Safety Evaluation (TSE). More information can be found at: http://www.techtransfer.berkeley.edu/tse/

Informal field assessments and more formal RSAs provide an opportunity for local safety practitioners to gather and summarize all of the information sources discussed in Section 2. They can also be used to identify potential project delivery obstacles. The field assessments/RSAs should identify major environmental, right-of-way, infrastructure, and operational issues that need to be considered when applying countermeasures.

Recommended Action: Consider completing formal or informal field assessments and RSAs at certain locations to help ensure all relevant information is collected and available for the safety practitioners to complete their safety analysis and identify the most appropriate countermeasures. It's recommended that local agencies develop simple straightforward criteria on when one of these will be undertaken. The information gathered during the assessments should be added to the agency's tracking spreadsheet, as discussed in section 2.

3. Safety Data Analysis

Proactive safety analysis will assist in making informed decisions on the type, deployment levels, and locations for safety countermeasures. This builds on the previous discussions on information sources that identify safety issues. 'Safety Data Analysis' is one of the most critical steps in an agency's overall proactive safety analysis approach. Ideally, agencies regularly analyze the safety data for their entire roadway networks to identify and prioritize the locations with the most severe safety issues. This step is often skipped by agencies reacting to a recent tragic crash and the corresponding public outcry, which may leave their most critical safety locations undetected.

As agencies analyze their safety data, they will need to select the implementation approach that most effectively address the safety issues identified; Systemic Approach, Spot Location Approach, Comprehensive Approach, or a combination of these approaches. For example, if a high number of crashes are occurring at a particular curve or along a short segment of roadway, a spot treatment may be appropriate. However, systemic treatment of multiple locations experiencing similar crash types may be necessary and most beneficial for reducing overall fatalities and injuries. These implementation approaches were described in Section 1.5. With all of the approaches, safety practitioners should be looking for patterns in the crash data and not just the total number of crashes. These patterns include: types of crashes, severity of crashes, mode of travel, pavement conditions, time of day, etc. Identifying and analyzing the patterns in the crash data will help ensure the most appropriate countermeasure is selected and the safety problems are effectively addressed.

3.1 Quantitative Analysis

Crash data analysis is used to determine the extent of the roadway safety issues, the priority for application of scarce resources, and the selection of appropriate countermeasures. The two main quantitative analysis methods for roadway crashes are crash frequency and crash rate.

Crash Frequency

Crash frequency is defined as the number of crashes occurring within a determined study area. A practitioner can determine crash volumes using methods discussed in Section 2, including: State crash database (SWITRS), TIMS, local agency crash databases, law enforcement crash reports, pin-maps, etc. The practitioner should analyze the data to identify locations and crash characteristics with the highest frequency. There are numerous methods to assist practitioners in this process. Each agency will have their own preferred methods for initially selecting their top priority locations. The following are a few examples of the methods used to determine Crash Frequency:

- Summarize the crashes by attributes such as type, severity and location to identify patterns in the crash data and the most significant problem locations.
    - Top 10 (or 20) lists of intersections and roadway segments. It is common to weight more severe crashes higher in this process.
- Spatially display the sites on a pin-map or a GIS software package.

    - For small or rural agencies with lower volume roadways, network-wide pin-maps may be all that is needed to identify the highest priority locations.
- Develop collision diagrams showing the direction of movement of vehicles, types of crashes, and pedestrians involved in the crashes.

As stated earlier, this manual acknowledges many local agency safety practitioners may have their preferred methods for completing these analyses. For those agencies that do not and for those willing to try something new, Caltrans recommends using the new TIMS website along with the processes outlined in this document to complete these analyses.

Once the crash frequency information is collected and displayed, the practitioner can complete a methodical analysis by geographic area, route, or a cluster analysis to determine which locations have experienced a high or moderate level of crashes. The resulting crash information can be further analyzed for recurring patterns or events. As agencies consider their locations with high levels of crashes, they should understand the overall random nature of crashes and the concept of “regression to the mean”, as discussed in Section 2. Otherwise, if the natural variations in crash occurrence are not accounted for, a site might be selected for study when the number of crashes is randomly high, or overlooked when the number of crashes is randomly low.

Crash Rate

Crash rate analysis can be a useful tool to determine how a specific roadway or segment compares with similar roadway types on the network. A simple count of the number of crashes can be inadequate when comparing multiple roadways of varying lengths and/or traffic volume. Local agencies are also encouraged to compare their crashes with those occurring in similar areas around the state; doing so will help in determining just how severe the number and types of crashes are in the local area. When working with limited budgets, Crash Rates are often used to prioritize locations for safety improvements that will achieve the greatest safety benefits with limited resources. Where traffic volume data is unavailable, other information can be used to provide exposure information. One often-used factor is the length of the roadway segment on each route studied. Comparing the number of roadway crashes per mile or per intersection can help an agency identify potential opportunities to improve safety. The FHWA Roadway Departure Safety and Intersection Safety manuals include the following formulas for calculating crash rates on roadway segments and intersections:

The crash rate for crashes on a roadway is calculated as:

R = (C x 100,000,000) / (V x 365 x N x L)

Where:

R = Crash rate for the road segment expressed as crashes per 100 million vehicle-miles of travel,
C = Total number of crashes in the study period
V = Traffic volumes using Average Annual Daily Traffic (AADT) volumes
N = Number of years of data
L = Length of the roadway segment in miles

The crash rate for crashes at an intersection is calculated as:

R = (1,000,000 x C) / (365 x N x V)

Where:

R = Crash rate for the intersection expressed as crashes per million entering vehicles (MEV)
C= Total number of intersection-related crashes in the study period
N = Number of years of data
V = Traffic volumes entering the intersection daily

Similar to Crash Frequency, there are numerous methods for local safety practitioners to utilize Crash Rate in their safety data analysis and each will have their own preferred methods for initially selecting their top priority locations. The following are a few examples:

- Top 10 (or 20) lists of roadway segments with the highest crashes in relationship to roadway length, traffic volumes, and/or population density.
- Top 10 (or 20) lists of intersections, sorted by crash rate.
- Top 10 (or 20) lists of the highest volume intersections, sorted by crash frequency or rate.

Even though crash frequency and crash rate are helpful for local agency safety practitioners to effectively rank their most critical locations for improvements, the lack of reliable statewide traffic volumes for all roadway types precludes Caltrans from using the crash rate methodology in their statewide project scoring and ranking processes for the HSIP (discussed in more detail in Section 5).

Recommended Action: Complete a quantitative analysis of the roadway data using both Crash Frequency and Crash Rate methodologies. Safety practitioners should look for patterns in the crash data, including: types of crashes, severity of crashes, mode of travel, pavement conditions, roadway characteristics, time of day, intersection control, etc.

3.2 Qualitative Analysis

Qualitative analysis considers the physical characteristics of the roadway network, through the examination of maps, photographs, and field assessments. Certain roadway infrastructure characteristics relate to design standard and compliance issues and should continually be identified and upgraded on a network-wide basis (e.g., signing and pavement delineation characteristics relating to CA-MUTCD compliance as discussed in more detail below). Other roadway characteristics are more important as they relate to locations with high crash frequencies and rates (e.g., well defined pedestrian paths crossing the roadway or a high number of utility poles/fixed objects adjacent to the edge of travel way). All of these characteristics should to be accounted for in an agency's proactive safety analysis.

Ensuring Compliance with CA-MUTCD and Design Standards

It is important for local agencies to continually evaluate their roadways for compliance with the minimum safety standards. The CA-MUTCD provides the minimum standard requirements for traffic control devices on all public streets, highways, bikeways, and private roads open to public travel. In addition to ensuring compliance with the CA-MUTCD, geometric standards should be evaluated as they relate to sight distance, curve radius, and intersection skew angle and roadway standards for lane width, shoulder width, clear recovery zone, and super-elevation. Many local agencies have their own specific roadway design standards, while others rely on Caltrans' Highway Design Manual[7], FHWA's "Green Book" policy manual[8] and PEDSAFE guide[9], and AASHTO's Roadside Design Guide[10]. If the traffic control devices or roadway geometry are not in compliance, appropriate devices/countermeasures should be installed. Non-compliance is an important consideration that can affect road safety and may have liability implications for a jurisdiction. Using CA-MUTCD compliant devices results in uniformity among California roadways and serves to meet road user expectations.

Field Assessments

While the qualitative analysis of compliance issues should continually occur on a network-wide basis, a qualitative analysis should also occur for each of the locations and corridors identified as a result of a 'Quantitative Analysis'. The consideration of roadway infrastructure characteristics in conjunction with crash frequency or crash rate gives a more complete picture of overall safety and should be used in an agency's identification and prioritization process for locations needing safety improvements. The qualitative assessment of HCCLs can be completed through the examination of maps and photographs, but the importance of in-field assessments by multi-disciplinary teams should not be underestimated. In some cases, field reviews of all potential project locations may not be practical, so safety practitioners are encouraged to utilize internet-mapping tools to view maps and photographs and virtually visit these sites from their offices.

Actual field visits or RSAs can be done at the highest priority locations before or during the countermeasure selection process. In many cases, field assessments are often the only way for practitioners to identify potential countermeasure implementation and project delivery obstacles. Without in-field assessments, right-of-way, infrastructure, and operational constraints can be overlooked, including: sensitive environmental resources (widening may not be feasible next to wetlands), roadway users (rumble strips may not be feasible on roadways with high bicycle volumes and narrow shoulders), or nearby roadway stakeholders (flashing beacons may be problematic for adjacent residents.) Assessments can provide critical information for local practitioners as they prioritize their crash locations and select countermeasures with the greatest potential for cost effective deployment.

Recommended Action: Incorporate qualitative analysis elements into agency's proactive analysis approach. Consider completing field assessments and RSAs to identify locations with roadway infrastructure characteristics that relate to both compliance issues and high crash frequencies/rates. As part of field assessments, common roadway and crash characteristics should be identified for the potential systemic deployment of countermeasures. Rather than reviewing all crash sites individually, agencies may find the use of Internet mapping tools offers significant time savings. For agencies without a preferred virtual field review method, the SafeTREC TIMS website automatically links the SWITRS crash locations to Google Maps and Google Street View.

Caltrans recommends all agencies complete both quantitative and qualitative analyses before starting their applications for HSIP program funding. The findings from these analyses should be documented in spreadsheets and/or pin-maps similar to the ones discussed in Section 2.

4. Countermeasure Selection

Once locations and crash problems are identified as illustrated in Sections 2 and 3, the safety practitioners will need to select the set of proposed safety improvements to reduce the likelihood of future crashes. Individual elements of standard safety improvements are referred to as countermeasures and most countermeasures have corresponding Crash Modification Factors (CMFs).

When applied correctly, CMFs can help agencies identify the expected safety impacts of installing various countermeasures to reduce crashes. CMFs are multiplicative factors used to estimate the expected number of crashes after implementing a given countermeasure at a specific site (the lower the CMF, the greater the expected reduction in crashes). Crash Reduction Factors (CRFs) are directly connected to the CMFs and are another indication of the effectiveness of a particular treatment, measured by the percentage of crashes the countermeasure is expected to reduce. The CRF for a countermeasure is defined mathematically as 1 – CMF (the higher the CRF, the greater the expected reduction in crashes). *NOTE: Given that CRF values can be more intuitive when analyzing roadways for potential "reductions" in crashes; this document shows CRF values in the countermeasure tables. The terms CMFs and CRFs are used interchangeably throughout the text of this section and in other sections of this document.*

In an effort to stretch the limited highway safety funding, local transportation agencies are encouraged to identify and implement the optimal combination of countermeasures to achieve the greatest benefits. Combined with crash cost data and project cost information, CRFs can help safety practitioners compare the B/C ratio of multiple countermeasures and then choose the most appropriate application for their proposed safety improvement projects.

As agencies consider the overall scope/cost of their projects, they also need to consider the number of locations to which each countermeasure may be applied in order to maximize the B/C ratio and the overall effectiveness of their limited safety funding. For HCCLs with varying causes, the Spot Location Approach may be the most appropriate. In contrast, the Systemic Approach should be considered where a high proportion of similar crash types tend to occur at locations that share common geometric or operational elements. In these situations, installing the same low-cost safety countermeasure at multiple locations can increase the cost effectiveness of the safety improvement, allowing an increased number of treatments to be applied.

It is important to note that there are many safety issues and corresponding countermeasures that are more "maintenance" in nature (e.g., visibility issues relating to the need for brush clearing and roadway departure issues relating to the need to replace shoulder backing). As these issues are identified when investigating crash locations, it's expected that the local safety practitioners would take the necessary steps to remedy the situation in the short-term. For this reason, most of the common maintenance-type safety countermeasures are not included in this document.

4.1 Selecting Countermeasures and Crash Modification Factors / Crash Reduction Factors

Selecting an appropriate countermeasure and corresponding CMF is similar to choosing the right tool for a job. In some cases, a countermeasure and CMF may not be perfect, but will still work well enough to get the job done by providing a reasonable estimation of the countermeasure's effect. In other cases, using an improper countermeasure or CMF may do more harm than good. Applying a CMF that does not fit a specific situation may give a false sense of the countermeasure's safety effectiveness and may result in an increased safety problem.

The Federal Highway Administration (FHWA) is leading a concerted effort to develop information on CMFs and makes it available to State and local agencies to assist with highway safety planning. The CMF Clearinghouse, a free online database introduced in 2009 and accessible at www.cmfclearinghouse.org, details the varying quality and reliability of CMFs available to transportation professionals.

FHWA has identified three main considerations to assure appropriate selection of CMFs for a given countermeasure: the **availability** of relevant CMFs, the **applicability** of available CMFs, and the **quality** of applicable CMFs.[11] The following sections detail these considerations and describe how Caltrans recommended CRF and service life values meet these criteria.

Availability: The availability of a CMF that applies to a specific situation depends on whether research has been conducted to determine the safety effects of a particular countermeasure or combination of countermeasures, and whether researchers have documented it. The CMF Clearinghouse contains more than 2,900 CMFs and receives quarterly updates to include the latest research.

At this point, Caltrans has established a small subset of 77 countermeasures and a single CRF for each of these countermeasures that must be used when submitting applications for Caltrans statewide calls-for-projects. This methodology allows for a statewide data-driven process that facilitates a fair and accurate comparison of project applications. (The reason for limiting the number of countermeasures is further explained below under “applicability”).

Applicability: In general, once a local safety practitioner determines that one or more CMFs exist for a specific countermeasure, the next step is to determine which CMF is the most applicable. Applicability depends on how closely the CMF represents the situation to which it will be applied. Safety practitioners should evaluate the potentially applicable CMFs, eliminating any that are not appropriate for the situation. Practitioners should only choose the most appropriate CMFs for their specific project based on factors including but not limited to: urban areas vs. rural areas; low vs. high traffic volumes; 2-lane vs. 6-lane roadways; individual vs. combination treatments; signalized vs. non-signalized intersections; and minor crashes vs. fatal crashes. If practitioners choose to use a CMF outside the range of applicability, the safety effect will likely be over or underestimated.

The mix of countermeasures and CRFs included in this document is intended to meet Caltrans' goal for a data-driven award process for local agencies to follow that allows for a fair and accurate comparison of project applications. Where possible and appropriate, the CRF value intended for use in statewide calls-for-projects is based on research studies that specifically established the CRF to be used for 'all' project areas, roadway types, and traffic volumes. Where CRFs are appropriate for 'all' applicability-factors were not already established by prior research, Caltrans worked closely with FHWA to approximate CRFs for countermeasures often utilized by local agencies.

Quality: Often a search of the CMF Clearing House results in multiple CMFs for the same countermeasure. A practitioner needs to examine the quality of each CMF. The quality of a CMF can vary greatly depending on several factors associated with the process of developing the CMF. The primary factors that determine the quality of a CMF are the study design, sample size, standard error, potential bias, and data source. The CMF Clearinghouse provides a star rating for each based on a scale of 1 to 5, where 5 indicates the highest quality. The most reliable CMFs in the HSM are indicated with a bold font.

Wherever possible, the CRFs included in this document are based on research that has a CMF Clearinghouse star rating of 3 or more. For countermeasures that do not have corresponding research of a star rating of 3 or more but were deemed important to provide flexibility to local practitioners, Caltrans worked closely with FHWA to establish CRFs based on the best available research.

4.2 List of Countermeasures

The list of countermeasures discussed in this section is not an all-inclusive list, and only includes those available in the Caltrans' HSIP calls-for-projects process. Only thoroughly researched countermeasures with a readiness to be applied by local agencies on a statewide basis are utilized. Practitioners are encouraged to utilize the FHWA CMF Clearinghouse for a more comprehensive list as they establish their local agency specific set of proposed improvements and prioritize their projects.

The countermeasures listed in the following three tables have been sorted into 3 categories: Signalized Intersection, Non-Signalized Intersection, and Roadway Segment. Pedestrian and bicycle related countermeasures have been included in each of these categories, as the consideration of non-motorized travel is important for all roadway classifications and locations. The countermeasures included in these tables are also included in the SafeTREC TIMS tools. When selecting countermeasures and CMFs to apply to their specific safety needs, local agency safety practitioners should consider the **availability, applicability**, and **quality** of CMFs, as discussed in section 4.1.

Intersection Countermeasures								
SIGNALIZED								
CM #	**Project Type**	**Countermeasures**	**Opportunity to Implement using a Systematic Approach**	**General Values for Agency's Internal Use**		**Values for Caltrans Local HSIP Program**		
				Primary Crash Types	**Range of Crash Reduction Factors**	**Crash Type**	**CRF**	**Service Life**
S1*	Lighting	Add intersection lighting (S.I.)	Medium	Night (All)	20 - 74%	Night	40	20
S2*	Signal Mod.	Improve signal hardware: lenses, back-plates, mounting, size, and number	Very High	Rear-End, Angle	0 - 46%	All	15	10
S3*	Signal Mod.	Improve signal timing (coordination, phases, red, yellow, or operation)	Very High	All (varies)	0 - 41%	All	15	10
S4*	Signal Mod.	Provide Advanced Dilemma Zone Detection for high speed approaches	High	All (varies)	39%	All	40	10
S5*	Signal Mod.	Install emergency vehicle pre-emption systems	High	Emrg. Vehicle - only	70%	Emerg vehicle	70	10
S6*	Signal Mod.	Provide protected left turn phase (left turn lane already exists)	High	Rear-End, Sideswipe	16 - 99%	All	30	20
S7*	Signal Mod.	Convert signal to mast arm (from pedestal-mounted)	Medium	Rear-End, Angle	12 - 74%	All	30	20
S8*	Operation/ Warning	Install raised pavement markers and striping (Through Intersection)	Very High	Wet, Night, All	10 - 33%	All	10	10
S9*	Operation/ Warning	Install flashing beacons as advance warning (S.I.)	Medium	Rear End, Angle	36 - 62%	All	30	10
S10	Operation/ Warning	Install cameras to detect red-light running	Medium	Angle	16 - 34%	N/A	N/A	N/A
S11	Operation/ Warning	Improve pavement friction (High Friction Surface Treatments)	Medium	Wet, Night, All	10 - 62%	All	25	10
S12	Geometric Mod.	Install raised median on approaches (S.I.)	Medium	Angle	21 - 55%	All	25	20
S13	Geometric Mod.	Create directional median openings to allow (and restrict) left-turns and u-turns (S.I.)	Medium	All (varies)	51%	All	50	20
S14	Geometric Mod.	Install right-turn lane (S.I.)	Low	Rear-End	14 - 27%	N/A	N/A	N/A
S15	Geometric Mod.	Install left-turn lane (signal **has no** left-turn phase - before and after)	Low	All (varies)	10 - 24%	N/A	N/A	N/A
S16	Geometric Mod.	Install left-turn lane (signal **has a** left-turn phase - before and after)	Low	All (varies)	31 - 44%	N/A	N/A	N/A
S17	Geometric Mod.	Install left-turn lane and add turn phase (signal has no left-turn lane or phase before)	Low	All (varies)	17 - 58%	All	55	20
S18*	Geometric Mod.	Convert intersection to roundabout (from signal)	Low	All (varies)	35 - 67%	All	50	20
S19*	Ped and Bike	Install pedestrian countdown signal heads	Very High	Pedestrian, Bicycle	25%	P & B	25	20
S20*	Ped and Bike	Install pedestrian crossing (S.I.)	High	Pedestrian, Bicycle	25%	P & B	25	20
S21*	Ped and Bike	Install advance stop bar before crosswalk (Bicycle Box)	Very High	Pedestrian, Bicycle	35%	P & B	15	10
S22	Ped and Bike	Install pedestrian overpass/underpass	Low	Pedestrian, Bicycle	5 - 100%	N/A	N/A	N/A
S23	Geometric Mod.	Install pedestrian median fencing on approaches	Low	Pedestrian, Bicycle	25 - 40%	P & B	35	20

***Countermeasure eligible for 100% federal reimbursement**
Local Agencies are encouraged to go to FHWA's Crash Modification Factors Clearinghouse for more information on Roadway Safety Countermeasures.
http://www.cmfclearinghouse.org/index.cfm

Intersection Countermeasures								
Non-Signalized								
CM #	**Project Type**	**Countermeasures**	**Opportunity to Implement using a Systematic Approach**	**General Values for Agency's Internal Use**		**Values for Caltrans Local HSIP Program**		
				Primary Crash Types	**Range of Crash Reduction Factors**	**Crash Type**	**CRF**	**Service Life**
NS1*	Lighting	Add intersection lighting (NS.I.)	Medium	Night (All)	25 - 50%	Night	40	20
NS2*	Control	Convert to all-way STOP control (from 2-way or Yield control)	High	Left-turn, Angle	6 - 80%	All	50	10
NS3*	Control	Install signals	Low	All (varies)	0 - 74%	All	25	20
NS4*	Control	Convert intersection to roundabout (from 2-way stop or Yield control)	Low	Left-Turn, Angle	12 - 78%	All	45	20
NS5*	Operation/ Warning	Install/upgrade larger or additional stop signs or other intersection warning/regulatory signs	Very High	All (varies)	11 - 55%	All	15	10
NS6*	Operation/ Warning	Upgrade intersection pavement markings (NS.I.)	Very High	All (varies)	13 - 60%	All	25	10
NS7*	Operation/ Warning	Install Flashing Beacons at Stop-Controlled Intersections	High	Angle, Rear-End	5 - 34%	All	15	10
NS8*	Operation/ Warning	Install flashing beacons as advance warning (NS.I.)	High	Angle, Rear-End	36 - 62%	All	30	10
NS9	Operation/ Warning	Install transverse rumble strips on approaches	High	All (varies)	0 - 35%	All	20	10
NS10	Operation/ Warning	Improve sight distance to intersection (Clear Sight Triangles)	High	All (varies)	11 - 56%	All	20	10
NS11	Geometric Mod.	Install splitter-islands on the minor road approaches	Medium	Angle, Rear-End	35 - 100%	All	40	20
NS12	Geometric Mod.	Install raised median on approaches (NS.I.)	Medium	All (varies)	20 - 39%	All	25	20
NS13	Geometric Mod.	Create directional median openings to allow (and restrict) left-turns and u-turns (NS.I.)	Medium	All (varies)	51%	All	50	20
NS14	Geometric Mod.	Install right-turn lane (NS.I.)	Low	All (varies)	14 - 26%	All	20	20
NS15	Geometric Mod.	Install left-turn lane (where no left-turn lane exists)	Low	All (varies)	9 - 55%	All	35	20
NS16	Ped and Bike	Install raised medians / refuge islands (NS.I.)	Medium	Pedestrian, Bicycle	30 - 56%	P & B	45	20
NS17*	Ped and Bike	Install pedestrian crossing at uncontrolled locations (new signs and markings only)	High	Pedestrian, Bicycle	25%	P & B	25	10
NS18*	Ped and Bike	Install pedestrian crossing at uncontrolled locations (with enhanced safety features)	Medium	Pedestrian, Bicycle	37%	P & B	35	20
NS19*	Ped and Bike	Install pedestrian signal or HAWK	Low	Pedestrian, Bicycle	15 - 69%	P & B	55	20
NS20	Operation/ Warning	Improve pavement friction (High Friction Surface Treatments)	Medium	Wet, Night, All	10 - 62%	All	25	10

***Countermeasure eligible for 100% federal reimbursement**
Local Agencies are encouraged to go to FHWA's Crash Modification Factors Clearinghouse for more information on Roadway Safety Countermeasures.
http://www.cmfclearinghouse.org/index.cfm

Roadway Countermeasures								
	Project Type	Countermeasures	Opportunity to Implement using a Systematic Approach	General Values for Agency's Internal Use		Values for Caltrans Statewide Programs		
				Primary Crash Types	Range of Crash Reduction Factors	Crash Type	CRF	Service Life
R1*	lighting	Add segment lighting	Medium	Night (All)	18 - 69%	Night	35	20
R2	Remove/ Shield Obstacles	Remove or relocate fixed objects outside of Clear Recovery Zone	High	Fixed Object	17 - 100%	All	35	20
R3*	Remove/ Shield Obstacles	Install Median Barrier	Medium	Head-on	0 - 94%	All	25	20
R4*	Remove/ Shield Obstacles	Install Guardrail	High	Fixed Object, Run-off Road	11 - 78%	All	25	20
R5*	Remove/ Shield Obstacles	Install impact attenuators	High	Fixed Object, Run-off Road	5 - 50%	All	25	10
R6	Remove/ Shield Obstacles	Flatten side slopes	Medium	Fixed Object, Run-off Road	5 - 62%	All	30	20
R7	Remove/ Shield Obstacles	Flatten side slopes and remove guardrail	Medium	Roll Over, Fixed Object	42%	All	40	20
R8	Remove/ Shield Obstacles	Upgrade bridge railing	Low	All (varies)	5 - 20%	N/A	N/A	N/A
R9	Geometric Mod.	Install raised median	Medium	Head-on	20 - 75%	All	25	20
R10	Geometric Mod.	Install median (flush)	Medium	All (varies)	15 - 78%	All	15	20
R11	Geometric Mod.	Install acceleration/ deceleration lanes	Low	Sideswipe, Rear-End	10 - 75%	All	25	20
R12	Geometric Mod.	Install climbing lane (where large difference between car and truck speed)	Low	All (varies)	20 - 33%	N/A	N/A	N/A
R13	Geometric Mod.	Widen lane (initially less than 10 ft)	Medium	All (varies)	5 - 70%	All	25	20
R14	Geometric Mod.	Add two-way left-turn lane (without reducing travel lanes)	Medium	All (varies)	8 - 50%	All	30	20
R15	Geometric Mod.	Road Diet (Reduce travel lanes from 4 to 3 and add a two way left-turn and bike lanes)	Medium	All (varies)	26 - 43%	All	30	20
R16	Geometric Mod.	Widen shoulder (paved)	Medium	Fixed Object, Run-off Road, Sideswipe	15 - 75%	All	30	20
R17	Geometric Mod.	Widen shoulder (unpaved)	Medium	All (varies)	15 - 22%	All	20	20
R18	Geometric Mod.	Pave existing shoulder	Medium	All (varies)	10 - 25%	All	15	20
R19	Geometric Mod.	Improve horizontal alignment (flatten curves)	Low	All (varies)	24 - 90%	All	50	20
R20	Geometric Mod.	Flatten crest vertical curve	Low	All (varies)	20 - 51 %	All	25	20
R21	Geometric Mod.	Improve horizontal and vertical alignments	Low	All (varies)	50 - 73%	All	60	20
R22	Geometric Mod.	Improve curve superelevation	Medium	Run-off Road, All	40 - 50%	All	45	20

R23	Geometric Mod.	Convert from two-way to one-way traffic	Medium	All (varies)	26 - 43%	All	35	20
R24	Geometric Mod.	Improve pavement friction (High Friction Surface Treatments)	High	Wet, Rear-End, All	17 - 68%	All	30	10
R25	Geometric Mod.	Provide Safety Edge for Pavement Edge Drop-off	Very High	Run-off Road	4 - 63%	N/A	N/A	N/A
R26*	Operation/ Warning	Install/Upgrade signs with new fluorescent sheeting (regulatory or warning)	Very High	Head on, Run-off road, Sideswipe, Night	18 - 35%	All	15	10
R27*	Operation/ Warning	Install chevron signs on horizontal curves	Very High	Run-off Road, All	6 - 64%	All	40	10
R28*	Operation/ Warning	Install curve advance warning signs	Very High	Run-off Road, All	20 - 30%	All	25	10
R29*	Operation/ Warning	Install curve advance warning signs (flashing beacon)	High	All (varies)	30%	All	30	10
R30*	Operation/ Warning	Install dynamic/variable speed warning signs	High	All (varies)	0 - 41%	All	30	10
R31*	Operation/ Warning	Install delineators, reflectors and/or object markers	Very High	All (varies)	0 - 30%	All	15	10
R32*	Operation/ Warning	Install edge-lines and centerlines	Very High	Head-on, Run-off Road, All	0 - 44%	All	25	10
R33*	Operation/ Warning	Install no-passing line	Very High	Head-on, Side-swipe, All	40 - 53%	All	45	10
R34*	Operation/ Warning	Install centerline rumble strips/stripes	High	Head-on, Side-swipe, All	15 - 68%	All	20	10
R35*	Operation/ Warning	Install edgeline rumble strips/stripes	High	Run-off Road	10 - 41%	All	15	10
R36	Ped and Bike	Install bike lanes	High	Pedestrian, Bicycle	0 - 53%	P & B	35	20
R37	Ped and Bike	Install sidewalk/pathway (to avoid walking along roadway)	Medium	Pedestrian, Bicycle	65 - 89%	P & B	80	20
R38	Ped & Bike	Install pedestrian crossing (with enhanced safety features)	Medium	Pedestrian, Bicycle	8 - 56%	P & B	30	10
R39	Ped and Bike	Install raised pedestrian crossing	Medium	Pedestrian, Bicycle	30 - 46%	P & B	35	10
R40	Animal	Install animal fencing	Medium	Animal	70 - 90%	Animal	80	20
R41	Truck	Install truck escape ramp	Low	Run-off Road, Rear-end	33 - 75%	N/A	N/A	N/A
R42	Geometric Mod.	Install pedestrian median fencing on approaches	Low	Pedestrian, Bicycle	25 - 40%	P & B	35	20

***Countermeasure eligible for 100% federal reimbursement**

Local Agencies are encouraged to go to FHWA's Crash Modification Factors Clearinghouse for more information on Roadway Safety Countermeasures.
http://www.cmfclearinghouse.org/index.cfm

4.3 Countermeasure Details and Characteristics

The list of countermeasures above is intended to be a quick-reference summary. Appendix B of this manual provides more details on each of these countermeasures. The format of Appendix B is shown in the sample below: (To improve the flow of the document, only one example is included in the body of the manual.)

<table>
<tr><td colspan="2">Name: Improve pavement friction (High Friction Surface Treatments)</td><td>Caltrans CM Number: S11</td></tr>
<tr><td colspan="3">Where to use: Signalized Intersections noted as having crashes on wet pavements or under dry conditions when the pavement friction available is less than desirable for the roadway. This treatment is intended to target locations where skidding and failure to stop is determined to be a problem.
* For Caltrans' statewide Calls-for-Projects: This CM only applies to crashes occurring within the limits of the improved friction overlay. This CM is not intended to apply to standard maintenance/repaving projects.</td></tr>
<tr><td colspan="3">Why it works: Improving the skid resistance at locations with high wet-road and/or failure to stop accident frequencies can result in significant reductions in wet-road and total crashes.</td></tr>
<tr><td colspan="3">General Qualities (Time, Cost, Effectiveness): This strategy can be relatively inexpensive and implemented in a short timeframe. The installation would be done by either agency personnel or contractors. In general, these CMs can be very effective and can be considered on a systematic approach.</td></tr>
<tr><td></td><td>General Use</td><td>Values for Caltrans Statewide Programs (Calls-for-Projects)</td></tr>
<tr><td>Crash Types Addressed:</td><td>Wet, Night, ALL</td><td>ALL</td></tr>
<tr><td>Crash Reduction Factor:</td><td>10 - 62 %</td><td>25% (with an expected life of 10 years)</td></tr>
</table>

The countermeasure details are described below:

- ***Where to use*** – Roadway segments and intersections with specific common characteristics can be addressed with similar countermeasures that are most effective. Specific requirements are also provided for utilizing the countermeasure on applications for Caltrans statewide calls-for-projects.
- ***Why it works*** – A discussion of the benefit of a countermeasure is important to determine its appropriateness in addressing certain roadway crash types at areas with specific issues as determined by the data and roadway features.
- ***General Qualities (Time, Cost and Effectiveness)*** – This category is more subjective and can vary substantially. 'Time' refers to the approximate relative time it can take to implement the countermeasure. Costs can vary considerably due to local conditions, so 'cost' represents the relative cost of applying a countermeasure. A relative overall 'effectiveness' is also provided for some countermeasures. All of this subjective information may not be applicable to the unique circumstances for the agency and should not be utilized without verification by the safety practitioner.
- ***Crash Types Addressed*** – In order to effectively reduce the number and severity of roadway crashes, it is necessary to match countermeasures to the crash types they are intended to address.

Depending on the type of problem, one or more of a range of countermeasures could be the most effective way to reduce the number and severity of future crashes.

- ***Crash Reduction Factor*** – The crash reduction factor (CRF) is an indication of the effectiveness of a particular treatment, measured by the percentage of crashes it is expected to reduce. Note: As mentioned earlier in this section, the effectiveness of a countermeasure can also be expressed as a Crash Modification Factor (CMF), which is defined mathematically as 1 – CRF. However, this document uses CRFs as they can be more insightful when analyzing roadways for potential "reductions" in crashes. There is both a single CRF value for Caltrans calls-for-projects and a range of CRF values that exist for each of the countermeasures (or similar countermeasures). The range of CRFs is provided to give local safety practitioners a clear understanding that they may need to go to the FHWA CMF Clearinghouse to find the most appropriate countermeasure and CRF for their specific projects and local prioritization.

Recommended Action: At this point, agencies should use all information and results obtained by completing the actions in Sections 2, 3 and 4 to select the appropriate countermeasures for their HCCLs and systemic improvements. As novice safety practitioners select countermeasures, they must realize that a reasonable level of traffic 'engineering judgment' is required and that this manual should not be used as a simple cheat-sheet for preparing and submitting applications for funding.

5. Calculating the B/C Ratio and Comparing Projects

Practitioners need to consider the expected B/C ratio of their proposed projects. This is an important step in a proactive safety analysis process because it provides two key pieces of information: First, it defines the cost effectiveness of the proposed projects; and second, it gives the safety practitioner a means to help prioritize their safety projects both inside the agency's traffic safety section and against other proposed operational and maintenance projects competing for funding.

5.1 Estimate the Benefit of Implementing Proposed Improvements

Sections 2 through 4 provide the practitioner all the information needed to calculate the expected 'Benefit' of the proposed safety projects. The resulting expected benefit value is derived by applying the proposed countermeasures and corresponding CMFs to the expected crashes. It is of critical importance for the practitioner to understand that misapplication of a CMF will lead to misinformed decisions. Four main factors need to be considered when applying countermeasures and CMFs to calculate the expected benefit value: (1) how to estimate the number of expected crashes without treatment, (2) how to apply CMFs by type and severity, (3) how to apply multiple CMFs if multiple treatments are to be included in the same project, and (4) how to apply a benefit value by crash severity. The following text explains how these factors affect the expected benefit value in more detail.

Estimating expected crashes without treatment: Before applying CMFs, local safety practitioners first need to select countermeasures and CMFs. The CMF is applied to the expected safety performance (expected crashes) without any treatment in order to estimate the expected crashes with the treatment. The reduction in expected crashes multiplied by the expected costs per each crash gives the practitioner the expected benefit.

As mentioned earlier in this manual, the random nature of roadway crashes suggests that over time the number of crashes at any particular locations will change. This concept is known as "regression to the mean" and it gives rise to the concern that a site might be selected for study when the crashes are at a randomly high fluctuation, or overlooked from study when the site is at a randomly low fluctuation. The HSM presents several methods for estimating the expected safety performance of a roadway or intersection including the Empirical Bayes method, which combines observed information from the site of interest with information from similar sites to estimate the expected crashes without treatment. Another common way to minimize the impact of regression to the mean is to increase the number of years of crash data being analyzed.

For statewide calls-for-projects, Caltrans strives to ensure that all projects are fairly ranked based on a consistent statewide approach. Given this, Caltrans has avoided using methodology requiring agencies to mathematically adjust their crash data (e.g., Empirical Bayes) and instead has opted to use a minimum of 5 years of "observed crashes" in estimating "expected crashes."

Applying CMFs by type and severity: Section 4.1 of this manual discusses the application of CMFs and the need for them to represent the situation to which they will be applied. It also stresses the need for practitioners to choose the most appropriate CMFs for their specific project. In many circumstances, estimating the change in crashes by type and severity is useful; however, local safety practitioners only can use this approach when CMFs exist for the specific crash types and severities in question. If practitioners choose to use a CMF outside the range of applicability, the safety effect may be over- or underestimated. (For example: past research relating to installing a channelized left turn lane, has estimated CMFs as high as 68% for Right-Angle crashes of all severities and as low as 11% for Rear-End crashes with severities of only fatal and injury).

Applying multiple CMFs: In real-world scenarios, transportation agencies commonly install more than one countermeasure per project as part of their safety improvement program. This leads to the question, "What is the safety effect of the combined countermeasures?" One common practice is to assume that CMFs are multiplicative. In other words, each successive countermeasure will achieve an additional benefit when implemented in combination with other countermeasures. The multiplicative method is a common, generally accepted method and is presented in the HSM and in the CMF Clearinghouse. However, transportation agencies also are using other methods including: applying the CMF for the single countermeasure expected to achieve the greatest reduction, applying CMFs separately by crash type and summing them to get a project-level effect, and applying CMFs based on a review of crash patterns. Regardless of the specific method employed, "engineering judgment" is required when combining multiple CMFs and it is important for local agencies to apply their method consistently throughout their analysis to ensure a fair comparison of projects.

Caltrans has established some key requirements and procedures for its calls-for-projects to allow agencies maximum flexibility in combining countermeasures into a single project while ensuring all projects can be consistently ranked on a statewide basis. First, only three individual countermeasures can be utilized in the B/C ratio for a project. Next, for a countermeasure to be utilized in the B/C ratio calculations, it must represent a minimum of 15% of the project's total construction cost. (This is intended to ensure that minor and insignificant elements of the project are not misrepresented to be a major safety effort by the agency). Finally, when combining countermeasures, agencies are able to apply multiple countermeasures with differing limits. This allows agencies to apply different types of countermeasures (e.g., roadway segment and intersection countermeasures) as well as different locations for each countermeasure (e.g., combining multiple spot location improvements into the same project). In order to account for significantly different countermeasure limits in a single project, Caltrans has opted to calculate the benefit of each countermeasure separately, accounting for differing crash numbers and then adding them together to calculate the total expected benefit for the project (the only limitation to adding the three countermeasures together is that the combined CFRs applied to any crashes do not exceed 0.8). Caltrans understands that elements of these requirements and procedures vary from generally accepted evaluation procedures in the HSM and other publications, but has concluded that they offer local agencies the maximum flexibility while allowing Caltrans to implement a true data driven statewide selection process. (Note: More information on these requirements and procedures are provided in the separate "Application Instructions" for each call-for-projects.)

Appling benefit value by crash severity: The last step in estimating the overall benefit of a proposed improvement project is to multiply the expected reduction in crashes by a generally accepted value for the "cost" of crashes. In other words, the expected "benefit" value for a project is actually the expected "reduction in costs" value from reducing future crashes. There are many sources for the costs of crashes (e.g., HSM, FHWA & National Safety Council) and some of the sources vary widely depending on how they account for the economic value of a life and when the numbers were last updated.

When calculating the "benefit" to be used in calculating an improvement's B/C ratio, it is important for the practitioner to consider whether a total benefit value for the "life" of the improvement is needed or if the benefit value should be annualized (i.e., benefit per year). Whichever method is used to calculate the overall cost of the improvements must also be used for calculating the benefit.

Caltrans has currently chosen to use published Cost-of-Crash values from the first edition of the HSM. These values may be updated in the future, when updated cost-of-crash values are published by FHWA or another national source. The specific values for each of the crash severities and the formulas uses to calculate the total benefit are shown in Appendix D.

Recommended Action: Prepare Total Benefit estimates for the proposed projects being evaluated in the proactive safety analysis.

5.2 Estimate the Cost of Implementing Proposed Improvements

After calculating the expected benefit of the proposed safety projects, the next step for the practitioner is to develop an estimate of the Total Project Costs. These costs need to include both the construction costs and the project development and administration costs. The most common approach to estimating construction costs is through an "Engineer's Cost Estimate." An example has been included in Appendix E. When calculating the administration costs for a project, the complexity of the improvements must be accounted for: Low-cost countermeasures, typically used in the Systemic Approach, often have minimal environmental and right-of-way impacts and require minimal design effort. In contrast, many medium to high cost improvements tend to have greater impacts to the environment and right-of-way and require significant design efforts. It's crucial to account for these differences to accurately determine the true B/C ratio of the projects and prioritize them correctly.

When an agency is initially evaluating several potential locations and countermeasures as part of their proactive safety analysis or Caltrans call-for-projects, they should consider first using rough 'ballpark' cost estimates using previous projects that had similar scope, if possible. Ballpark cost estimates can allow the practitioner to quickly establish B/C ratios for all of their potential projects and identify the projects with high cost effectiveness and with a reasonable chance of receiving federal funding in a Caltrans call-for-projects.

Recommended Action: Prepare 'Total Project Cost' estimates for the proposed projects being evaluated in the proactive safety analysis.

5.3 Calculate the B/C Ratio

In general, the B/C ratio is calculated by taking a project's overall benefit (as calculated in Section 5.1) and dividing it by the project's overall cost (as calculated in Section 5.2). There are, however, several methods and input-factors available for calculating a project's B/C ratio and practitioners may want to consider other methods as defined in the HSM.

Based on Caltrans' need for a fair, data-driven, statewide project selection process for HSIP call-for-projects, Caltrans requires the B/C ratio for all applications to be completed using the same process. Applicants for these programs must utilize the B/C calculator in SafeTREC's TIMS. Additional details and formulas included in this B/C calculator are included in this document as Appendix D.

Recommended Action: Calculate the B/C ratio for each of the proposed projects being evaluated in the proactive safety analysis. If the B/C ratio is being calculated as part of an HSIP application, Caltrans requires agencies to utilize TIMS.

5.4 Compare B/C Ratios and Consider the Need to Reevaluate Project Elements

By implementing a comprehensive proactive safety analysis approach, agencies will likely identify more potential safety projects than they can fund and deliver. It will be important for an agency to prioritize their projects internally before funding is sought. It is not uncommon for projects to have a B/C ratio as low as 0.1 or as high as 100. Once the relative cost effectiveness of an agency's potential projects has been established, the projects with low to mid-ranged B/C ratios should be reassessed. Projects with very low initial B/C ratios may be dropped while projects with low to mid ranged B/C ratios may be redefined by changing the limits of the proposed improvements to focus on higher crash locations or incorporating lower-cost countermeasures. This reiterative process is illustrated in Figure 1 in Section 1 of this document.

At the conclusion of this step, the local agency should have several potential safety projects ready to move into the project development and construction phases. Ideally, there will be a variety of low cost safety projects and potentially a few higher cost roadway reconstruction projects. How each local agency prioritizes their list of safety improvements will vary, but projects with the highest B/C ratios should generally have a high overall priority. It should be understood that available funding will play a key role in local agency prioritization (e.g., higher-cost projects may have to wait for funding to become available while low-cost improvements with lower B/C ratios can be constructed with in-house maintenance crews), but in the goal of maximizing overall safety benefits, the role of politics and public influence should be minimized.

Recommended Action: Compare, reevaluate, and prioritize the potential safety projects. Consider changing the project limits to maximize the number of fatal and injury crashes addressed within the limits. Consider lower cost countermeasures in areas where high and medium cost countermeasures resulted in low B/C ratios.

6. Identifying Funding and Construct Improvements

Funding strategies for implementing safety projects need to vary as widely as local agency's roadway types, project costs, and proposed improvements. At this point in the proactive safety analysis process, local agencies should have several potential safety projects ready to move into the project development and construction phases. There are likely a wide range of 'approaches' to fund each of these projects. This section of the document discusses some of the most common approaches.

6.1 Existing Funding for Low-cost Countermeasures

For projects utilizing low-cost countermeasures, the total project cost may be low enough that the agency can construct the project using its existing roadway funding by utilizing the ongoing activities of their roadway maintenance staff and equipment. Other low-cost projects (e.g., overlays, sealcoats, drainage, signing, and striping projects) may be more important to incorporate into larger maintenance projects. It is common for agencies to have 1-, 5-, and 10-year plans for making these standard maintenance improvements. With upfront planning and coordination between agency staff, the low-cost safety projects identified through the proactive safety analysis can be incorporated with minimal costs to an agency's maintenance program. Maximizing the cost effectiveness of the program may even allow the transportation managers to justify increasing the funding for their overall roadway maintenance program.

In addition to their maintenance program, transportation managers should also strategically seek out planned capital improvement and development projects that can incorporate low and medium cost countermeasures identified in their safety analysis. Local agencies may also find opportunities to partner with private enterprises and insurance companies to fund special safety projects that further both organizations' strategic goals.

Recommended Action: Survey planned maintenance, developer and capital projects to determine whether they overlap any of the proposed safety projects. Where projects overlap, leverage the existing funding sources to include safety countermeasures.

6.2 HSIP and Other Funding Sources

In addition to the HSIP Program, the Division of Local Assistance's web site includes several other Caltrans administered funding programs:
http://www.dot.ca.gov/hq/LocalPrograms/programInformation.htm

Recommended Action: Consider all potential funding opportunities to incorporate the identified safety countermeasures.

6.3 Project Development and Construction Considerations

In general, roadway safety projects don't garner the same level of attention from decision makers, media, elected officials, and the general public, that large operational and development-driven projects do. As a result, local safety practitioners and project sponsors often find their projects have difficulty in competing for the agencies' limited project delivery resources. Establishing and implementing a comprehensive safety analysis process can assist safety practitioners in delivering their safety programs in many ways, including:

- Credibility and awareness to individual projects and delivery schedules.
- Increased stakeholders tracking and delivery of a project when low-cost improvements are incorporated into ongoing maintenance and capital projects.
- An increased focus on low-cost countermeasures typically corresponds to projects with less environmental, right-of-way and other impacts; resulting in projects that have streamlined project delivery processes and short construction schedules.

Recommended Action: Safety practitioners should follow their safety projects all the way through the project delivery and construction process. In addition, they should establish a safety program delivery plan that brings awareness and support to the expedited delivery of safety projects. Where possible, safety practitioners should involve the media and even consider having their own program intended to "toot their own safety-horn."

7. Evaluation of Improvements

Evaluation of the effectiveness of roadway treatments following installation should be used to guide future decisions regarding roadway countermeasures. Field reviews should also be conducted shortly after the project is completed to insure the project is operating as intended.

A record of crash history and countermeasure installation forms the foundation for assessing how well the implemented strategies have performed. An important database to maintain is a current list of installed countermeasures with documented “when/where/why” information. Periodic assessments will provide the necessary information to make informed decisions on whether each countermeasure contributed to an increase in safety, whether the countermeasure could or should be installed at other locations, and which factors may have contributed to each countermeasure’s success.

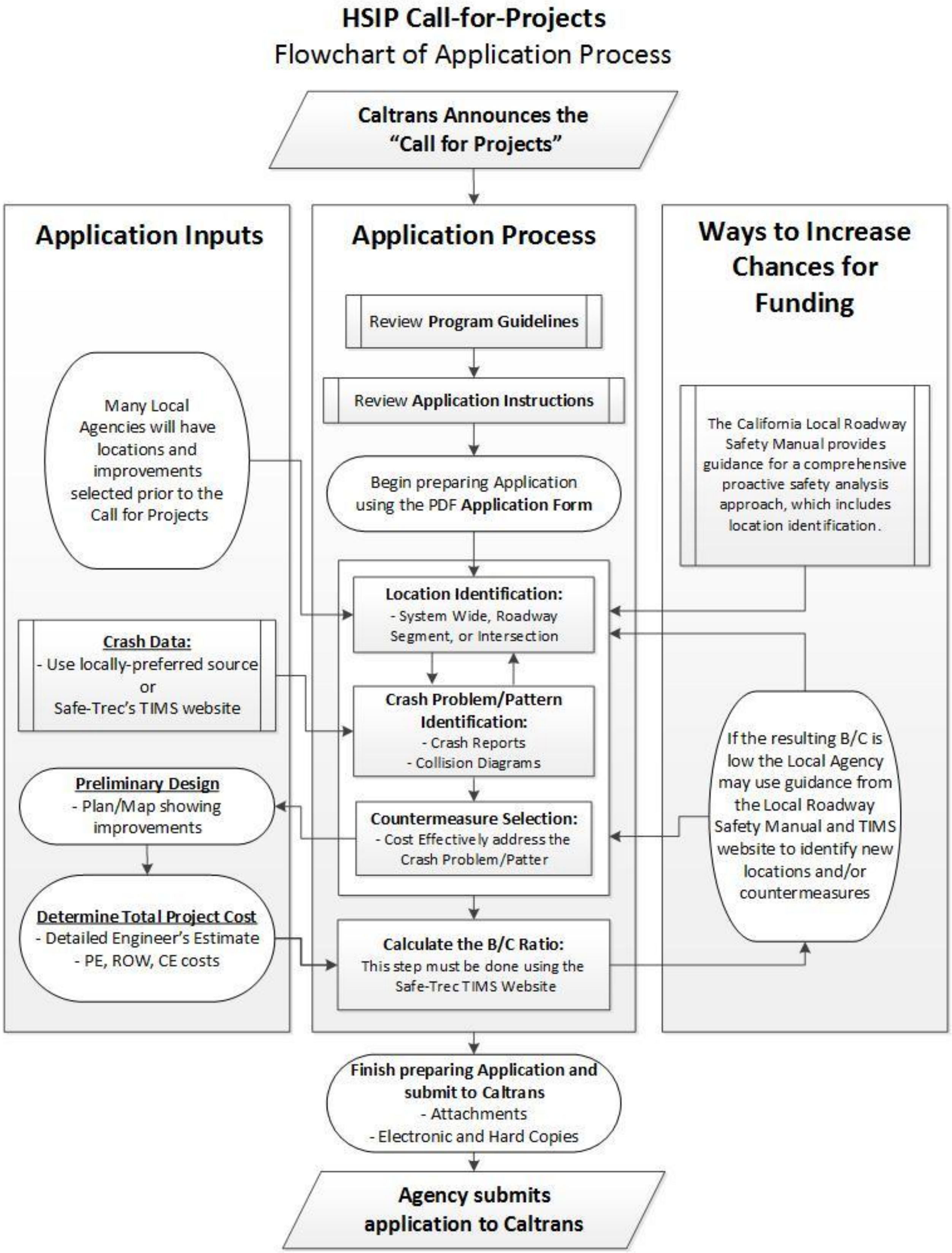
In order to perform the assessment, it is necessary to collect the required information for a certain period after strategies have been deployed at the locations. The time period varies, but whenever possible, 3 to 5 years is recommended to reduce the effects of the random nature of roadway crashes (i.e., Regression to the Mean). The information required may consist of public input and complaints, police reports, observations from maintenance crews, and local and State crash data.

It is important to keep the list of safety installations up-to-date since it will serve as a record of countermeasure deployment history (see table below for an example). By using this type of system, assessment dates can be scheduled to review the crashes and other pertinent information on segments where roadway countermeasures have been installed. Making “after” assessments will inform the practitioner on the effectiveness of past improvements and can provide data to help justify the value of continuing and expanding the local agency’s safety program in the future.

Location	Type of Countermeasure Installed	Date Installed	Crashes Before (Duration and Severity)	Crashes After (Duration and Severity)	Comments

Recommended Action: Develop a spreadsheet or database to track future safety project installations and record 3 or more years of “before” and “after” crash information at those locations. Once safety countermeasures are constructed, schedule and track assessment dates to ensure they happen.

Appendix A: HSIP Call-for-Projects Process



Appendix B: Table of Countermeasures and Crash Reduction Factors

Appendix B is a table of countermeasures. The table includes detailed information on each of the countermeasures, including: Where to use, Why it works, General Qualities (Time, Cost and Effectiveness), Crash Type Addressed, and Crash Reduction Factor.

Note: These pages have their own unique page numbering.

Local Roadway Safety

A Manual for California's Local Road Owners

Version 1.2 April 2015

Based on feedback and lessons learned from Cycle 6, Caltrans has updated Appendix B to better clarify text in "Where to use", "Why it works", and "General Qualities" for several of the countermeasures included in Version 1.1 of the manual. All text changes between Version 1.1 and 1.2 have been shown in red to help users quickly identify the changes between HSIP Cycle 6 and Cycle 7 calls-for-projects.

Appendix B: Table of Countermeasures and Crash Reduction Factors

The intent of the information contained in these countermeasure tables is to provide local agency safety practitioners with a list of effective countermeasures that are appropriate remedies to many common safety issues. The countermeasures have been sorted into 3 categories: Signalized Intersection, Non-Signalized Intersection, and Roadway Segment. Pedestrian and bicycle related countermeasures have been included in each of these categories.

As presented in Section 4 of this Manual, the information in the tables illustrates: where the countermeasure should be used, why it works, and the general qualities that can be used to suggest the potential complexity of installation. The tables also include "General Use" information on the type of crashes where the countermeasure is best used and a range of their expected overall effectiveness. Finally, the table illustrates the specific values that the Caltrans Division of Local Assistance uses to assess and select projects for its Call- for-Projects.

Caltrans gives careful consideration to the fair application of its Call-for-Projects process. Starting in 2012, the award of safety funding will be solely based on a determined benefit-to-cost ratio for each project. The fixed set of countermeasures and CRFs included in these tables are intended to allow for all projects to be evaluated consistently and fairly throughout the project selection process. However, at this time, there are no CRFs/CMFs available for several safety improvements, such as: "dynamic/variable speed regulatory signs", "non-motorized signs and markings (regulatory and warning)", "Square-up (reduce curve radius) turn lanes" and non-infrastructure elements. These safety improvement items can be included in project applications, but they will not be included into the B/C ratio calculations, unless the safety improvements meet the intent of other separate countermeasures included in the attached lists. Caltrans is interested in adding these countermeasures (and many others) to these tables once CRFs/CMFs have been established. Caltrans will continue to periodically update this list of allowable countermeasures and CRFs as new safety research data becomes available. With this in mind, Caltrans is interested in feedback and suggestions from local agency safety practitioners on the overall countermeasure list as well as specific details of individual countermeasures,

Caltrans used the following references to assist it's team in developing the information shown in the following tables. Safety Practitioners are encouraged to utilize these references for a more expansive list of countermeasures and CRFs / CMFs.

The Crash Modification Factors Clearinghouse
http://www.cmfclearinghouse.org/

NCHRP Report 500 Series: Volumes 4, 5, 6, 7, 10, 12, 13, and others
http://www.trb.org/Main/Blurbs/152868.aspx

Highway Safety Manual (HSM), First Edition, 2010
http://www.highwaysafetymanual.org

Toolbox of Countermeasures to reduce pedestrian crashes
http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_tctpepc/

FHWA Manual for Rural Road Owners - Roadway Departure Safety
FHWA Manual for Rural Road Owners - Intersection Safety
FHWA Manual for Rural Road Owners - Non-Motorized Safety
http://safety.fhwa.dot.gov/local_rural/training/

FHWA Desktop Reference for Crash Reduction Factors
http://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/

*Countmeasure eligible for 100% federal funding

Intersection Countermeasures - Signalized

Name: Add intersection lighting (Signalized Intersection => S.I.)	Caltrans CM Number: **S1***

Where to use: Signalized intersections that have a disproportionate number of night-time crashes and do not currently provide lighting at the intersection or at its approaches. Crash data should be studied to ensure that safety at the intersection could be improved by providing lighting (this strategy would be supported by a significant number of crashes that occur at night).
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "night" crashes (all types) occurring within limits of the proposed roadway lighting 'engineered'

Why it works: Providing lighting at the intersection itself, or both at the intersection and on its approaches, improves the safety of an intersection during nighttime conditions by (1) making drivers more aware of the surroundings at an intersection, which improves drivers' perception-reaction times, (2) enhancing drivers' available sight distances, and (3) improving the visibility of non-motorists. Intersection lighting is of particular benefit to non-motorized users. Lighting not only helps them navigate the intersection, but also helps drivers see them better.

General Qualities (Time, Cost, Effectiveness): A lighting project can usually be completed relatively quickly, but generally requires at least 1 year to implement because the lighting system must be designed and the provision of electrical power must be arranged. 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. Some locations can result in high B/C ratios, but due to higher costs, these projects often result in medium to low B/C ratios.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Night, All	Night (All types)
Crash Reduction Factor:	*20 - 74%*	40% (with an expected life of 20 years)

Name: Improve signal hardware: lenses, back-plates, mounting, size, and number	Caltrans CM Number: **S2***

Where to use: Signalized intersections with a high frequency of right-angle and rear-end crashes occurring because drivers are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. Signal intersection improvements include new LED lighting, signal back plates, retro-reflective tape outlining the back plates, or visors to increase signal visibility, larger signal heads, relocation of the signal heads, or additional signal heads.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the upgraded signals. Note: 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). If new signal mast arms are part of the proposed project, CM "S2" should **not** be used and the signal improvements would be included under CM "S7".

Why it works: Providing better visibility of intersection signals aids the drivers' advance perception of the upcoming intersection. Visibility and clarity of the signal should be improved without creating additional confusion for drivers.

General Qualities (Time, Cost, Effectiveness): Installation costs and time should be minimal as these type strategies are classified as low cost and implementation does not typically require the approval process normally associated with more complex projects. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Rear-End, Angle	ALL
Crash Reduction Factor:	*0 - 46%*	15% (with an expected life of 10 years)

Name: Improve signal timing (coordination, phases, red, yellow, or operation)	Caltrans CM Number: **S3***

Where to use: 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. Understanding the corridor or roadway's crash history can provide insight into the most appropriate strategy for improving safety.
Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new signal timing. For projects coordination signals along a corridor, the crashes related to side-street movements should not be applied. Note: This CM 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 (TOCs).*

Why it works: Certain timing, phasing, and control strategies can produce multiple safety benefits. Sometimes capacity improvements come along with the safety improvements and other times adverse effects on delay or capacity occur. Corridor improvements often have the highest benefit but may take longer to implement. Projects focused on capacity improvements (without a separate focus on signal timing safety needs) may not result in a reduction in future crashes.

General Qualities (Time, Cost, Effectiveness): In general, these low-cost improvements to multiple signalized intersections can be implemented in a short time. Typically these low cost improvements are funded through local funding by local maintenance crews. However, some projects requiring new interconnect infrastructure can have moderate to high costs making them more appropriate to seek state or federal funding. The expected effectiveness of this CM must be assessed for each individual project.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	ALL	ALL
Crash Reduction Factor:	*0 - 41%*	15% (with an expected life of 10 years)

*Countermeasure eligible for 100% federal funding

Name: Provide Advanced Dilemma-Zone Detection for high speed approaches	Caltrans CM Number: **S4***

Where to use: 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 may reduce rear-end crashes associated with unsafe stopping and angle crashes due to illegally continuing into the intersection during the red phase.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new detection and signal timing.

Why it works: Clearance times provide safe, orderly transitions in ROW assignment between conflicting streams of traffic. An Advanced Dilemma-Zone Detection system has several benefits relative to traditional multiple detector systems, which have upstream detection for vehicles in the dilemma zone but do not take the speed or size of individual vehicles into account. These benefits include: Reducing the frequency of red-light violations; Reducing the frequency of crashes associated with the traffic signal phase change (for example, rear-end and angle crashes); Reducing delay and stop frequency on the major road and a reduction in overall intersection delay.

General Qualities (Time, Cost, Effectiveness): Installation costs should be low and the time to implement short. Additional modifications to the traffic signal controller may also necessary. In general, these CMs can be very effective and can be considered on a systematic approach. Video detection equipment is now available for this purpose, making installation and maintenance more efficient.

	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	ALL	ALL
Crash Reduction Factor:	*39%*	40% (with an expected life of 10 years)

Name: Install emergency vehicle pre-emption systems	Caltrans CM Number: **S5***

Where to use: Corridors that have a history of crashes involving emergency response vehicles. 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. These conflicts could lead to almost any type of crash, due to the potential for erratic maneuvers of vehicles moving out of the paths of emergency vehicles.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "E.V." crashes occurring on the approaches / influence area of the new pre-emption system.

Why it works: Providing emergency vehicle preemption capability at a signal or along a corridor can be a highly effective strategy in two ways; any type of crash could occur as emergency vehicles try to navigate through intersections and as other vehicles try to maneuver out of the path of the emergency vehicles. In addition, a signal preemption system can decrease emergency vehicle response times therefore decreasing the time in receiving emergency medical attention, which is critical in the outcome of any crash. When past data is not readily available for past crashes with emergency vehicles, an agency may consider combining the E.V. pre-emption improvements into a comprehensive project that also makes significant signal hardware and/or signal timing improvements.

General Qualities (Time, Cost, Effectiveness): 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. The number of detectors, a requirement for new signal controllers, and the intricacy of the preemption system could increase costs. This CM is considered systemic as it is usually implemented on a corridor-basis.

	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Emergency Vehicle - only	Emergency Vehicle - only
Crash Reduction Factor:	*70%*	70% (with an expected life of 10 years)

Name: Provide protected left turn phase (left turn lane already exists)	Caltrans CM Number: **S6***

Where to use: 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 and sideswipe crashes between left-turning vehicles and the through vehicles as well as vehicles behind them. Protected left-turn phases are warranted based on such factors as turning volumes, delay, visibility, opposing vehicle speed, distance to travel through the intersection, presence of non-motorized road users, and safety experience of the intersections. Agencies need to document their consideration of the MUTCD, Section 4D.19 guidelines; the section on implementing protected left-turn phases.
Note: For Caltrans' statewide Calls-for-Projects, 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).

Why it works: Left turns are widely recognized as the highest-risk movements at signalized intersections. Providing Protected the left-turn phases (i.e., the provision for a specific phase for a turning movement) for signalized intersections with existing left turn pockets significantly improve the safety for left-turn maneuvers by removing the need for the drivers to navigate through gaps in oncoming/opposing through vehicles. Where left turn pockets are not protected, the pedestrian and bicyclist crossing phase often conflicts with these left turn maneuvers. Drivers focused on navigating the gaps of oncoming cars may not anticipate and/or perceive the non-motorized road users.

General Qualities (Time, Cost, Effectiveness): 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. The time to implement this countermeasure is short because there is no actual construction that has to take place. In-house signal maintainers can perform this operation once the proper signal phasing is determined so the cost is low. In addition, the countermeasure is tried and proven to be affective. Has the potential of being applied on a systemic/systematic approach.

	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Rear-End, Sideswipe, Broadside	ALL
Crash Reduction Factor:	*16 - 99%*	30% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Convert signal to mast arm (from pedestal-mounted)	Caltrans CM Number: **S7***

Where to use: 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. Intersections that have pedestal-mounted signals may have poor visibility and can result in vehicles not being able to stop in time for a signal change. 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the converted signal heads that are relocated from median and/or outside shoulder pedestals to signal heads on master arms over the travel-lanes. Projects using CM "S7" should not also apply "S2" in the B/C calc.

Why it works: Providing better visibility of intersection signs and signals aids the drivers' advance perception of the upcoming intersection. Visibility and clarity of the signal should be improved without creating additional confusion or distraction for drivers.

General Qualities (Time, Cost, Effectiveness): Dependant on the scope of the project. Costs are generally moderate for this type of project. There is usually no right-of-way costs, minimal roadway reconstruction costs, and a shorter project development timeline. At the same time, new mast arms can be expensive. Some locations can result in high B/C ratios, but due to moderate costs, some locations may result in medium to low B/C ratios.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Rear-End, Angle	ALL
Crash Reduction Factor:	*12 - 74%*	30% (with an expected life of 20 years)

Name: Install raised pavement markers and striping (Through Intersection)	Caltrans CM Number: **S8***

Where to use: 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. Driver confusion can exist in regard to choosing the proper turn path or where through-lanes do not line up. This is especially relevant at intersections where the overall pavement area of the intersection is large, and multiple turning lanes are involved or other unfamiliar elements are presented to the driver.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in the intersection and influence areas of the new pavement markers and/or markings .

Why it works: Adding clear pavement markings can guide motorists through complex intersections. When drivers approach and traverse through complex intersections, drivers may be required to perform unusual or unexpected maneuvers. Providing more effective guidance through an intersection will minimize the likelihood of a vehicle leaving its appropriate lane and encroaching upon an adjacent lane.

General Qualities (Time, Cost, Effectiveness): Costs of implementing this strategy will vary based on the scope and number of applications. Applying raised pavement markers is relatively low cost but can be variable and determined largely by the material used for pavement markings (paint, thermoplastic, epoxy, RPMs etc.). When using this type delineators, an issue of concern is the cost-to-service-life of the material. (Note: When federal safety funding is used for these installations in high-wear-locations, the local agency is expected to maintain the improvement for a minimum of 10 years.) When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Wet, Night, All	ALL
Crash Reduction Factor:	*10 - 33%*	10% (with an expected life of 10 years)

Name: Install flashing beacons as advance warning (S.I.)	Caltrans CM Number: **S9***

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new flashing beacons.

Why it works: Increased driver awareness of an approaching signalized intersection and an increase in the driver's time to react. Driver awareness of both downstream intersections and traffic control devices is critical to intersection safety. Crashes often occur when the driver is unable to perceive an intersection, signal head or the back of a stopped queue in time to react. Advance flashing beacons can be used to supplement and call driver attention to intersection control signs. Most advance warning flashing beacons can be powered by solar, thus reducing the issues relating to power source.

General Qualities (Time, Cost, Effectiveness): Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option). Flashing beacons can be constructed with minimal design, environmental and right-of-way issues and have relatively low costs. This combined with a relatively high CRF, can result in high B/Cs for locations with a history of crashes and lead to a high effectiveness.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Rear End, Angle	ALL
Crash Reduction Factor:	*36 - 62%*	30% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install cameras to detect red-light running	Caltrans CM Number: **S10**

Where to use: 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.

Note: For Caltrans' statewide Calls-for-Projects, this CM is not eligible for California's federal safety programs. Typically these improvements are funded through private-vendor contracts and not through state or federal funding.

Why it works: Automated enforcement of red-light running has been shown to significantly decrease violations, not only at intersections where cameras are installed, but also at other intersections in the area. This often corresponds to a reduction in severe crashes, but can result in an increase in rear-end crashes from drivers making abrupt stops. Because it is not feasible to provide police officers to enforce traffic signals as often or in as many locations as an agency might need, automated enforcement is an attractive effective alternative.

General Qualities (Time, Cost, Effectiveness): Installation of installing cameras will be moderate as studies will need to done on where and how many cameras are needed to attack the problem intersections. The cost to install and monitor the cameras is also moderate, as no right-of-way is typically needed.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Angle	Not eligible for California's federal safety programs
Crash Reduction Factor:	*16 - 34%*	Not eligible for California's federal safety programs

Name: Improve pavement friction (**High Friction Surface Treatments**)	Caltrans CM Number: **S11**

Where to use: Nationally, this countermeasure is referred to as "High Friction Surface Treatments" or HFST. 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.

Note: For Caltrans' statewide Calls-for-Projects, 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.

Why it works: Improving the skid resistance at locations with high wet-road and/or failure to stop crashes frequencies can result in reductions of 50 percent for wet-road crashes and 20 percent for total crashes. Applying HFST can double friction numbers, e.g. low 40s to high 80s. This CM represents a special focus area for both FHWA and Caltrans, which means there are extra resources available for agencies interested in more details on High Friction Surface Treatment projects.

General Qualities (Time, Cost, Effectiveness): This strategy can be relatively inexpensive and implemented in a short timeframe. The installation would be done by either agency personnel or contractors and can be done by hand or machine. In general, these CMs can be very effective and can be considered on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Wet, Night, ALL	ALL
Crash Reduction Factor:	*10 - 62 %*	25% (with an expected life of 10 years)

Name: Install raised median on approaches (S.I.)	Caltrans CM Number: **S12**

Where to use: 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.

*Note: For Caltrans' statewide Calls-for-Projects, 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. This new requirement is being implemented to maximize the safety-effectiveness of the limited HSIP funding and to minimize project impacts.*

Why it works: Raised medians next to left-turn lanes at intersections offer a cost-effective means for reducing crashes and improving operations at higher volume intersections. The raised medians prohibit left turns into and out of driveways that may be located too close to the functional area of the intersection.

General Qualities (Time, Cost, Effectiveness): 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. The result is these CMs can be very effective and can be considered on a systematic approach. Raised medians can often be installed directly over the existing pavement. When agencies opt to install landscaping in conjunction with new raised medians, these locations must be excluded from their federally funded HSIP application scope.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Angle	ALL
Crash Reduction Factor:	*21 -55 %*	25% (with an expected life of 20 years)

Name: Create directional median openings to allow (and restrict) left-turns and u-turns (S.I.)	Caltrans CM Number: **S13**

Where to use: Crashes related to turning maneuvers include angle, rear-end, pedestrian, and sideswipe (involving opposing left turns) type crashes. If any of these crash types are an issue at an intersection, restriction or elimination of the turning maneuver may be the best way to improve the safety of the intersection.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in the intersection / influence area of the new directional openings.

Why it works: Restricting turning movement into and out of an intersection can help reduce conflicts between through and turning traffic. The number of access points, coupled with the speed differential between vehicles traveling along the roadway, contributes to crashes. Affecting turning movements by either allowing them or restricting them, based on the application, can ensure safe movement of traffic.

General Qualities (Time, Cost, Effectiveness): Turn prohibitions that are implemented by closing a median opening can be implemented quickly. The cost of this strategy will depend on the treatment. Impacts to businesses and other land uses must be considered and controversy can delay the implementation. In general, these CMs can be very effective and can be considered on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*51%*	50% (with an expected life of 20 years)

Name: Install right-turn lane (S.I.)	Caltrans CM Number: **S14**

Where to use: A 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. Many collisions at signalized intersections are related to right-turn maneuvers. 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. **When considering new right-turn lanes, potential impacts to non-motorized users should be considered and mitigated as appropriate.**
Note: For Caltrans' statewide Calls-for-Projects, this CM 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.

Why it works: The provision of right-turn lanes can minimize collisions between vehicles turning right and following vehicles, particularly on high-volume and high-speed major roads. Installation of a right turn lane at a signalized intersection is expected to reduce total crashes and improve overall intersection delay. Right-turn lanes can increase the length of the intersection crossing and create an additional potential conflict point for non-motorized users.

General Qualities (Time, Cost, Effectiveness): Implementing this strategy may take from months to years. At some locations, right-turn lanes can be quickly and simply installed by restriping the roadway. At other locations, widening of the roadway, acquisition of additional right-of-way, and extensive environmental processes may be needed. Such projects require a substantial time for development and construction. Costs are highly variable and range from very low to high. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Rear-End	Not eligible for California's federal safety programs
Crash Reduction Factor:	*14 - 27%*	Not eligible for California's federal safety programs

Name: Install left-turn lane (signal has no left-turn phase - before and after)	Caltrans CM Number: **S15**

Where to use: 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. They are most effective on particularly on high-volume and high-speed major-road approaches and should be considered on a single major road approach basis. 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM is not eligible for California's federal safety programs. When appropriate based on the existing and planned signal phasing, CMs "S6" and "S17" are still available for use. This is being implemented to maximize the safety-effectiveness of the limited HSIP funding.

Why it works: Left-turn lanes allow separation of left-turn and through-traffic streams, thus reducing the potential for rear-end collisions. Because they provide a sheltered location for drivers to wait for a gap in opposing traffic, left-turn lanes may encourage drivers to be more selective in choosing a gap to complete the left-turn maneuver. This may reduce the potential for collisions between left-turn and opposing through vehicles and/or non-motorized road users. Provision of a left-turn lane also provides additional flexibility in designing a phasing plan. Unprotected left turn lanes are generally not as safe as protected ones.

General Qualities (Time, Cost, Effectiveness): Implementation time may vary from months to years. At some locations, left-turn lanes can be quickly installed simply by restriping the roadway. At other locations, widening of the roadway, acquisition of additional right-of-way, and extensive environmental processes may be needed. Such projects require a substantial time for development and construction. Costs are highly variable and range from very low to high. Unprotected left turn lanes are generally not as effectiveness as protected ones and will usually have lower B/C ratios.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	Not eligible for California's federal safety programs
Crash Reduction Factor:	*10 - 24%*	Not eligible for California's federal safety programs

*Countmeasure eligible for 100% federal funding

Name: Install left-turn lane (signal has a left-turn phase - before and after)	Caltrans CM Number: **S16**

Where to use: 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. Many intersection safety problems can be traced to difficulties in accommodating left-turning vehicles. A key strategy for minimizing collisions related to left-turning vehicles (angle, rear-end, sideswipe) is to provide exclusive left-turn lanes and appropriate signal phasing , particularly on high-volume and high-speed major-road approaches.
Note: For Caltrans' statewide Calls-for-Projects, this CM is not eligible for California's federal safety programs. When appropriate based on the existing and planned signal phasing, CMs "S6" and "S17" are still available for use. This is being implemented to maximize the safety-effectiveness of the limited HSIP funding.

Why it works: Left-turn lanes allow separation of left-turn and through-traffic streams, thus reducing the potential for rear-end collisions. Because they provide a sheltered location for drivers to wait for the left turn phase the potential for collisions between left-turning vehicles and through vehicles in same direction is greatly reduced.

General Qualities (Time, Cost, Effectiveness): Implementation time may vary from months to years. At some locations, left-turn lanes can be quickly installed simply by restriping the roadway. At other locations, widening of the roadway, acquisition of additional right-of-way, and extensive environmental processes may be needed. Such projects require a substantial time for development and construction. Costs are highly variable and range from very low to high.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	Not eligible for California's federal safety programs
Crash Reduction Factor:	*31 - 44%*	Not eligible for California's federal safety programs

Name: Install left-turn lane and add turn phase (signal has no left-turn lane or phase before)	Caltrans CM Number: **S17**

Where to use: Intersections that do not currently have a left turn lane or a related left-turn phase that are experiencing a large number of crashes. Many intersection safety problems can be traced to difficulties in accommodating left-turning vehicles, in particular where there is currently no accommodation for left turning traffic. A key strategy for minimizing collisions related to left-turning vehicles (angle, rear-end, sideswipe) is to provide exclusive left-turn lanes and the appropriate signal phasing , particularly on high-volume and high-speed major-road approaches. Agencies need to document their consideration of the MUTCD, Section 4D.19 guidelines; the section on implementing protected left-turn phases.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to 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.

Why it works: Left-turn lanes allow separation of left-turn and through-traffic streams, thus reducing the potential for rear-end collisions. Left-turn phasing also provides a safer opportunity for drivers to make a left-turn. The combination of left-turn storage and a left turn signal has the potential to reduce many collisions between left-turning vehicles and through vehicles and/or non-motorized road users.

General Qualities (Time, Cost, Effectiveness): Implementation time may vary from months to years. At some locations, left-turn lanes can be quickly installed simply by restriping the roadway. At other locations, widening of the roadway, acquisition of additional right-of-way, and extensive environmental processes may be needed. Such projects require a substantial time for development and construction. Costs are highly variable and range from very low to high. Installing a protected left turn lane and phase where none exists results in a high Crash Reduction Factor and is often highly effective.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*17 - 58 %*	55% (with an expected life of 20 years)

Name: Convert intersection to roundabout (from signal)	Caltrans CM Number: **S18***

Where to use: Signalized intersections that have a significant crash problem and the only alternative is to change the nature of the intersection itself. Roundabouts can also be very effective at intersections with complex geometry and intersections with frequent left-turn movements.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in influence area of the new roundabout. This CM is not intended for mini-roundabouts.

Why it works: The types of conflicts that occur at roundabouts are different from those occurring at conventional intersections; namely, conflicts from crossing and left-turn movements are not present in a roundabout. The geometry of a roundabout forces drivers to reduce speeds as they proceed through the intersection. This helps keep the range of vehicle speed narrow, which helps reduce the severity of crashes when they do occur. Pedestrians only have to cross one direction of traffic at a time at roundabouts, thus reducing their potential for conflicts.

General Qualities (Time, Cost, Effectiveness): Provision of a roundabout requires substantial project development. The need to acquire right-of-way is likely and will vary from site to site and depends upon the geometric design. These activities may require up to 4 years or longer to implement. Mini-roundabouts may be able to be built more expediently with signs and markings, but do not have the same CRFs as those shown in this CM. Costs are variable, but construction of a roundabout to replace an existing signalized intersection are relatively high. The result is this CM may have reduced relative-effectiveness compared to other CMs.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*35 - 67%*	50% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Install pedestrian countdown signal heads	Caltrans CM Number: **S19***

Where to use: Signals that have signalized pedestrian crossing with walk/don't walk indicators and where there have been pedestrian vs. vehicle crashes.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring in the intersection/crossing with the new countdown heads.

Why it works: A pedestrian countdown signal contains a timer display and counts down the number of seconds left to finish crossing the street. Countdown signals can reassure pedestrians who are in the crosswalk when the flashing "DON'T WALK" interval appears that they still have time to finish crossing. Countdown signals begin counting down either when the "WALK" or when the flashing "DON'T WALK" interval appears and stop at the beginning of the steady "DON'T WALK" interval. These signals also have been shown to encourage more pedestrians to use the pushbutton rather than jaywalk.

General Qualities (Time, Cost, Effectiveness): 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. When considered at a single location, these low cost improvements are usually funded through local funding by local crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*25%*	25% (with an expected life of 20 years)

Name: Install pedestrian crossing (S.I.)	Caltrans CM Number: **S20***

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, 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).

Why it works: Adding pedestrian crossings has the opportunity to enhance pedestrian safety at locations noted as being problematic. Nearly one-third of all pedestrian-related crashes occur at or within 50 feet of an intersection. Of these, 30 percent may involve a turning vehicle. Another 22 percent of pedestrian crashes involve a pedestrian either running across the intersection or darting out in front of a vehicle whose view was blocked just prior to the impact. Finally, 16 percent of these intersection-related crashes occur because of a driver violation (e.g., failure to yield right-of-way). 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.

General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely, depending if curb ramps and sidewalk modifications are required with the crossing. When considered at a single location, these low cost improvements are may be funded through local funding by local crews. However, these CMs can be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in moderate to high cost projects that are appropriate to seek state or federal funding.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*25%*	25% (with an expected life of 20 years)

Name: Install advance stop bar before crosswalk (Bicycle Box)	Caltrans CM Number: **S21***

Where to use: Signalized Intersections with a marked crossing, where significant bicycle and/or pedestrians volumes are known to occur.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring in the intersection-crossing with the new advanced stop bars.

Why it works: Adding advance stop bar before the striped crosswalk has the opportunity to enhance both pedestrian and bicycle safety. Stopping cars well before the crosswalk provides a buffer between the vehicles and the crossing pedestrians. It also allows for a dedicated space for cyclists, making them more visible to drivers (This dedicated space is often referred to as a bike-box.)

General Qualities (Time, Cost, Effectiveness): 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. When considered at a single location, these low cost improvements are usually funded through local funding by local crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*35%*	15% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install pedestrian overpass/underpass		Caltrans CM Number: **S22**
Where to use: Areas noted as having many pedestrian-vehicle conflicts. Possible installation sites include a freeway or other high-speed, high-volume arterial street. Railroad tracks are also sometimes targeted for overpasses or underpasses. *Note: For Caltrans' statewide Calls-for-Projects, this CM 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.*		
Why it works: Installation of the overpass offers complete separation of vehicular and pedestrian movements. Most pedestrians/bicyclists will use an overpass if the walking /biking time to use the overpass is the same (or less) as crossing at street level. If the walking/biking time is longer, installing roadway features to guide the users to the overpass may be needed.		
General Qualities (Time, Cost, Effectiveness): Significant time is required to design the structure and acquire additional right-of-way. The cost for an overpass or underpass are usually very high, but not always for certain site characteristics. The effectiveness of pedestrian/bicycle grade separation depends largely upon the proportion of pedestrians/bicycles crossing at or near that use it and the existing crashes that are occurring. The B/C Ratios will be low for most locations.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Pedestrian, Bicycle	Not eligible for California's federal safety programs
Crash Reduction Factor:	*5 - 100%*	Not eligible for California's federal safety programs

Name: Install pedestrian median fencing on approaches		Caltrans CM Number: **S23**
Where to use: Signalized Intersections with high pedestrian-generators near by (e.g. transit stops) may experience a high volumes of pedestrians J-walking across the travel lanes at mid-block locations instead of walking to the intersection and waiting to cross during the walk-phase. 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. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring on the approaches/influence area of the new pedestrian median fencing.*		
Why it works: Adding pedestrian median fencing has the opportunity to enhance pedestrian safety at locations noted as being problematic involving pedestrians running/darting across the roadway outside the intersection crossings. Pedestrian median fencing can significantly reduce this safety issue by creating a positive barrier, forcing pedestrians to the designated pedestrian crossing.		
General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely depending on the type and placement of the median fencing. Impacts to transit and other land uses may need to be considered and controversy can delay the implementation. In general, this CM can be effective as a spot-location approach.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*25- 40%*	35% (with an expected life of 20 years)

Intersection Countermeasures - Non-signalized

Name: Add intersection lighting (NS.I.)	Caltrans CM Number: **NS1***

Where to use: Non-signalized intersections that have a disproportionate number of night-time crashes and do not currently provide lighting at the intersection or at its approaches. Crash data should be studied to ensure that safety at the intersection could be improved by providing lighting (this strategy would be supported by a significant number of crashes that occur at night).
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "night" crashes (all types) occurring within limits of the proposed roadway lighting 'engineered' area.

Why it works: Providing lighting at the intersection itself, or both at the intersection and on its approaches, improves the safety of an intersection during nighttime conditions by (1) making drivers more aware of the surroundings at an intersection, which improves drivers' perception-reaction times, (2) enhancing drivers' available sight distances, and (3) improving the visibility of non-motorists. Intersection lighting is of particular benefit to non-motorized users as lighting not only helps them navigate the intersection, but also helps drivers see them better.

General Qualities (Time, Cost, Effectiveness): A lighting project can usually be completed relatively quickly, but generally requires at least 1 year to implement because the lighting system must be designed and the provision of electrical power must be arranged. The provision of lighting involves both a fixed cost for lighting installation and an ongoing maintenance and power cost. For rural intersections, studies have shown the installation of streetlights reduced nighttime crashes at unlit intersections and can be more effective in reducing nighttime crashes than either rumble strips or overhead flashing beacons. Some locations can result in high B/C ratios, but due to higher costs, these projects often result in medium to low B/C ratios.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Night, All	Night (All types)
Crash Reduction Factor:	*25 - 50%*	40% (with an expected life of 20 years)

Name: Convert to all-way STOP control (from 2-way or Yield control)	Caltrans CM Number: **NS2***

Where to use: Unsignalized intersection locations that have a crash history and have no controls on the major roadway approaches. However, all-way stop control is suitable only at intersections with moderate and relatively balanced volume levels on the intersection approaches. Under other conditions, the use of all-way stop control may create unnecessary delays and aggressive driver behavior. MUTCD warrants should always be followed.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in the intersection and/or influence area of the new control. CA-MUTCD warrant must be met.

Why it works: All-way stop control can reduce right-angle and turning collisions at unsignalized intersections by providing more orderly movement at an intersection, reducing through and turning speeds, and minimizing the safety effect of any sight distance restrictions that may be present. Advance public notification of the change is critical in assuring compliance and reducing crashes.

General Qualities (Time, Cost, Effectiveness): The costs involved in converting to all-way stop control are relatively low. All-way stop control can normally be implemented at multiple intersections with just a change in signing, and on intersection approaches, and typically are very quick to implement. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Left-turn, Angle	ALL
Crash Reduction Factor:	*6 - 80%*	50% (with an expected life of 10 years)

Name: Install signals	Caltrans CM Number: **NS3***

Where to use: Traffic signals can be used to prevent the most severe type crashes (right-angle, left-turn). Consideration to signalize an unsignalized intersection should only be given after (1) 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 (2) signal warrants have been met. Refer to the CA MUTCD, Section 4C.01, Studies and Factors for Justifying Traffic Control Signals.
Note: For Caltrans' statewide Calls-for-Projects, 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 over-arching 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.*

Why it works: Traffic signals have the potential to reduce the most severe type crashes but will likely cause an increase in rear-end collisions. A reduction in overall injury severity is likely the largest benefit of traffic signal installation.

General Qualities (Time, Cost, Effectiveness): Typical traffic signal costs fall in the medium to high category and are affected by application, type of signal and right-of-away considerations. Projects of this magnitude should only be considered after alternate and lesser means of correction have been evaluated. Some locations can result in high B/C ratios, but due to higher costs, these projects often result in medium to low B/C ratios.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*0 - 74%*	25% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Convert intersection to roundabout (from 2-way stop or Yield control)	Caltrans CM Number: **NS4***

Where to use: Intersections that have a high frequency of right-angle and left-turn type crashes. Whether such intersections have existing crash patterns or not, a roundabout provides an alternative to signalization. The primary target locations for roundabouts should be moderate-volume unsignalized intersections. Roundabouts may not be a viable alternative in many suburban and urban settings where right-of-way is limited.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in the intersection and/or influence area of the new control. This CM is not eligible for use at existing all-way stop intersections.

Why it works: Roundabouts provide an important alternative to signalized and all-way stop-controlled intersections. Modern roundabouts differ from traditional traffic circles in that they operate in such a manner that traffic entering the roundabout must yield the right-of-way to traffic already in it. Roundabouts can serve moderate traffic volumes with less delay than all-way stop-controlled intersections and provide fewer conflict points. Crashes at roundabouts tend to be less severe because of the speed constraints and elimination of left-turn and right-angle movements.

General Qualities (Time, Cost, Effectiveness): Construction of roundabouts are usually relatively costly and major projects, requiring the environmental process, right-of-way acquisition, and implementation under an agency's long-term capital improvement program. (For this reason, roundabouts may not be appropriate for California's Federal Safety Programs that have relatively short delivery requirements.) Even with roundabouts higher costs, they still can have a relatively high effectiveness.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Left-turn, Angle	ALL
Crash Reduction Factor:	*12 - 78 %*	45% (with an expected life of 20 years)

Name: Install/upgrade larger or additional stop signs or other intersection warning/regulatory signs	Caltrans CM Number: **NS5***

Where to use: The target for this strategy should be approaches to unsignalized intersections with patterns of rear-end, right-angle, or turning collisions related to lack of driver awareness of the presence of the intersection.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in the influence area of the new signs. The influence area must be determined on a location by location basis.

Why it works: The visibility of intersections and, thus, the ability of approaching drivers to perceive them can be enhanced by installing larger regulatory and warning signs at or prior to an intersections. A key to success in applying this strategy is to select a combination of regulatory and warning sign techniques appropriate for the conditions on a particular unsignalized intersection approach.

General Qualities (Time, Cost, Effectiveness): Signing improvements do not require a long development process and can typically be implemented quickly. 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, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*11 - 55%*	15% (with an expected life of 10 years)

Name: Upgrade intersection pavement markings (NS.I.)	Caltrans CM Number: **NS6***

Where to use: Unsignalized intersections that are not clearly visible to approaching motorists, particularly approaching motorists on the major road. The strategy is particularly appropriate for intersections with patterns of rear-end, right-angle, or turning crashes related to lack of driver awareness of the presence of the intersection. Also at minor road approaches where conditions allow the stop bar to be seen by an approaching driver at a significant distance from the intersection. Typical improvements include "Stop Ahead" markings and the addition of Centerlines and Stop Bars.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new pavement markings. This CM is not intended to be used for general maintenance activities (i.e. the replacement of existing pavement markings in-kind) and must include upgraded safety features over the existing pavement markings and striping.

Why it works: The visibility of intersections and, thus, the ability of approaching drivers to perceive them can be enhanced by installing appropriate pavement delineation in advance of and at intersections will provide approaching motorists with additional information at these locations. Providing visible stop bars on minor road approaches to unsignalized intersections can help direct the attention of drivers to the presence of the intersection. Drivers should be more aware that the intersection is coming up, and therefore make safer decisions as they approach the intersection.

General Qualities (Time, Cost, Effectiveness): Pavement marking improvements do not require a long development process and can typically be implemented quickly. Costs for implementing this strategy are nominal and depend on the number of markings. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, these CMs 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. Note: When federal safety funding is used for these installations in high-wear-locations, the local agency is expected to maintain the improvement for a minimum of 10 years.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*13 - 60%*	25% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install Flashing Beacons at Stop-Controlled Intersections		Caltrans CM Number: NS7*
Where to use: Flashing beacons can reinforce driver awareness of the Non-Signalized intersection control and can help mitigate patterns of right-angle crashes related to stop sign violations. Post-mounted advanced flashing beacons or overhead flashing beacons can be used at stop-controlled intersections to supplement and call driver attention to stop signs. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the stop-controlled approaches / influence area of the new beacons.*		
Why it works: Flashing beacons provide a visible signal to the presence of an intersection and can be very effective in rural areas where there may be long stretches between intersections as well as locations where night-time visibility of intersections is an issue.		
General Qualities (Time, Cost, Effectiveness): Flashing beacons can be constructed with minimal design, environmental and right-of-way issues and have relatively low costs. Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option). In general, these CMs can be very effective and can be considered on a systematic approach.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Angle, Rear-End	ALL
Crash Reduction Factor:	*5-34%*	15% (with an expected life of 10 years)

Name: Install flashing beacons as advance warning (NS.I.)		Caltrans CM Number: NS8*
Where to use: 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. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new beacons placed in advance of the intersection .*		
Why it works: Advance flashing beacons can be used to supplement and call driver attention to intersection control signs. Flashing beacons are intended to reinforce driver awareness of the stop or yield signs and to help mitigate patterns of crashes related to intersection regulatory sign violations. Most advance warning flashing beacons can be powered by solar, thus reducing the issues relating to power source.		
General Qualities (Time, Cost, Effectiveness): Use of flashing beacons requires minimal development process, allowing flashing beacons to be installed within a short time period. Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option). In general, these CMs can be very effective and can be considered on a systematic approach.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Angle, Rear-End	ALL
Crash Reduction Factor:	*36 - 62%*	30% (with an expected life of 10 years)

Name: Install transverse rumble strips on approaches		Caltrans CM Number: NS9
Where to use: Transverse rumble strips are installed in the travel lane for the purposes of 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. Due to the noise generated by vehicles driving over the rumble strips, care must be taken to minimize disruption to nearby residences and businesses. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new rumble strips.*		
Why it works: When motorists are traveling along the roadway, they are sometimes unaware they are approaching an intersection. This is especially true on rural roads, as there may be fewer cues indicating an intersection ahead. Transverse rumble strips warn motorists that something unexpected is ahead that they need to pay attention to.		
General Qualities (Time, Cost, Effectiveness): Use of transverse rumble strips requires minimal development process, allowing transverse rumble strips to be installed within a short time period. In general, these CMs can be very effective and can be considered on a systematic approach, although care should be taken to not over-use this CM. Note: When federal safety funding is used for these installations in high-wear-locations, the local agency is expected to maintain the improvement for a minimum of 10 years.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*0 - 35%*	20% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Improve sight distance to intersection (Clear Sight Triangles)		Caltrans CM Number: **NS10**
Where to use: Unsignalized intersections with restricted sight distance and patterns of crashes related to lack of sight distance where sight distance can be improved by clearing roadside obstructions without major reconstruction of the roadway. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the significantly improved new sight distance. Minor/incidental improvements to sight distance would not likely result in the CRF shown below.*		
Why it works: Adequate sight distance for drivers at stop or yield-controlled approaches to intersections has long been recognized as among the most important factors contributing to overall safety at unsignalized intersections. By removing sight distance restrictions (e.g., vegetation, parked vehicles, signs, buildings) from the sight triangles at stop or yield-controlled intersection approaches, drivers will be able see approaching vehicles on the main line, without obstruction and therefore make better decisions about entering the intersection safely.		
General Qualities (Time, Cost, Effectiveness): Projects involving clearing sight obstructions on the highway right-of-way can typically be accomplished quickly, assuming the objects are readily moveable. Clearing sight obstructions on private property requires more time for discussions with the property owner. Costs will generally be low, assuming that in most cases the objects to be removed are within the right-of-way. In general, this CMs can be very effective and can be implemented by agencies' maintenance staff and/or implemented on a systematic approach. Usually only high-cost removals would be good candidates for Caltrans Federal Safety Funding. Note: When federal safety funding is used to remove vegetation that has the potential to grow back, the local agency is expected to maintain the improvement for a minimum of 10 years.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*11 - 56%*	20% (with an expected life of 10 years)

Name: Install splitter-islands on the minor road approaches		Caltrans CM Number: **NS11**
Where to use: Minor road approaches to unsignalized intersections where the presence of the intersection or the stop sign is not readily visible to approaching motorists. The strategy is particularly appropriate for intersections where the speeds on the minor road are high. In creation of a splitter island allows for an additional stop sign to be placed in the median for the minor approach. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new splitter island on the minor road approaches.*		
Why it works: The installation of splitter islands allows for the addition of a stop sign in the median to make the intersection more conspicuous. Additionally, the splitter island on the minor-road provides for a positive separation between turning vehicles on the through road and vehicles stopped on the minor road approach.		
General Qualities (Time, Cost, Effectiveness): Splitter islands at non-signalized intersections can usually be installed with minimal roadway reconstruction and relatively quickly. In general, these CMs can be very effective and can be considered on a systematic approach.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Angle, Rear-End	ALL
Crash Reduction Factor:	*35 - 100 %*	40% (with an expected life of 20 years)

Name: Install raised median on approaches (NS.I.)		Caltrans CM Number: **NS12**
Where to use: Where related or nearby turning movements affect the safety and operation of an intersection. Effective access management is key to improving safety at, and adjacent to, intersections. 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. *Note: For Caltrans' statewide Calls-for-Projects, 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. This new requirement is being implemented to maximize the safety-effectiveness of the limited HSIP funding and to minimize project impacts.*		
Why it works: Raised medians with left-turn lanes at intersections offer a cost-effective means for reducing crashes and improving operations at higher volume intersections. The raised medians also prohibit left turns into and out of driveways that may be located too close to the functional area of the intersection.		
General Qualities (Time, Cost, Effectiveness): 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 approaches would be too expensive because of limited right-of-way and the constraints of the built environment. Because raised medians limit property access to right turns only, the need for providing alternative access ways should be considered. In general, these CMs can be very effective and can be considered on a systematic approach. When agencies opt to install landscaping in conjunction with new raised medians, these locations must be excluded from their federally funded HSIP application scope.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*20 - 39 %*	25% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Create directional median openings to allow (and restrict) left-turns and u-turns (NS.I.)		Caltrans CM Number: **NS13**
Where to use: Crashes related to turning maneuvers include angle, rear-end, pedestrian, and sideswipe (involving opposing left turns) type crashes. If any of these crash types are an issue at an intersection, restriction or elimination of the turning maneuver may be the best way to improve the safety of the intersection. Because 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. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring in the intersection / influence area of the new directional openings.*		
Why it works: Agencies are increasingly using access management techniques on urban and suburban arterials to manage the number of conflicts experienced at an intersection. A key element of access management is to restrict certain movements, create directional median openings, or close median openings that are deemed too close to an intersection.		
General Qualities (Time, Cost, Effectiveness): Turn prohibitions that are implemented by closing a median opening can usually be implemented quickly. Costs are highly variable but in many cases could be considered low. In some cases this strategy may involve acquiring access or constructing replacement access; those actions will significantly increase the cost of the project. Impacts to businesses and other land uses must be considered and controversy can delay the implementation. In general, these CMs can be very effective and can be considered on a systematic approach.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*51%*	50% (with an expected life of 20 years)

Name: Install right-turn lane (NS.I.)		Caltrans CM Number: **NS14**
Where to use: Many collisions at unsignalized intersections are related to right-turn maneuvers. A key strategy for minimizing such collisions is to provide exclusive right-turn lanes, particularly on high-volume and high-speed major-road approaches. When considering new right-turn lanes, potential impacts to non-motorized users should be considered and mitigated as appropriate. When considering new right-turn lanes, potential impacts to non-motorized users should be considered and mitigated as appropriate. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring on the approaches / influence area of the new right-turn lanes. This CM is not eligible for use at existing all-way stop intersections.*		
Why it works: The strategy is targeted to reduce the frequency of rear-end collisions resulting from conflicts between vehicles turning right and following vehicles and vehicles turning right and through vehicles coming from the left on the cross street. Right-turn lanes also remove slow vehicles that are decelerating to turn right from the through-traffic stream, thus reducing the potential for rear-end collisions. Right-turn lanes can increase the length of the intersection crossing and create an additional potential conflict point for non-motorized users.		
General Qualities (Time, Cost, Effectiveness): Implementing this strategy may take from months to years. At some locations, right-turn lanes can be quickly and simply installed by restriping the roadway. At other locations, widening of the roadway, acquisition of additional right-of-way, and extensive environmental processes may be needed. Such projects require a substantial time for development and construction. Costs are highly variable and range from very low to high. The expected effectiveness of this CM must be assessed for each individual location.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*14 - 26 %*	20% (with an expected life of 20 years)

Name: Install left-turn lane (where no left-turn lane exists)		Caltrans CM Number: **NS15**
Where to use: Many collisions at unsignalized intersections are related to left-turn maneuvers. A key strategy for minimizing such collisions is to provide exclusive left-turn lanes, particularly on high-volume and high-speed major-road approaches. When considering new left-turn lanes, potential impacts to non-motorized users should be considered and mitigated as appropriate. *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to 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. This CM is not eligible for use at existing all-way stop intersections.*		
Why it works: Adding left-turn lanes remove vehicles waiting to turn left from the through-traffic stream, thus reducing the potential for rear-end collisions. Because they provide a sheltered location for drivers to wait for a gap in opposing traffic, left-turn lanes may encourage drivers to be more selective in choosing a gap to complete the left-turn maneuver. This strategy may reduce the potential for collisions between left-turn and opposing through vehicles.		
General Qualities (Time, Cost, Effectiveness): Implementing this strategy may take from months to years. At some locations, left-turn lanes can be quickly and simply installed by restriping the roadway. At other locations, widening of the roadway, acquisition of additional right-of-way, and extensive environmental processes may be needed. Such projects require a substantial time for development and construction. Costs are highly variable and range from very low to high. The expected effectiveness of this CM must be assessed for each individual location.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*9 -55 %*	35% (with an expected life of 20 years)

Name: Install raised medians (refuge islands)	Caltrans CM Number: **NS16**

Where to use: Intersections that have a long pedestrian crossing distance, a higher number of pedestrians, or a crash history. Raised medians decrease the level of exposure for pedestrians and allow pedestrians to concentrate on (or cross) only one direction of traffic at a time.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring in the crossing with the new islands. 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. This new requirement is being implemented to maximize the safety-effectiveness of the limited HSIP funding and to minimize project impacts.

Why it works: Raised pedestrian refuge islands, or medians at crossing locations along roadways, are another strategy to reduce exposure between pedestrians and motor vehicles. Refuge islands and medians that are raised (i.e., not just painted) provide pedestrians more secure places of refuge during the street crossing. They can stop partway across the street and wait for an adequate gap in traffic before completing their crossing.

General Qualities (Time, Cost, Effectiveness): Median and pedestrian refuge areas are a low-cost countermeasure to implement. This cost can be applied to retrofit improvements or if it is a new construction project, implementing this countermeasure is even more cost-effective. In general, these CMs can be very effective and can be considered on a systematic approach. When agencies opt to install landscaping in conjunction with new raised medians, these locations must be excluded from their federally funded HSIP application scope.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian and Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*30 - 56 %*	45% (with an expected life of 20 years)

Name: Install pedestrian crossing at uncontrolled locations (signs and markings only)	Caltrans CM Number: **NS17***

Where to use: Non-signalized intersections without a marked crossing, where pedestrians are known to be crossing intersections that involve significant vehicular traffic. They are especially important at school crossings and intersections with right and/or left turns pockets. See Zegeer study (Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations) for additional guidance regarding when to install a marked crosswalk.
Note: For Caltrans' statewide Calls-for-Projects, 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).

Why it works: Adding pedestrian crossings has the opportunity to enhance pedestrian safety at locations noted as being problematic. Pavement markings delineating a portion of the roadway that is designated for pedestrian crossing. These markings will often be different for controlled verses uncontrolled locations. The use of "ladder", "zebra" or other enhanced markings at uncontrolled crossings can increase both pedestrian and driver awareness to the increased exposure at the crossing. Incorporating advanced "stop" or "yield" markings provides an extra safety buffer and can be effective in reducing the 'multiple-threat' danger to pedestrians. Nearly one-third of all pedestrian-related crashes occur at or within 50 feet of an intersection. Of these, 30 percent may involve a turning vehicle. There are several types of pedestrian crosswalks, including: continental, ladder, zebra, and standard. 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.

General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely, depending upon if curb ramps and sidewalk modifications are required with the crossing. When considered at a single location, these low cost improvements are usually funded through local funding by local crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian and Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*25%*	25% (with an expected life of 10 years)

Name: Install pedestrian crossing at uncontrolled locations (with enhanced safety features)	Caltrans CM Number: **NS18***

Where to use: Non-signalized intersections with or without a marked crossing, where pedestrians are known to be crossing intersections that involve significant vehicular traffic. They are especially important at school crossings and intersections with turns pockets. Based on the Zegeer study (Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations) at many locations, a marked crosswalk alone may not be sufficient to adequately protect non-motorized users. In these cases, **rectangular rapid flashing beacons, overhead flashing beacons, curb extensions, advanced "stop" or "yield" markings, and other safety feature**s should be added to complement the standard crossing elements.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring in the crossing (influence area) with the new enhanced safety features. This CM is not intended to be used for high-cost aesthetic enhancements to intersection crosswalks (i.e. stamped concrete or stamped asphalt).

Why it works: Adding pedestrian crossings that include enhances safety features has the opportunity to enhance pedestrian safety at locations noted as being especially problematic. The enhanced safety elements help delineate a portion of the roadway that is designated for pedestrian crossing. Incorporating advanced "yield" markings provide an extra safety buffer and can be effective in reducing the 'multiple-threat' danger to pedestrians. Nearly one-third of all pedestrian-related crashes occur at or within 50 feet of an intersection. 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.

General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely, depending upon the types of enhanced features that will be combined with the standard crossing improvements. The need for new curb ramps and sidewalk modifications will also be a factor. These CMs may be effectively and efficiently implemented using a systematic approach with more than one location and can have relatively high B/C ratios based on past non-motorized crash history.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian and Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*37%*	35% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Install pedestrian signal or HAWK	Caltrans CM Number: **NS19***

Where to use: Intersections noted as having a history of pedestrian vs. vehicle crashes and in areas where the likelihood of a pedestrian 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 beacons are needed to provide an active warning to motorists when a pedestrian is in the crosswalk.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring in the intersection/crossing with the new signal.

Why it works: Adding a pedestrian signal has the opportunity to greatly enhance pedestrian safety at locations noted as being problematic. Nearly one-third of all pedestrian-related crashes occur at or within 50 feet of an intersection. In combination with this CM, better guidance signs and markings for non-motorized and motorized roadway users should be considered, including: sign and markings directing pedestrians and cyclists on appropriate/legal travel paths and signs and markings warning motorists of non-motorized uses of the roadway that should be expected.

General Qualities (Time, Cost, Effectiveness): The cost of improvements are generally high, but can vary dependant on the type of signal and overall scope of the project. In most cases the project duration can be short. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Pedestrian and Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*15 - 69%*	55% (with an expected life of 20 years)

Name: Improve pavement friction (High Friction Surface Treatments)	Caltrans CM Number: **NS20**

Where to use: Nationally, this countermeasure is referred to as "High Friction Surface Treatments" or HFST. Non-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.
Note: For Caltrans' statewide Calls-for-Projects, 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.

Why it works: Improving the skid resistance at locations with high wet-road and/or failure to stop crashes frequencies can result in reductions of 50 percent for wet-road crashes and 20 percent for total crashes. Applying HFST can double friction numbers, e.g. low 40s to high 80s. This CM represents a special focus area for both FHWA and Caltrans, which means there are extra resources available for agencies interested in more details on High Friction Surface Treatment projects.

General Qualities (Time, Cost, Effectiveness): This strategy can be relatively inexpensive and implemented in a short timeframe. The installation would be done by either agency personnel or contractors and can be done by hand or machine. In general, these CMs can be very effective and can be considered on a systematic approach.

	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Wet, Night, ALL	ALL
Crash Reduction Factor:	*10 - 62 %*	25% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Roadway Countermeasures

Name: Add Segment Lighting	Caltrans CM Number: **R1***

Where to use: Noted substantial patterns of nighttime 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "night" crashes (all types) occurring within limits of the proposed roadway lighting 'engineered'

Why it works: Providing roadway lighting, improves the safety during nighttime conditions by (1) making drivers more aware of the surroundings, which improves drivers' perception-reaction times, (2) enhancing drivers' available sight distances to perceive roadway characteristic in advance of the change, and (3) improving non-motorist's visibility and navigation.

General Qualities (Time, Cost, Effectiveness): It expected that projects of this type may be constructed in a year or two and are relatively costly. There are several types of costs associated with providing lighting, including the cost of providing a permanent source of power to the location, the cost for the luminaire supports (i.e., poles), and the cost for routinely replacing the bulbs and maintenance of the luminaire supports. Some locations can result in high B/C ratios, but due to higher costs, these projects often result in medium to low B/C ratios.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Night, All	Night (All types)
Crash Reduction Factor:	*18 - 69 %*	35% (with an expected life of 20 years)

Name: Remove or relocate fixed objects outside of Clear Recovery Zone	Caltrans CM Number: **R2**

Where to use: 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. A clear recovery zone should be developed on every roadway, as space is available. In situations where public right-of-way is limited, steps should be taken to request assistance from property owners, as appropriate.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new clear recovery zone (per Caltrans' HDM).

Why it works: While this strategy does not prevent the vehicle leaving the roadway, it does provide a mechanism to reduce the severity of a resulting crash. A clear zone is an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway. Removing or moving fixed objects, flattening slopes, or providing recovery areas reduces the likelihood of a crash.

General Qualities (Time, Cost, Effectiveness): Projects involving removing fixed objects from highway right-of-way can typically be accomplished quickly, assuming the objects are readily moveable. Clearing objects on private property requires more time for discussions with the property owner. Costs will generally be low, assuming that in most cases the objects to be removed are within the right-of-way. This CMs can be very effective and can be implemented by agencies' maintenance staff and/or implemented on a systematic approach. High-cost removals or removals implemented using a systematic approach would be good candidates for Caltrans Federal Safety Funding.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Fixed Object	ALL
Crash Reduction Factor:	*17 - 100 %*	35% (with an expected life of 20 years)

Name: Install Median Barrier	Caltrans CM Number: **R3***

Where to use: Areas where crash history indicates drivers are unintentionally crossing the median and the cross-overs are resulting in high severity crashes. The installation of median barriers can increase the number of PDO and non-severe injuries. The net result in safety from this countermeasure is connected more to reducing the severity of crashes not the number of crashes. It is recommended to review the warrants as outlined in Chapter 7 of the Caltrans Traffic Manual when considering whether to install median barriers.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new barrier.

Why it works: This strategy is designed to prevent head-on collisions by providing a barrier between opposing lanes of traffic. The variety of median barriers available makes it easier to choose a site-specific solution. The main advantage is the reduction of the severity of the crashes. The key to success would be in selecting an appropriate barrier based on the site, previous crash history, maintenance needs, and median width.

General Qualities (Time, Cost, Effectiveness): This strategy would in many cases be possible to implement within a short period after site selection. 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. Maintenance costs and worker exposure will also vary depending on the type of barrier selected. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Head-on	ALL
Crash Reduction Factor:	*0 - 94 %*	25% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Install Guardrail	Caltrans CM Number: **R4***

Where to use: Guardrail is installed to reduce the severity of lane departure crashes. However, guardrail can reduce crash severity only for those conditions where striking the guardrail is less severe than going down an embankment or striking a fixed object. Guardrail should only be installed where it is clear that crash severity will be reduced, or there is a history of run-off-the-road crashes at a given location that have resulted in sever crashes. New and upgraded guardrail and end-treatments must meet current safety standards; see Method for Assessing Safety Hardware (MASH) for more information. Caltrans (or other national accepted guidance) slope/height criteria need to be considered and documented.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new guardrail. This CM is not intended to be used for general maintenance activities (i.e. the replacement of existing damaged rail). For projects proposing to upgrade existing guardrail to current standards, this CM and corresponding CRF should only be applied to locations where past crash data or engineering judgment applied to the existing rail conditions suggests the upgraded guardrail may result in fewer or less severe crashes (justifying the use of the 25% CRF for this CM).

Why it works: Guardrail redirects a vehicle away from embankment slopes or fixed objects and dissipates the energy of an errant vehicle.

General Qualities (Time, Cost, Effectiveness): Strategies range from relatively inexpensive to costly. Costly projects may include those that upgrade existing guardrail applications to more semi-rigid and rigid barrier systems over extended distances. In general, this CMs can be effective and can be implemented by agencies' maintenance staff and/or implemented on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Fixed Object, Run-off Road	ALL
Crash Reduction Factor:	*11 - 78 %*	25% (with an expected life of 20 years)

Name: Install impact attenuators	Caltrans CM Number: **R5***

Where to use: Impact attenuators are typically used to shield rigid roadside objects such as concrete barrier ends, steel guardrail ends and bridge pillars from oncoming automobiles. Attenuators should only be installed where it is impractical for the objects to be removed. New and upgraded barrier end-treatments must meet current safety standards; see MASH for more information.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new attenuators. This CM is not intended to be used for general maintenance activities (i.e. the replacement of existing damaged attenuators). For projects proposing to upgrade existing attenuators to current standards, this CM and corresponding CRF should only be applied to locations where past crash data or engineering judgment applied to the existing attenuator conditions suggests the upgraded attenuators may result in fewer or less severe crashes (justifying the use of the 25% CRF for this CM).

Why it works: Attenuators bring a errant vehicle to a more-controlled stop or redirect the vehicle away from a rigid object. Attenuators are effective at absorbing impact energy and increasing occupant safety. They also tend to draw attention to the fixed object, which helps drivers steer clear of the fixed objects.

General Qualities (Time, Cost, Effectiveness): Costs depending on the scope of the project, type(s) used, and associated ongoing maintenance costs. Time to install is fairly quick once site is identified.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Fixed Object, Run-off Road	ALL
Crash Reduction Factor:	*5 - 50 %*	25% (with an expected life of 10 years)

Name: Flatten side slopes	Caltrans CM Number: **R6**

Where to use: 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. When there is a need to reduce the severity of lane departure crashes without installing a barrier system that could result in increased numbers of crashes.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new side slopes. 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.

Why it works: Flattened slopes provide a greater area for a driver to regain control of a vehicle. Steep slopes, ditches or unprotected hazardous drops-offs adjacent to a travel lane offer little opportunities to correct an inappropriate action by a driver and can result in sever crashes.

General Qualities (Time, Cost, Effectiveness): Roadside modifications range from relatively inexpensive to very costly. Strategies that include creating safer side slopes where none exist can be moderately expensive based on the scope of the project and the associated clearing, grading, etc. The potential for high environmental and right-of-way impacts are high with can take several years to clear. In other cases these CMs can be effective and can be implemented by agencies' maintenance staff and/or implemented on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Fixed Object, Run-off Road	ALL
Crash Reduction Factor:	*5 - 62 %*	30% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Flatten side slopes and remove guardrail	Caltrans CM Number: **R7**

Where to use: **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. The guardrail may or may not meet current standards. Even though guardrails are generally installed to reduce the severity of departure crashes, they still can result in severe crashes in some locations.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of both the removed guardrail and the new side slopes.

Why it works: Flattened side slopes and an unobstructed clear zone provide a greater area for a driver to regain control of a vehicle. The existing guardrail may help protect the steep slopes, fixed objects, or unprotected hazardous drops-offs adjacent to a travel lane, but removing all of these obstacles generally improves safety.

General Qualities (Time, Cost, Effectiveness): Roadside modifications range from relatively inexpensive to very costly. Strategies that include creating safer side slopes where none exist can be moderately expensive based on the scope of the project and the associated clearing, grading, etc. The potential for high environmental and right-of-way impacts are high with can take several years to clear.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Roll Over, Fixed Object	ALL
Crash Reduction Factor:	*42%*	40% (with an expected life of 20 years)

Name: Upgrade bridge railing	Caltrans CM Number: **R8**

Where to use: Open-faced railings that can present a snagging hazard, which may produce high deceleration forces leading to occupant injuries. Curbs or walkways between the driving lane and the bridge railing are another common hazard of older railing systems. Impacting vehicles may go over the railing or rollover.
Note: For Caltrans' statewide Calls-for-Projects, this CM 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.

Why it works: Bridge railings are very important components of roadway safety systems and play an important role in preventing and mitigating crashes. Since the primary purpose of a bridge railing is to prevent penetration, it must be strong enough to redirect an impacting vehicle. Bridge railings differ from other longitudinal roadside barriers because they are physically connected to the structure, and are not usually designed to deflect when struck by a vehicle.

General Qualities (Time, Cost, Effectiveness): Strategies range from moderately expensive to very costly; much is dependant on the scope of the project. Given the high costs, the result B/C ratio of these projects is generally low.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	Not eligible for California's federal safety programs
Crash Reduction Factor:	*5 - 20 %*	Not eligible for California's federal safety programs

Name: Install raised median	Caltrans CM Number: **R9**

Where to use: 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. Installing a raised median is a more restrictive approach in that it represents a more ridged barrier between opposing traffic. Application of raised medians on roadways with higher speeds is not advised - instead a median barrier should be considered. Including landscaping in new raised medians can be counterproductive to the HSIP safety goals and should only be done in ways that do not increase drivers exposure to fixed objects and that will maintain driver's sight distance needs throughout the life of the proposed landscaping. Agencies need to consider and document impacts of additional turning movements at nearby intersections.
Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits 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. This new requirement is being implemented to maximize the safety-effectiveness of the limited HSIP funding and to minimize project impacts.*

Why it works: Adding raised medians is a particularly effective strategy as it adds to or reallocates the existing cross section to incorporate a buffer between the opposing travel lanes and reinforces the limits of the travel lane. Raised median may also be used to limit unsafe turning movements along a roadway.

General Qualities (Time, Cost, Effectiveness): In some cases this strategy may be a retrofit into the existing roadway by utilizing a portion of the existing paved shoulder. These raised medians can be installed directly over the existing pavement. Cost and time to implement could significantly increase if the paved area is not sufficient to include a median. The surface treatment of the raised median also significantly affects their cost-effectiveness: standard concrete or other hardscape surfaces are usually more cost effective than landscaped medians. When agencies opt to install landscaping in conjunction with new raised medians, the project design and construction costs can significantly increase due to excavation, backfill/top-soil, water-connection, irrigation, planting, maintenance needed for the landscaping. When agencies opt to install landscaping in conjunction with new raised medians, these locations must be excluded from their federally funded HSIP application scope.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Head-on	ALL
Crash Reduction Factor:	*20 - 75 %*	25% (with an expected life of 20 years)

Name: Install median (flush)	Caltrans CM Number: **R10**

Where to use: 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. Roadways with oversized lanes offer an opportunity to restripe the roadway to reduce the lanes to standard widths and use the extra width for the median.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new flush median. The new median must be a minimum of 4 feet wide (or "wider" if a narrow median exists before the proposed project).

Why it works: Adding medians is a particularly effective strategy as it adds to or reallocates the existing cross section to incorporate a narrow buffer median between opposing flows, thereby providing a greater opportunity to correct a errant maneuver and further reinforce the limits of the travel lane. Application widths can vary based on the available cross section and intended application. Additional safety can be provided by combining this CM with rumble strips.

General Qualities (Time, Cost, Effectiveness): In some cases this strategy may be retrofitted into the existing roadway by utilizing a portion of the existing paved shoulder and can ultimately be as simple as restriping the roadway. Costs and time to implement could significantly increase if the paved area is not sufficient to include a median.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*15 - 78 %*	15% (with an expected life of 20 years)

Name: Install acceleration/ deceleration lanes	Caltrans CM Number: **R11**

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new accel/decel lanes on high speed roadways. Significant improvements to the merge length for lane-drop locations is also an acceptable use of this CM.

Why it works: A lane that does not provide enough deceleration length and storage space for turning traffic may cause the turn queue to back up into the adjacent through lane. This can contribute to rear-end and sideswipe crashes. An acceleration lane is an auxiliary or speed-change lane that allows vehicles to accelerate to highway speeds (high speed roadways) before entering the through-traffic lanes of a highway. Additionally, if acceleration by entering traffic takes place directly on the traveled way, it may disrupt the flow of through-traffic and cause rear-end and sideswipe collisions.

General Qualities (Time, Cost, Effectiveness): Costs are highly variable. Where sufficient median or shoulder space exists it may be possible to provide acceleration/deceleration lanes at a moderate cost. Where the roadway must be widened and additional right-of-way must be acquired, higher costs and a lengthy time-to-construct are likely. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Sideswipe, Rear-End	ALL
Crash Reduction Factor:	*10 - 75 %*	25% (with an expected life of 20 years)

Name: Install climbing lane (where large difference between car and truck speed)	Caltrans CM Number: **R12**

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM 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.

Why it works: Separation between slower vehicles and all others results in a smoother flow of traffic and reduces disruptions in the flow of through-traffic, reducing rear-end, sideswipe, and roadway departure collisions.

General Qualities (Time, Cost, Effectiveness): Costs are usually very high. Usually these CMs require the roadway to be widened, additional right-of-way, and a lengthy time-to-construct. The expected effectiveness of this CM must be assessed for each individual location and the B/C ratios may be very low.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	Not eligible for California's federal safety programs
Crash Reduction Factor:	*20 - 33 %*	Not eligible for California's federal safety programs

*Countmeasure eligible for 100% federal funding

Name: Widen lane (initially less than 10 ft)	Caltrans CM Number: **R13**

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the widened lanes. Widening must a minimum of 1 foot.

Why it works: Increasing pavement width can affect almost all crash types. A common practice is to widen the traveled way on horizontal curves to make operating conditions on curves comparable to those on tangents. Speed is a primary consideration when evaluating potential adverse impacts of lane width on safety. On high-speed, rural two-lane highways, an increased risk of cross-centerline head-on or cross-centerline sideswipe crashes is a concern because drivers may have more difficulty staying within the travel lane.

General Qualities (Time, Cost, Effectiveness): Costs will depend on the amount of reconstruction necessary and on whether additional right-of-way is required. In general, this is one of the higher-cost strategies recommended, but it can also be very beneficial. Since this is 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*5 - 70 %*	25% (with an expected life of 20 years)

Name: Add two-way left-turn lane (without reducing travel lanes)	Caltrans CM Number: **R14**

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new lane, where an existing median did not already exist.

Why it works: Two-way left-turn lanes provide a buffer between opposing directions of travel and separate left turning traffic from through traffic. They can also help to allow vehicles to begin to accelerate before entering the through-traffic lanes. They reduce the disruption of flow of through-traffic and reducing rear-end and sideswipe collisions. For some roadways the option of converting a four-lane undivided arterials to three-lane roadways with a center left-turn lane and bike lanes should be considered (see "Road Diet" CM.)

General Qualities (Time, Cost, Effectiveness): In some cases this strategy may be retrofitted into the existing roadway by utilizing a portion of the existing paved shoulder and can ultimately be as simple as restriping the roadway. 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. The expected effectiveness of this CM must be assessed for each individual location as the B/C ratios will very from low to high.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*8 - 50 %*	30% (with an expected life of 20 years)

Name: Road Diet (Reduce travel lanes from 4 to 3 and add a two way left-turn **and bike** lanes)	Caltrans CM Number: **R15**

Where to use: 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. Using this strategy in locations with traffic volumes that are too high could result in diversion of traffic to routes less safe than the original four-lane design. It may also result in congestion levels that contribute to other crashes.
Note: For Caltrans' statewide Calls-for-Projects,this CM 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. This CM 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 CM 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.

Why it works: The application of this strategy usually reduces the roadway segment speeds and serious head-on crashes. In many cases the extra pavement width can be used for the installation of bike lanes. In addition to increasing bicycle safety, these bike lanes can improve the safety of on-street parking.

General Qualities (Time, Cost, Effectiveness): Implementation would require more time than in other low-cost treatments to complete environmental analyses (traffic studies?) and public input. 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 These striping and signal modification costs should be considered part of this CM and not an additional CM. (If additional signal hardware improvements are being made, over what is needed for the road diet, then the Improve Signal Hardware CM may also be used.) Often road diet projects need a seal-coat placed on the roadway to fully remove the old striping. These seal coats are considered part of the proper installation of this CM. In contrast, structural-overlays should not be considered part of this CM and are not considered eligible for funding in the California Local HSIP.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*26 - 43 %*	30% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Widen shoulder (paved)	Caltrans CM Number: **R16**

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new paved shoulder. A minimum of 2 feet width must be added and the new/resulting shoulders must be a minimum of 4 feet wide. ***This CM 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.*

Why it works: Based on the best available research, adding shoulder or widening an existing shoulder provides a greater area to regain control of a vehicle, as well as lateral clearance to roadside objects such as guardrail, signs and poles. They may also provide space for disabled vehicles to stop or drive slowly, provide increased sight distance for through vehicles and for vehicles entering the roadway, and in some cases reduce passing conflicts between motor vehicles and bicyclists and pedestrians. The likely safety benefits for adding or widening an existing shoulder generally increase as the widening width increases - practitioners should refer to NCHRP Report 500 Series, the CMF Clearinghouse or other references for more details.

General Qualities (Time, Cost, Effectiveness): Shoulder widening costs would depend on whether new right-of-way is required and whether extensive roadside moderation 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Fixed Object, Run-off Road, Sideswipe	ALL
Crash Reduction Factor:	*15 - 75 %*	30% (with an expected life of 20 years)

Name: Widen shoulder (unpaved)	Caltrans CM Number: **R17**

Where to use: Roadways with 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 area in which to initiate such a recovery. Unpaved shoulders usually have flatter cross sections and some structural integrity as compared to areas of "flatten slide slopes".
Note: For Caltrans' statewide Calls-for-Projects, 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.

Why it works: Adding shoulders creates a recovery area in which a driver can regain control of a vehicle, as well as lateral clearance to roadside objects such as guardrail, signs and poles. They may also provide increased sight distance for through vehicles and for vehicles entering the roadway. In suburban and rural areas, unpaved shoulders can also be use by pedestrians to avoid walking in the travel lanes.

General Qualities (Time, Cost, Effectiveness): Unless shoulder widening requires additional right-of-way and environmental impacts, these treatments can be implemented in a relatively short timeframe. Adding unpaved shoulders is the least costly shoulder enhancement alternative. The cost of adding a navigable non-paved shoulder would depend whether extensive roadside modifications and shoulder stabilization is required. These projects can offer similar benefits to widen with a 'paved' shoulder at reduced costs. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*15 - 22 %*	20% (with an expected life of 20 years)

Name: Pave existing shoulder	Caltrans CM Number: **R18**

Where to use: 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. Paving the existing shoulder provides a wider recovery area with a smooth surface that has a higher friction factor.
Note: For Caltrans' statewide Calls-for-Projects, 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.

Why it works: Paving the existing shoulder adds a recovery area to regain control of a vehicle. They also provide space for disabled vehicles to stop or drive slowly, maneuvering room vehicles entering the roadway, and reduce passing conflicts between motor vehicles and bicyclists and pedestrians.

General Qualities (Time, Cost, Effectiveness): This treatments can be implemented in a relatively short timeframe. Shoulder pavement costs should be similar to lane pavement costs, but will depend on how much shoulder stabilization is required. These projects are generally in the medium cost range and can be cost effective with high B/C ratio if targeting higher-hazard roadways.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*10 - 25 %*	15% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Name: Improve horizontal alignment (flatten curves)	Caltrans CM Number: **R19**

Where to use: 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 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.
*Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits (or influence area) of the improved alignment. **This CM 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.*

Why it works: Increasing the radius of a horizontal curve can be very effective in improving the safety performance of the curve. Curve modification reduces the likelihood of a vehicle leaving its lane, crossing the roadway centerline, or leaving the roadway at a horizontal curve; and minimizes the adverse consequences of leaving the roadway. Horizontal alignment improvement projects are expected to include standard/improved superelevation elements, which should be considered part of this CM and not an additional CM.

General Qualities (Time, Cost, Effectiveness): This strategy is a long-term, higher-cost alternative for improving the safety of a horizontal curve because it usually involves total reconstruction of the roadway. It may also require acquisition of additional right-of-way and an environmental review. This strategy, albeit costly, has shown that increasing the radius of curvature can significantly reduce total curve-related crashes by up to 80 percent. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*24 - 90%*	50% (with an expected life of 20 years)

Name: Flatten crest vertical curve	Caltrans CM Number: **R20**

Where to use: 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.
*Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits (or influence area) of the improved alignment. **This CM 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.*

Why it works: Adequate sight distance for drivers at stopped approaches to intersections has long been recognized as among the most important factors contributing to overall intersection safety. Vertical alignment improvement projects are expected to include standard/improved superelevation elements, which should be considered part of this CM and not an additional CM.

General Qualities (Time, Cost, Effectiveness): Projects involving changing the horizontal and/or vertical alignment to provide more sight distance are quite extensive and usually take several years to accomplish. If additional right-of-way is required or environmental impacts are expected, these projects will require a substantial period of time. Since this is usually an expensive treatment, one of the keys to creating a cost effective project with at least a medium B/C ratio is targeting higher-hazard locations.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*20 - 51 %*	25% (with an expected life of 20 years)

Name: Improve horizontal and vertical alignments	Caltrans CM Number: **R21**

Where to use: Roadways that have compound issues with curves (horizontal and vertical) and are experiencing lane departure and sight distance related crashes. Curve modification reduce the likelihood of a vehicle leaving its lane, crossing the roadway centerline, and helps in providing adequate sight distance. The target for this strategy is usually unsignalized intersections with restricted sight distance. 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.
*Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits (or influence area) of the improved alignment. **This CM 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.*

Why it works: Curve modification reduces the likelihood of a vehicle leaving its lane, crossing the roadway centerline, and helps in providing adequate sight distance. Roadways with curve realignments will clearly affect the number of lane departure and sight distance crashes. Horizontal and vertical alignment improvement projects are expected to include standard/improved superelevation elements, which should be considered part of this CM and not an additional CM.

General Qualities (Time, Cost, Effectiveness): Projects involving changing the horizontal and/or vertical alignment to provide more sight distance are quite extensive and usually take several years to accomplish. If additional right-of-way is required or environmental impacts are expected, these projects will require a substantial period of time. Since this is usually an expensive treatment, one of the keys to creating a cost effective project with at least a medium B/C ratio is targeting higher-hazard locations.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*50 - 73 %*	60% (with an expected life of 20 years)

*Countermeasure eligible for 100% federal funding

Name: Improve curve superelevation	Caltrans CM Number: **R22**

Where to use: Roadways noted as having frequent lane departure crashes and inadequate or no superelevation. Safety can be enhanced when the superelevation is improved or restored along curves where the actual superelevation is less than the optimal.
Note: For Caltrans' statewide Calls-for-Projects, 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.

Why it works: Superelevation works with friction between the tires and pavement to counteract the forces on the vehicle associated with cornering. Many curves may have inadequate superelevation because of vehicles traveling at higher speeds than were originally designed for, because of loss of effective superelevation after resurfacing, or because of changes in design policy after the curve was originally constructed.

General Qualities (Time, Cost, Effectiveness): This strategy can be a 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 roadways features. When simple overlay fixes are pursued, a systematic installation approach may be appropriate. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Run-off Road, All	ALL
Crash Reduction Factor:	*40 - 50 %*	45% (with an expected life of 20 years)

Name: Convert from two-way to one-way traffic	Caltrans CM Number: **R23**

Where to use: 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. While studies have shown that con-version of two-way streets to one-way generally reduces pedestrian crashes and the number of conflict points one-way streets tend to have higher speeds which creates new problems. Care must be taken not to create conditions that cause driver confusion and erratic maneuvers.
Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new one-way sections.*

Why it works: Studies have shown a 10 to 50-percent reduction in total crashes after conversion of a two-way street to one-way operation. While studies have shown that con-version of two-way streets to one-way generally reduces pedestrian crashes, one-way streets tend to have higher speeds which creates new problems. At the same time, this strategy (1) increases capacity significantly and (2) can have safety-related drawbacks including pedestrian confusion and minor sideswipe crashes.

General Qualities (Time, Cost, Effectiveness): The costs will vary depending on length of treatment and if the conversion requires modification to signals. Conversion costs can high to build "crossovers" where the one-way streets convert back to two-way streets and to rebuild traffic signals. It's also likely that these types of modifications will require public involvement and could significantly add to the time it takes to complete the project. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*26 - 43 %*	35% (with an expected life of 20 years)

Name: Improve pavement friction **(High Friction Surface Treatments)**	Caltrans CM Number: **R24**

Where to use: Nationally, this countermeasure is referred to as "High Friction Surface Treatments" or HFST. 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 is intended to target locations where skidding is determined to be a problem, in wet or dry conditions and the target vehicle is one that runs (skids) off the road or is unable to stop due to insufficient skid resistance.
Note: For Caltrans' statewide Calls-for-Projects, 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.

Why it works: Improving the skid resistance at locations with high wet-road crash frequencies can result in reductions of 50 percent for wet-road crashes and 20 percent for total crashes. Applying HFST can double friction numbers, e.g. low 40s to high 80s. This CM represents a special focus area for both FHWA and Caltrans, which means there are extra resources available for agencies interested in more details on High Friction Surface Treatment projects.

General Qualities (Time, Cost, Effectiveness): This strategy can be relatively inexpensive and implemented in a short timeframe. The installation would be done by either agency personnel or contractors and can be done by hand or machine. In general, these CMs can be very effective and can be considered on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Wet, Rear-End, All	ALL
Crash Reduction Factor:	*17 - 68 %*	30% (with an expected life of 10 years)

Name: Provide Safety Edge for Pavement Edge Drop-off		Caltrans CM Number: **R25**
Where to use: 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 Safety Edge provides a 30-degree angle at the edge. *Note: For Caltrans' statewide Calls-for-Projects, this CM primarily applies to new structural overlay projects, which are not eligible in California's federal safety funding programs.*		
Why it works: As earth or gravel falls away from the edge of a typical pavement, a vertical edge drop-off is exposed. The Safety Edge eliminates the vertical edge by providing an angled edge to the side of the roadway, also providing a more durable pavement edge. A motorist can more safely re-enter the traveled way after the tires leave the pavement.		
General Qualities (Time, Cost, Effectiveness): The installation of a Safety Edge is a key part of new structural overlays. As such they do not require their own development process and only add a very minor cost to the project. When considered a overlay project, local agencies should include/consider a safety edge in their plans and specifications where the pavement-edge will have a dirt backing.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Run-off Road	Not eligible for California's federal safety programs
Crash Reduction Factor:	*4 - 63 %*	Not eligible for California's federal safety programs

Name: Install/Upgrade signs with new fluorescent sheeting (regulatory or warning)		Caltrans CM Number: **R26***
Where to use: 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. Ideally this type of safety CM would be combined with other sign evaluations and upgrades (install chevrons, warning signs, delineators, markers, beacons, and relocation of existing signs per MUTCD standards.) *Note: For Caltrans' statewide Calls-for-Projects, 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.*		
Why it works: This strategy primarily addresses crashes caused by lack of driver awareness (or compliance) roadway signing. It is intended to get the drivers attention and give them a visual warning by using fluorescent yellow sheeting (or other retroreflective material).		
General Qualities (Time, Cost, Effectiveness): Signing improvements do not require a long development process and can typically be implemented quickly. 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, these CMs 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. When considering any type of federally funded sign upgrade project, California local agencies are encouraged to consider "Roadway Safety Signing Audit (RSSA) and Upgrade Projects". Including RSSAs in the development phase of sign projects are expected to identify non-standard (per MUTCD) sign features and missing signs that may otherwise go unnoticed. More information on RSSA is available on the Local Assistance HSIP webpage.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Head on, Run-off road, Sideswipe, Night	ALL
Crash Reduction Factor:	*18 - 35%*	15% (with an expected life of 10 years)

Name: Install chevron signs on horizontal curves		Caltrans CM Number: **R27***
Where to use: 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.) *Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the influence area of the new signs. (ex: only through the curve).*		
Why it works: Post-mounted chevrons are intended to warn drivers of an approaching curve and provide tracking information and guidance to the drivers. While they are intended to act as a warning, it should also be remembered that the posts, placed along the roadside, represent a possible object with which an errant vehicle can crash into. Design of posts to minimize damage and injury is an important part of the considerations to be made when selecting these treatments.		
General Qualities (Time, Cost, Effectiveness): Signing improvements do not require a long development process and can typically be implemented quickly. 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, these CMs 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. When considering any type of federally funded sign upgrade project, California local agencies are encouraged to consider "Roadway Safety Signing Audit (RSSA) and Upgrade Projects". Including RSSAs in the development phase of sign projects are expected to identify non-standard (per MUTCD) sign features and missing signs that may otherwise go unnoticed. More information on RSSA is available on the Local Assistance HSIP webpage.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Run-off Road, All	ALL
Crash Reduction Factor:	*6 - 64 %*	40% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install curve advance warning signs	Caltrans CM Number: **R28***

Where to use: Roadways that have an unacceptable level of crashes on relatively sharp curves during periods of light and darkness. This countermeasure 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.)
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the influence area of the new signs. (ex: only through the curve)

Why it works: This strategy primarily addresses problem curves, and serves as an advance warning of an unexpected or sharp curve. It provides advance information and gives the driver a visual warning that his or her added attention is needed.

General Qualities (Time, Cost, Effectiveness): Signing improvements do not require a long development process and can typically be implemented quickly. 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, these CMs 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. When considering any type of federally funded sign upgrade project, California local agencies are encouraged to consider "Roadway Safety Signing Audit (RSSA) and Upgrade Projects". Including RSSAs in the development phase of sign projects are expected to identify non-standard (per MUTCD) sign features and missing signs that may otherwise go unnoticed. More information on RSSA is available on the Local Assistance HSIP webpage.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Run-off Road, All	ALL
Crash Reduction Factor:	*20 - 30 %*	25% (with an expected life of 10 years)

Name: Install curve advance warning signs (flashing beacon)	Caltrans CM Number: **R29***

Where to use: 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 sever crash history to help maintain their effectiveness.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the influence area of the new signs. (ex: only through the curve)

Why it works: This strategy primarily addresses problem curves, and serves as an enhanced advance warning of an unexpected or sharp curve. It provides advance information and gives the driver a visual warning that his or her added attention is needed. Flashing beacons are an added indication that a curve may be particularly challenging.

General Qualities (Time, Cost, Effectiveness): Use of flashing beacons requires minimal development process, allowing flashing beacons to be installed within a short time period. Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option). In general, these CMs can be very effective and can be considered on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*30%*	30% (with an expected life of 10 years)

Name: Install dynamic/variable speed warning signs	Caltrans CM Number: **R30***

Where to use: Curvilinear roadways that have an unacceptable level of crashes due to excessive speeds on relatively sharp curves.
Note: *For Caltrans' statewide Calls-for-Projects,this CM only applies to crashes occurring within the influence area of the new signs. (ex: through the curve) {This CM does not apply to dynamic regulatory speed warning signs. There are currently no nationally accepted CRFs for dynamic regulatory signs (also known as Radar Speed Feedback Signs) . CRFs are being developed and Caltrans hopes to included these CMs and CRFs in future calls for projects.}*

Why it works: This strategy primarily addresses crashes caused by motorists traveling too fast around sharp curves. It is intended to get the drivers attention and give them a visual warning that they may be traveling over the recommended speed for the approaching curve. Care should be taken to limit the placement of these signs to help maintain their effectiveness.

General Qualities (Time, Cost, Effectiveness): Use of dynamic speed warning signs requires minimal development process, allowing them to be installed within a short time period. Before choosing this CM, the agency needs to confirm the ability to provide power to the site (solar may be an option). In general, these CMs can be very effective and can be considered on a systematic approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*0 - 41 %*	30 % (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install delineators, reflectors and/or object markers — Caltrans CM Number: **R31***

Where to use: Roadways that have an unacceptable level of crashes on curves (relatively flat to sharp) during periods of light and darkness. Any road with a history of fixed object crashes is a candidate for this treatment, as are roadways with similar fixed objects along the roadside that have yet to experience crashes. If a fixed object cannot be relocated or made break-away, placing an object marker can provide additional information to motorists. Ideally this type of safety CM would be combined with other sign evaluations and upgrades (install warning signs, chevrons, beacons, and relocation of existing signs per MUTCD standards.)

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits / influence area of the new features. {This is not a striping-

Why it works: Delineators, reflectors and/or object markers are intended to warn drivers of an approaching curve or fixed object that cannot easily be removed. They are intended to provide tracking information and guidance to the drivers. The are generally less costly than Chevron Signs as they don't require posts to placed along the roadside, avoiding an additional object with which an errant vehicle can crash into.

General Qualities (Time, Cost, Effectiveness): These improvements do not require a long development process and can typically be implemented quickly. 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, these CMs 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. When considering any type of federally funded sign upgrade project, California local agencies are encouraged to consider "Roadway Safety Signing Audit (RSSA) and Upgrade Projects". Including RSSAs in the development phase of sign projects are expected to identify non-standard (per MUTCD) sign features and missing signs that may otherwise go unnoticed. More information on RSSA is available on the Local Assistance HSIP webpage.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	All	ALL
Crash Reduction Factor:	*0 - 30 %*	15% (with an expected life of 10 years)

Name: Install edge-lines and centerlines — Caltrans CM Number: **R32***

Where to use: 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 - install where the existing lane delineation is not sufficient to assist the motorist in understanding the existing limits of the roadway. Depending on the width of the roadway, various combinations of edge line and/or center line pavement markings may be the most appropriate. Incorporating raised/reflective pavement parkers (RPMs) into centerlines (and edge-lines) should be considered as it has been shown to improve safety.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new centerlines and/or edge-lines. This CM 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.

Why it works: Installing edge-lines and centerlines where none exist or making significant upgrades to existing lines (paint to thermoplastic, adding audible disks/bumps in the thermoplastic stripes, or adding RPMs) are intended/designed to help drivers who might leave the roadway because of their inability to see the edge of the roadway along the horizontal edge of the pavement or cross-over the centerline of the roadway into oncoming traffic. New pavement marking products tend to be more durable, are all-weather, more visible, and have a higher retroreflectivity than traditional pavement markings.

General Qualities (Time, Cost, Effectiveness): These improvements do not require a long development process and can typically be implemented quickly. Costs for implementing this strategy are nominal and depend on the number and length of locations. These CMs 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. When considering any type of federally funded striping upgrade project, California local agencies are encouraged to consider "Roadway Safety Striping Audit and Upgrade Projects". Including wide-scale striping audits in the development phase of striping projects are expected to identify non-standard (per MUTCD) striping/marking features, no-passing zone limits needing adjustment, and missing striping/markings that may otherwise go unnoticed. More information on this concepts is available on the Local Assistance HSIP webpage under an RSSA example document. Note: When federal safety funding is used for these installations in high-wear-locations, the local agency is expected to maintain the improvement for a minimum of 10 years.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Head-on, Run-off Road, All	ALL
Crash Reduction Factor:	*0 - 44%*	25% (with an expected life of 10 years)

Name: Install no-passing line — Caltrans CM Number: **R33***

Where to use: 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. General restriping projects can be good opportunities to reevaluate and incorporate new no-passing zones limits. The incorporation 'No Passing Zone' pennants should also be considered when reevaluating the limits of no-passing zones. Installing no-passing limits in areas that are not warranted may reduce the overall safety of the corridor as drivers may become frustrated and attempt passing maneuvers at other locations without the necessary sight distance.

Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new or extended no-passing zones.

Why it works: When the centerline markings due not differentiate between passing and no-passing areas, drivers may have difficulty determining where passing maneuvers can be completed safely. Providing clear and engineered passing and no-passing areas can encourage drivers to wait patiently for safe passing areas and avoid aggressively looking for passing opportunities.

General Qualities (Time, Cost, Effectiveness): These improvements do not require a long development process and can typically be implemented quickly. Costs for implementing this strategy are nominal and depend on the number and length of locations. When considered at a single location, these low cost improvements are usually funded through local funding by local maintenance crews. However, these CMs 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.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Head-on, Side-swipe	ALL
Crash Reduction Factor:	*40 - 53%*	45% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install centerline rumble strips/stripes		Caltrans CM Number: **R34***
Where to use: Center Line rumble strips/stripes can be used on virtually any roadway – especially those with a history of head-on crashes. It is recommended that rumble strips/stripes be applied systematically along an entire route instead of only at spot locations. For all rumble strips/stripes, pavement condition should be sufficient to accept milled rumble strips. Care should be taken when considering installing rumble strips in locations with residential land uses or in areas with high bicycle volumes. Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new rumble strips/stripes.*		
Why it works: Rumble strips provide an auditory indication and tactile rumble when driven on, alerting drivers that they are drifting out of their travel lane, giving them time to recover before they depart the roadway or cross the center line. Additionally, rumble stripes (pavement marking in the rumble itself) provide an enhanced marking, especially in wet dark conditions.		
General Qualities (Time, Cost, Effectiveness): These improvements do not require a long development process and can typically be implemented quickly. Costs for implementing this strategy are nominal and depend on the number and length of locations. These CMs can be effectively and efficiently implemented using a systematic approach with numerous and long locations, resulting in moderate cost projects that are more appropriate to seek state or federal funding.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Head-on, Side-swipe, All	ALL
Crash Reduction Factor:	*15 - 68%*	20% (with an expected life of 10 years)

Name: Install edgeline rumble strips/stripes		Caltrans CM Number: **R35***
Where to use: Shoulder and edge line milled rumble strips/stripes should be used on roads with a history of roadway departure crashes. It is recommended that rumble strips/stripes be applied systematically along an entire route instead of only at spot locations. For all rumble strips/stripes, pavement condition should be sufficient to accept milled rumble strips. Special requirements may apply and care should be taken when considering installing rumble strips in locations with residential land uses or in areas with high bicycle volumes. Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies to crashes occurring within the limits of the new rumble strips/stripes.*		
Why it works: Rumble strips provide an auditory indication and tactile rumble when driven on, alerting drivers that they are drifting out of their travel lane, giving them time to recover before they depart the roadway or cross the center line. Additionally, rumble stripes (pavement marking in the rumble itself) provide an enhanced marking, especially in wet dark conditions.		
General Qualities (Time, Cost, Effectiveness): These improvements do not require a long development process and can typically be implemented quickly. Costs for implementing this strategy are nominal and depend on the number and length of locations. These CMs can be effectively and efficiently implemented using a systematic approach with numerous and long locations, resulting in moderate cost projects that are more appropriate to seek state or federal funding.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Run-off Road	ALL
Crash Reduction Factor:	*10 - 41%*	15% (with an expected life of 10 years)

Name: Install bike lanes		Caltrans CM Number: **R36**
Where to use: Roadway segments noted as having crashes between bicycles and vehicles or crashes that may be preventable with a buffer/shoulder. Most studies suggest that bicycle lanes may provide protection against bicycle/motor vehicle collisions. Striped bike lanes can be incorporated into a roadway when is desirable to delineate which available road space is for exclusive or preferential use by bicyclists. Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies 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.*		
Why it works: Most studies present evidence that bicycle lanes provide protection against bicycle/motor vehicle collisions. Bicycle lanes provide marked areas for bicyclist to travel along the roadway and provide for more predictable movements for both bicyclist and motorist. Evidence also shows that riding with the flow of vehicular traffic reduces bicyclists' chances of collision with a motor vehicle. Locations with bicycle lanes have lower rates of wrong-way riding. In combination with this CM, better guidance signs and markings for non-motorized and motorized roadway users should be considered, including: sign and markings directing cyclists on appropriate/legal travel paths and signs and markings warning motorists of non-motorized uses of the roadway that should be expected.		
General Qualities (Time, Cost, Effectiveness): Adding striped bicycle lanes can range from the simply restriping the roadway and minor signing to projects that require roadway widening, right-of-way, and environmental impacts. It is most cost efficient to create bike lanes during street reconstruction, street resurfacing, or at the time of original construction. The expected effectiveness of this CM must be assessed for each individual location. For simple installation scenarios, these CMs can be very effective and can be considered on a systematic approach.		
	General Use	**Values for Caltrans Statewide Programs (Calls-for-Projects)**
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*0 - 53 %*	35% (with an expected life of 20 years)

Name: Install sidewalk/pathway (to avoid walking along roadway)	Caltrans CM Number: **R37**

Where to use: 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.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring within the limits of the new walkway. This CM 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. When an off-street multi-use 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.

Why it works: Sidewalks and walkways provide people with space to travel within the public right-of-way that is separated from roadway vehicles. The presence of sidewalks on both sides of the street has been found to be related to significant reductions in the "walking along roadway" pedestrian crash risk compared to locations where no sidewalks or walkways exist. Reductions of 50 to 90 percent of these types of pedestrian crashes. In combination with this CM, better guidance signs and markings for non-motorized and motorized roadway users should be considered, including: sign and markings directing pedestrians and cyclists on appropriate/legal travel paths and signs and markings warning motorists of non-motorized uses of the roadway that should be expected.

General Qualities (Time, Cost, Effectiveness): In general, the cost of new sidewalks for long segments are higher cost projects. Costs for sidewalks will vary, depending upon factors such as width, materials, and existing of curb, gutter and drainage. Asphalt curbs and walkways are less expensive, but require more maintenance. The expected effectiveness of this CM must be assessed for each individual location. These projects can be very effective in areas of high-pedestrian volumes with a past history of crashes involving pedestrians.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*65 - 89 %*	80% (with an expected life of20 years)

Name: Install pedestrian crossing (with enhanced safety features)	Caltrans CM Number: **R38**

Where to use: Roadway segments with no controlled crossing for a significant distance in high-use midblock crossing areas and/or multilane roads locations. Based on the Zegeer study (Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations) at many locations, a marked crosswalk alone may not be sufficient to adequately protect non-motorized users. In these cases, rectangular rapid flashing beacons, overhead flashing beacons, curb extensions and other safety features should be added to complement the standard crossing elements. For multi-lane roadways, advance "yield" markings can be effective in reducing the 'multiple-threat' danger to pedestrians.
Note: For Caltrans' statewide Calls-for-Projects, this CM 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. Note: This CM is not intended to be combined with the "Install raised pedestrian crossing" when calculating the improvement's B/C ratio. This CM is not intended to be used for high-cost aesthetic enhancements to intersection crosswalks (i.e. stamped concrete or

Why it works: Adding pedestrian crossings has the opportunity to greatly enhance pedestrian safety at locations noted as being problematic. The enhanced safety elements, which may include curb extensions, raised medians, beacons, and lighting, combined with pavement markings delineating a portion of the roadway that is designated for pedestrian crossing. Care must be taken to warn drivers of the potential for pedestrians crossing the roadway and enhanced improvements added to the crossing increase the likelihood of pedestrians crossing in a safe manner. In combination with this CM, better guidance signs and markings for non-motorized and motorized roadway users should be considered, including: sign and markings directing pedestrians and cyclists on appropriate/legal travel paths and signs. When agencies opt to install aesthetic enhancement to crossing 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.

General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely, depending the extend 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. These CMs can often be effectively and efficiently implemented using a systematic approach with numerous locations, resulting in moderate to high cost projects that are appropriate to seek state or federal funding.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*8 - 56%*	30% (with an expected life of 10 years)

Name: Install raised pedestrian crossing	Caltrans CM Number: **R39**

Where to use: On lower-speed roadways, where pedestrians are known to be crossing roadways that involve significant vehicular traffic. Based on the Zegeer study (Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations) at many locations, a marked crosswalk alone, may not be sufficient to adequately protect non-motorized users. In these cases, raised crossings can be added to complement the standard crossing elements. 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.
Note: *For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring in the area with the new raised crossing. Note: This CM is not intended to be combined with the "Install pedestrian crossing (with enhanced safety features)" when calculating the improvement's B/C ratio.*

Why it works: Adding a raised pedestrian crossing has the opportunity to enhance pedestrian safety at locations noted as being especially problematic. The raised crossing encourages motorists to reduce their speed and provides improved delineation for the portion of the roadway that is designated for pedestrian crossing. In combination with this CM, better guidance signs and markings for non-motorized and motorized roadway users should be considered, including: sign and markings directing pedestrians and cyclists on appropriate/legal travel paths.

General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely, depending upon the elements of the raised crossing and the need for new curb ramps and sidewalk modifications. These CMs may be effectively and efficiently implemented using a systematic approach with more than one location and can have medium to high B/C ratios based on past non-motorized crash history.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*30 - 46%*	35% (with an expected life of 10 years)

*Countmeasure eligible for 100% federal funding

Name: Install Animal Fencing	Caltrans CM Number: **R40**

Where to use: 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).
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "animal" crashes occurring within the limits of the new fencing.

Why it works: Animal fencing helps to channelize the identified animal to a natural or man-made crossing, eliminating the conflict between vehicle and animal on the same plane. Animal fencing is typically installed at a bridge location with its "run of need" dependant of the surrounding terrain.

General Qualities (Time, Cost, Effectiveness): Time to install fencing can be moderate to lengthy depending on the environmental commitments and agreed upon solution to mitigating project impacts. Costs will be fairly low and depend on the "run of need" length. There will be minimal reoccurring maintenance costs on keeping the fence in tack. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Animal	Animal
Crash Reduction Factor:	*70 - 90 %*	80% (with an expected life of 20 years)

Name: Install Truck Escape Ramp	Caltrans CM Number: **R41**

Where to use: 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.
Note: *For Caltrans' statewide Calls-for-Projects, this CM 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.*

Why it works: Runaway trucks generally results from brake failures which can arise for many different reasons. The inability of drivers to control vehicle speeds on downgrades is not only hazardous but it can also have costly consequences. A runaway truck ramp, runaway truck lane, emergency escape ramp or truck arrester bed is a traffic device that enables vehicles that are having braking problems to safely stop. It is typically a long, sand or gravel-filled lane adjacent to a road with a steep grade, and is designed to accommodate large trucks.

General Qualities (Time, Cost, Effectiveness): 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. The expected effectiveness of this CM must be assessed for each individual location.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Run-off Road, Rear-end	Not eligible for California's federal safety programs
Crash Reduction Factor:	*33 - 75 %*	Not eligible for California's federal safety programs

Name: Install pedestrian median fencing	Caltrans CM Number: **R42**

Where to use: Roadway segments with high pedestrian-generators and pedestrian-destinations near by (e.g. transit stops) may experience a high volumes of pedestrians J-walking across the travel lanes at mid-block locations instead of walking to the nearest intersection or designated mid-block crossing. When this safety issue cannot be mitigated with shoulder, sidewalk and/or crossing treatments, then installing a continuous pedestrian barrier in the median may be a viable solution.
Note: For Caltrans' statewide Calls-for-Projects, this CM only applies to "Ped & Bike" crashes occurring on the approaches/influence area of the new pedestrian median fencing.

Why it works: Adding pedestrian median fencing has the opportunity to enhance pedestrian safety at locations noted as being problematic involving pedestrians running/darting across the roadway outside designated pedestrian crossings. Pedestrian median fencing can significantly reduce this safety issue by creating a positive barrier, forcing pedestrians to the designated pedestrian crossing.

General Qualities (Time, Cost, Effectiveness): Costs associated with this strategy will vary widely depending on the type and placement of the median fencing. Impacts to transit and other land uses may need to be considered and controversy can delay the implementation. In general, this CM can be effective as a spot-location approach.

	General Use	Values for Caltrans Statewide Programs (Calls-for-Projects)
Crash Types Addressed:	Pedestrian, Bicycle	Pedestrian and Bicycle
Crash Reduction Factor:	*25 - 40%*	35% (with an expected life of 20 years)

*Countmeasure eligible for 100% federal funding

Appendix C: Summary of "Recommended Actions"

The information contained here represent a brief summary of each section of this manual as well as the Summary of "Recommended Actions" from Sections 2 through 7. This is intended to be a quick-reference for local agency practitioners working on a "proactive safety analysis" of their roadway network.

Introduction and Purpose

As safety practitioners consider implementing a 'proactive safety analysis approach' they should consider the overall context of the safety issues facing California local agencies and Caltrans primary goals for preparing this Safety manual for California's local roadway owners. Figure 1 provides a flowchart of the process and Appendices E and F provide examples and lessons learned from recent statewide calls-for-projects.

Identifying Safety Issues

This section provides an overview of the types of data to collect for the identification of roadway safety issues. It discusses sources of crash data and how they can be used. As practitioners gather information they are encouraged to develop one or more separate spreadsheets and/or pin-maps to help track and manage this data. The following spreadsheet is offered as an example, but each agency's spreadsheet should include data and be formatted as necessary to meet their needs.

Location & Date	General Information		Crash Information			Evaluation / Action		
	Source/Type of information	Safety Issue/Problem	Nature of Crashes	Time of Day	Weather/Traffic Conditions	Staff Evaluation	Recommend Action	Resolution
1) Intersection "X"								
2) Roadway Segment (PM 5.3 to PM 7.8)								

An example of a pin-map is shown in Section 2.2 as part of the TIMS output.

State and Local Crash Databases

Recommended Action: Obtain at least 5 years of network-wide crash data to identify local roads that have a history of roadway crashes. This will be used to identify predominant roadway crash locations, crash types and other common characteristics.

Transportation Injury Mapping System (TIMS)

Recommended Action: Consider augmenting your local agency's data collection approach with information available using the suite of TIMS tools. The TIMS tools (and/or tools from private for-profit vendors) can help the safety practitioner access and manage their crash data.

Law Enforcement Crash Reports

Recommended Action: Develop a working relationship with law enforcement officials responsible for enforcement and crash investigations. This could foster a partnership where sharing crash reports and safety information on problem roadway segments becomes an everyday occurrence. Practitioners with limited access to crash data are encouraged to use TIMS to assess the local crash report data.

Observational Information

Recommended Action: Gather information received from law enforcement and road maintenance crew observations. Develop a system for maintenance crews to report and record observed roadway safety issues and a mechanism to address them.

Public Notifications

Recommended Action: Review and summarize information received from these sources, identifying segments or corridors with multiple notifications and record the locations, dates, and nature of the problem that are cited.

Roadway Data and Devices

Recommended Action: Identify and track roadway characteristics for the intersections, roadway segments, and corridors, including compliance with the minimum standards. At a minimum, this should be done for locations being considered for safety improvements, but ideally agencies would establish an extensive database of roadway data to help them proactively identify high risk roadway features.

Exposure Data

Recommended Action: Consider the availability of exposure data and track it along with the other crash data to help prioritize potential locations for safety improvements.

Field Assessments and Road Safety Audits

Recommended Action: Consider completing formal or informal field assessments and RSAs at certain locations to help ensure all relevant information is collected and available for the safety practitioners to complete their safety analysis and identification of the most appropriate countermeasures. Develop simple straightforward criteria on when one of these will be undertaken.

Safety Data Analysis

This section summarizes the types of analyses that can be conducted to determine what roadway countermeasures should be implemented. This section is the link between the data (Section 2) and the selection of appropriate countermeasures (Section 4). It provides definitions and examples of the qualitative and quantitative factors that should be considered when evaluating roadway safety issues.

Quantitative Analysis

Recommended Action: Complete a quantitative analysis of their roadway data using both Crash Frequency and Crash Rate methodologies, including:

Crash Frequency

Top 10 (or 20) lists of intersections and roadway segments.

For lower volume roadways, network wide pin-maps may be more effective.

Develop collision diagrams showing the direction of movement of vehicles and pedestrians.

Crash Rate

Top 10 (or 20) lists of roadway segments in relationship to length, volumes, and/or density.

Top 10 (or 20) lists of intersections, sorted by crash rate.

Top 10 (or 20) lists of the highest volume intersections, sorted by crash frequency or rate.

Qualitative Analysis

Recommended Action: Consider completing field assessments and RSAs to identify roadway infrastructure characteristics relating to both locations with compliance issues and locations with high crash frequencies/rates. As part the field assessments, common roadway and crash characteristics should be identified for the potential systemic deployment of countermeasures.

Caltrans recommends all agencies complete both quantitative and qualitative analyses before starting their applications for HSIP program funding. The findings from these analyses should be documented in spreadsheets and/or pin-maps similar to the ones discussed in Section 2.

Countermeasures

This Section provides a description of selected countermeasures that have been shown in this manual. It includes a basic set of strategies to implement at locations experiencing a history of crashes and their corresponding crash modification factors (CMF). NOTE: Crash Reduction Factors (CRFs) are directly connected to the CMFs and are another indication of the effectiveness of a particular treatment. The CRF for a countermeasure is defined mathematically as 1 – CMF. The terms CMFs and CRFs are used interchangeably throughout this document.

Selecting Countermeasures and Crash Modification Factors / Crash Reduction Factors

Countermeasure Details and Characteristics

Recommended Action: Agencies should use all information and results obtained through completing the actions in Sections 2, 3 and 4 to select the appropriate countermeasures for their HCCLs and systemic improvements. As novice safety practitioners select countermeasures, they must realize that a reasonable level of traffic 'engineering judgment' is required and that this manual and should not be used as a simple cheat-sheet for preparing and submitting applications for funding.

Calculating the B/C ratio and Comparing Projects

This section defines a methodology for calculating a benefit to cost (B/C) ratio for a potential safety project. It includes sources for estimating projected costs and benefits and the specific values/formulas Caltrans uses for its statewide evaluations of HSIP projects. This section also discusses the potential value in reevaluating projects' overall cost effectiveness.

Estimating the Benefit of Implementing Proposed Improvements

Recommended Action: Prepare 'Total Benefit' estimates for the proposed projects being evaluated in the proactive safety analysis.

Estimating the Cost of Implementing Proposed Improvements

Recommended Action: Prepare 'Total Project Cost' estimates for the proposed projects being evaluated in the proactive safety analysis.

Calculating the B/C Ratio

Recommended Action: Calculate the B/C ratio for each of the proposed projects being evaluated in the proactive safety analysis. If the B/C ratio is being calculated as part of an HSIP application, Caltrans requires agencies to utilize TIMS.

Compare B/C Ratios and Consider the Need to Reevaluate Project Elements

Recommended Action: Compare, reevaluate, and prioritize the potential safety projects. Consider changing the project limits or utilizing lower cost countermeasures for projects with low initial B/C ratios.

Identifying Funding and Construct Improvements

This section identifies existing and new funding opportunities for safety projects that local agencies should be considering. This section also briefly discusses some unique project development issues and strategies for safety projects as they proceed through design and construction.

Existing Funding for Low-cost Countermeasures

Recommended Action: Survey planned maintenance, developer and capital projects to determine whether they overlap any of the proposed safety projects. Where projects overlap, leverage the existing funding sources to include safety countermeasures.

Other Funding Sources

Recommended Action: Consider all potential funding opportunities to incorporate the identified safety countermeasures including the HSIP and ATP Programs.

Project Development and Construction Considerations

Recommended Action: Safety practitioners should follow their safety projects all the way through the project delivery and construction process. In addition, they should establish a safety program delivery plan that brings awareness and support to the expedited delivery of safety projects. Where possible, safety practitioners should involve the media and even consider having their own program intended to "toot their own safety-horn."

Evaluation Improvements

This section presents the process to complete an evaluation of installed treatments. After the countermeasures are installed, assessing their effectiveness will provide valuable information and can help determine which countermeasures should continue to be installed on other roadways to make them safer as well.

Recommended Action: Develop a spreadsheet to track future safety project installations and record 3+ years of "before" and "after" crash information at those locations. Once safety countermeasures are constructed, schedule and track assessment dates to ensure they happen.

Appendix D: Benefit/Cost Ratio Calculations

This appendix includes the Benefit/Cost methodology used in the Caltrans calls-for-projects in the HSIP programs. The HSM, Part B - Chapter 7, includes more details on conducting Economic Appraisal for roadway safety projects. The University of California, Berkeley – SafeTREC Transportation Injury Mapping System (TIMS) website includes a tool to allow local agency users to complete the Benefit/Cost methodology used in the Caltrans calls-for-projects. Local agencies will be required to utilize the TIMS B/C calculator as part of their application for HSIP funding. Starting in Cycle 7 call for projects, the fatality and severe injury costs have been combined for calculating the benefit. Because fatality figures are small and are a matter of randomness, this change is being made to reduce the possibility of selecting an improvement project on the basis of randomness.

1) $Benefit\ (Annual) = \dfrac{CRF \times N \times CC_{ave}}{Y}$

- CRF : Crash reduction factor in each countermeasure
- S : Severity (0:PDO, 1:Minor Injury, 2:Injury, 3:Severe Injury, 4:Fatal)
- N : Number of Crashes, in severity levels, related to selected countermeasure
- Y : Crash data time period (Year)
- CC_{ave} : Crash costs in severity levels

Crash Severity *	Crash Cost ***
Fatality (K)	$5,579,400
Severe/Disabling Injury (A)	$297,100
**Combined (KA) – *Roadway*	*$1,730,000*
**Combined (KA) - *Non Signalized Intersection*	*$2,000,000*
**Combined(KA) – *Signalized Intersection*	*$1,260,000*
Evident Injury – Other Visible (B)	$108,600
Possible Injury – Complaint of Pain (C)	$61,300
Property Damage Only (O)	$10,000

* The letters in parenthesis (K, A, B, C and O) refer to the KABCO scale; it is commonly used by law enforcement agencies in their crash reporting efforts and is further documented in the HSM.

** Figures were calculated by determining a Severe Injury / Fatal ratio for each area type. These costs are used in the TIMS B/C calculator

*** Highway Safety Manual (HSM), First Edition, 2010 adjusted to 2014 Dollars.

2) *Benefit (Life) = Benefit (annual) x Years of service life*

3) Benefit/Cost Ratio (each countermeasure): $Benefit\ \ Cost\ Ratio_{(CM)} = \frac{Benefit\ \ (Life)_{(CM)}}{Total\ \mathrm{Pr}oject\ \ Cost_{(CM)}}$

4) Benefit/Cost Ratio (project): $Benefit/Cost\ Ratio(\mathrm{P}roject) = \frac{\sum_{CM=1}^{3} Benefit(Life)_{(CM)}}{Total\ \mathrm{P}rojectCost}$

Appendix E: Examples

Examples of Required Attachments for Statewide Applications

As part of the statewide data-driven approach to project selection of safety projects, Caltrans requires all applications for HSIPfunding include attachments documenting the proposed project scope and B/C ratio. The following attachments are requireed for all HSIPapplications:

- Project maps and pictures showing existing and proposed conditions
- Crash Diagram(s), Crash List(s), and Crash Summary
- Detailed Engineer's Estimate
- TIMS B/C output summary sheet

As part of every statewide call-for-projects, Caltrans includes examples of these attachments (and other attachments that are required when applicable) on the Program's website. The following is a link to the HSIP website where examples for the most recent call-for-projects are available: http://www.dot.ca.gov/hq/LocalPrograms/hsip.htm

Examples of Crash Data Collection and Analysis Techniques using TIMS

As demonstrated throughout the manual, SafeTREC's TIMS website can be used to assist local agencies in completing a proactive safety analysis of their roadway network and calculating B/C ratios for potential projects. *(Note: This manual focuses on TIMS as a tool to access and map SWITRS data because TIMS is free to local agencies and the general public. Local agencies are encouraged to try TIMS, but they should not feel obligated to make a switch if they prefer using their vendor-supplied crash analysis software to complete their data collection and analysis process).*

To assist local agencies, TIMS includes a "Help" tab specifically designed to walk local agencies step-by-step through some key data collection and data analysis processes outlined in this manual. . The "Help" section will guide the practitioner through the following steps:

<u>Data Review/Collection (Section 2):</u>

- View agency-wide pin-maps showing crashes.
  - The crashes can be sorted by type, severity, or other controlling factors
- Zoom in to see pin-maps for high crash areas and corridors.
- Review crash report details for individual crashes.
  - Including: date, time, victims, weather, primary collision factor, etc.
- View the roadway features using Google's Street-View.
  - Review roadway features and save pictures (screen-shots)
  - Use measuring features to evaluate existing and proposed features
- Spatially select collisions on the map and download the data for different potential projects

Data Analysis and countermeasure selection (Sections 3 and 4):

- TIMS intentionally leaves Data Analysis and Countermeasure Selection steps up to the local agency safety practitioner, as they require extensive "engineering judgment" to meet the needs of the roadway users, roadway features, and community expectations.
  - TIMS pin-maps, virtual field reviews (Google Street-View), and output files can assist the practitioners during these steps

Calculation the B/C Ratio and Comparing Projects (Sections 5):

- TIMS "SWITRS GIS Map" tool can be used to gather the crash data for specific improvement (i.e., countermeasure) limits.
  - Crash data files can be saved for each individual countermeasure
- TIMS intentionally leaves calculation of the improvement and project costs up to the local agency safety practitioner.
- TIMS "B/C Calculator" tool can be used to calculate the Benefit to Cost ratio for a proposed project with up to three safety countermeasures.
- TIMS "B/C Calculator" tool will also prepare basic pin-map style crash-diagrams of the crashes included for each of the countermeasures.
- TIMS intentionally leaves process of comparing and reevaluating potential projects up to the local agency safety practitioner.

Evaluations (Sections 7):

- TIMS "B/C Calculator" tool, through the steps listed above, can be used to compare the before and after crash data for specific improvement.
  - Once enough crash data is available to complete a post-construction evaluation (ideally 3+ years) then separate "before" and "after" crash data can be evaluated

The TIMS website can be assessed at: http://tims.berkeley.edu/

Appendix F: Case Studies and Lessons Learned

Case Studies

The FHWA manuals for Rural Road Owners, which this California manual is based on, includes some well documented case studies and examples that may be beneficial for local agencies to review. The "Roadway Departure Safety" manual includes several case studies in Section 6. The FHWA "Intersection Safety" manual does not include separate case studies, but does define several specific intersection safety issues and appropriate countermeasures in Section 3 and 4.

Caltrans Lessons Learned from switching from Qualitative/Subjective to Quantitative/Data-Driven HSIP calls-for-projects

The results from switching to a Benefit-to-Cost driven selection process in the last three HSIP calls-for-projects (Cycles 4, 5 and 6) illustrate Caltrans' local HSIP funds are reducing roadway crashes and fatalities by encouraging local agencies to make improvements to their roadways through the use of proven safety countermeasures (CMs) and enabling Caltrans to efficiently select the projects with the greatest potential for future safety benefits. The results also show how the HSIP B/C selection process is encouraging local agency traffic engineers and safety professionals to put a greater emphasis on analyzing the safety of their roadway networks, prioritizing the safety improvements for their HCCLs, and seeking out low-cost countermeasures to maximize the potential safety benefits with minimal funding. Additional benefits of the HSIP B/C selection process that are not as easily quantified are demonstrated by the fact that low-cost CMs and systemic projects usually have fewer environmental and right-of-way impacts and are generally easier to design and construct, thereby saving time and money.

This section includes several graphs and charts of data from HSIP Cycle 4 with corresponding text to explain how it relates to the benefits of the HSIP B/C ratio selection process.

Figure 1 shows how the new HSIP B/C selection process allowed Caltrans to effectively select the applications/projects with the highest expected total benefit. Even though Caltrans only had enough federal funding for 45% of the total funding requested ($74.5 M out of $165.6 M), the department was able to fund 88% of the total expected "Benefit Value" included in all of the applications. Making these kinds of intelligent investments in roadway projects is exactly the way the United States is going to move "Towards Zero Deaths!"

Figure 1

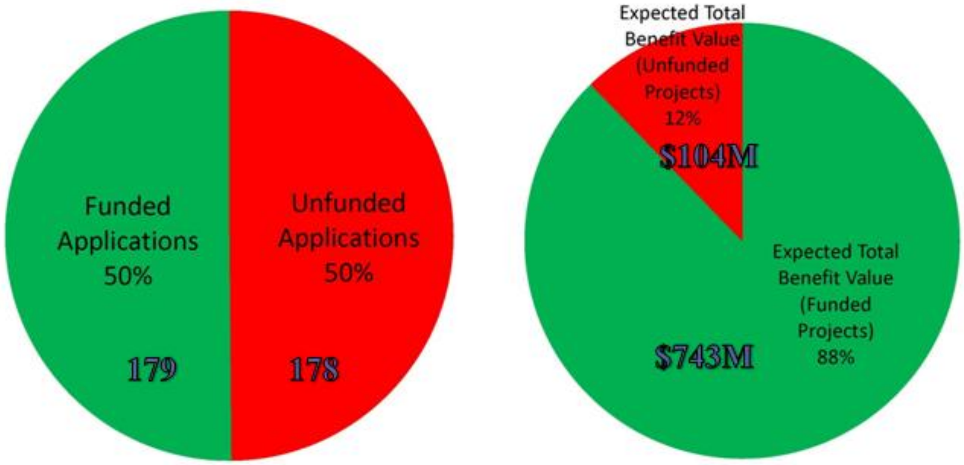
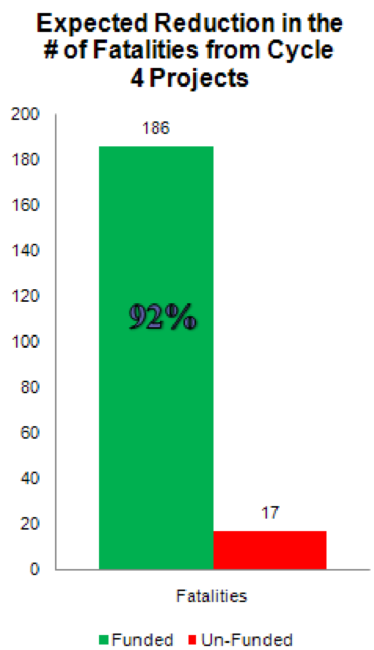


Figure 2 depicts the above Funded vs. Unfunded benefit-data in expected reductions in fatalities, injuries and properties damage only (PDOs). These graphs show how the HSIP Tool selects projects at locations and in corridors with higher numbers of past fatalities over locations with only PDOs or injuries crashes.

Figure 2



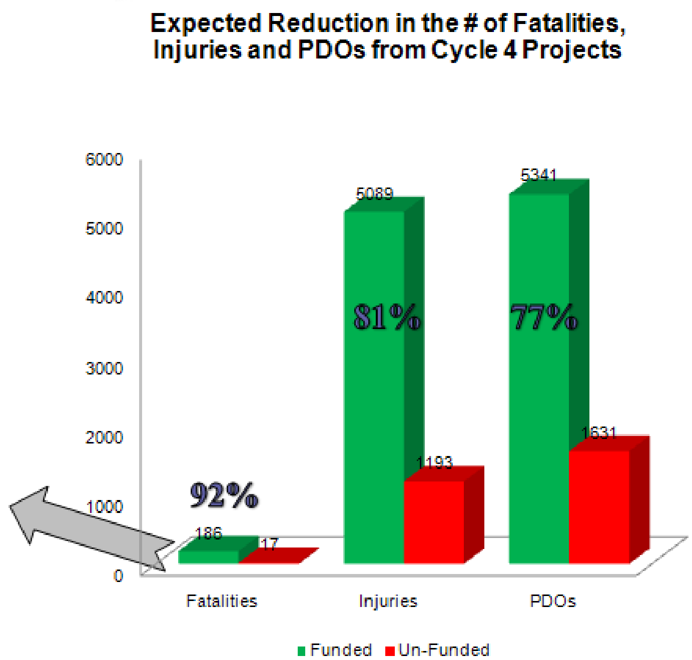
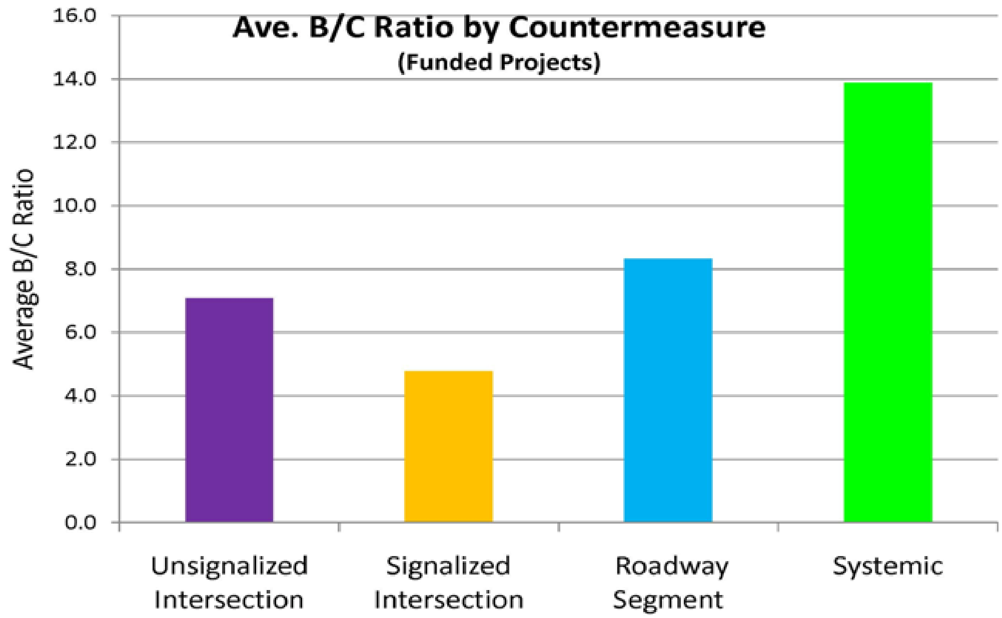


Figure 3 shows the Average Benefit vs. Cost ratio of the CMs in each of the four categories included in the HSIP Tool. As expected, it shows that systemic countermeasures will result in higher B/C ratios and maximize the efficient use of the federal funding resources.

Figure 3



Figures 4 and 5 use the same color scheme as Figure 3. In Figures 4 and 5, a green border around the primary color indicates that they are low-cost CMs with similar characteristics to systemic CMs.

Figure 4 shows how applicants that utilized systemic and low-cost CMs had a significantly higher chance of receiving HSIP funding. Comparing Figure 4 with Figure 5 also shows that many local agencies may not understand the overall safety benefits for their roadway networks from pursuing low-cost CMs instead of spot-location CMs. This is valuable in that it informs Caltrans where increased local agency outreach is needed to explain that higher cost improvements should only be proposed at locations with the worst historic fatality and severe injury rates in order for those projects to be selected for funding.

Figure 5 shows the CMs that were included in the greatest number of applications. It clearly demonstrates the disconnect between the CMs with the highest likelihood of being selected by local agencies (often due to competing political and maintenance reasons) compared with the CMs with the highest likelihood of resulting in roadway safety benefits.

Figure 4

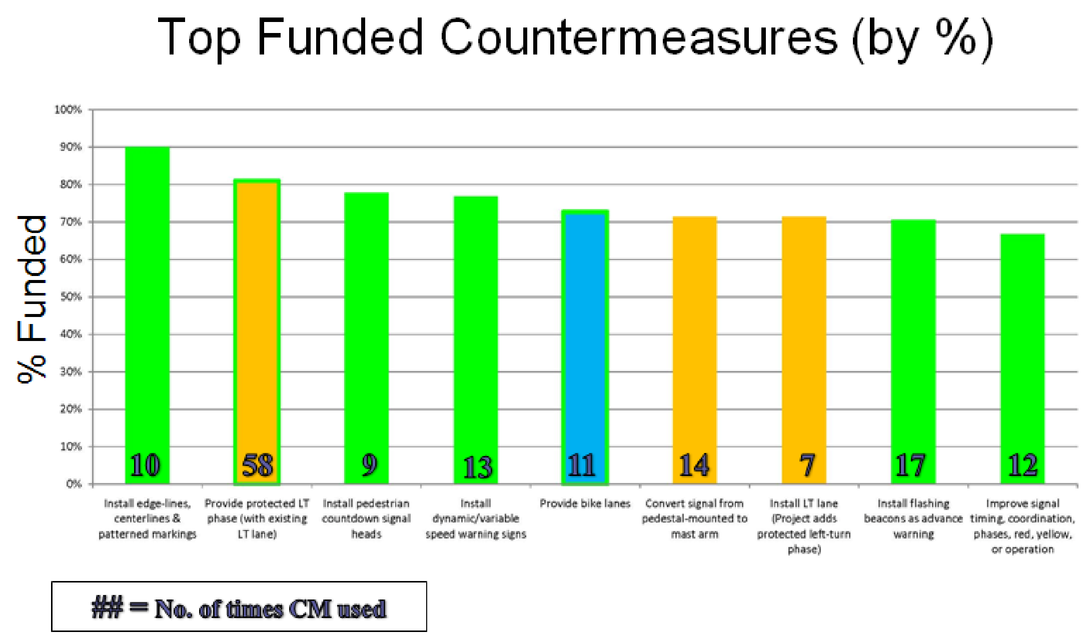


Figure 5

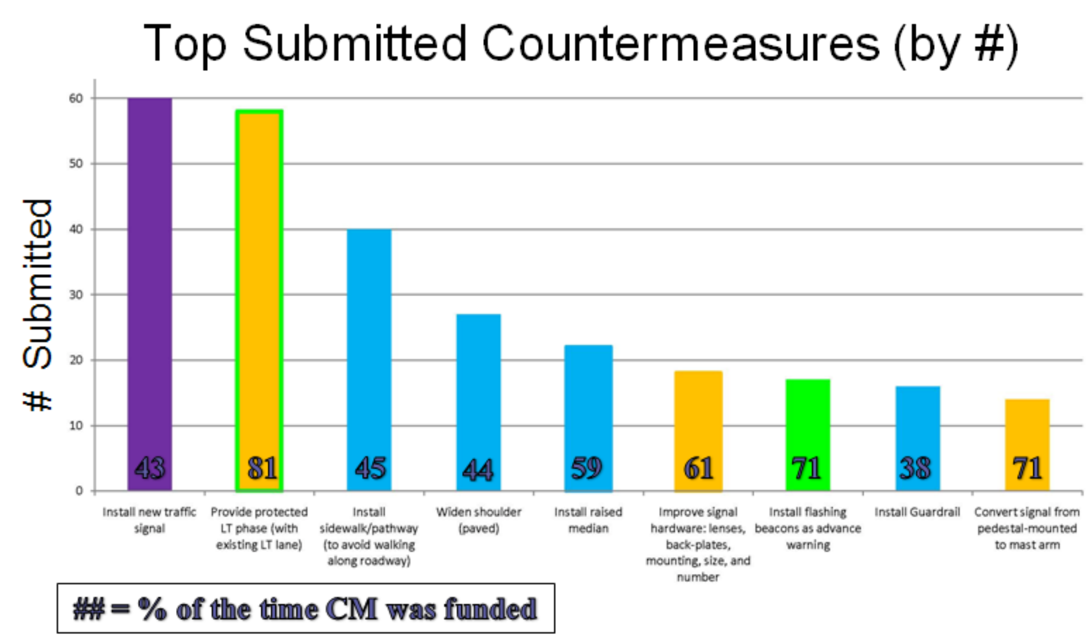
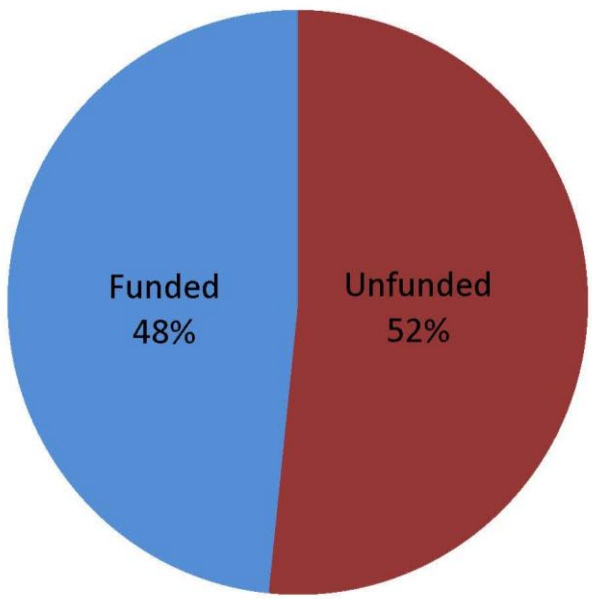


Figure 6 shows applications that included CMs primarily focused on reducing pedestrian and bicycle crashes. They faired similarly to CMs that were used to reduce all types of crashes. This is an important result for Caltrans and local agencies as they strive to accommodate all modes of travel and maximize the mobility and safety of roadway networks.

It is important to note that in addition to the 48% of funded pedestrian and bicycle CMs, many other projects focused on improving pedestrian and bicycle safety were funded using CMs related to signal, median and roadway widening improvements.

Figure 6

"Ped & Bike" Countermeasures Funded



Appendix G: List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ATP	Active Transportation Program
B/C	Benefit to Cost Ratio
Caltrans	California Department of Transportation (Division of Local Assistance)
CA-MUTCD	California - Manual on Uniform Traffic Control Devices
CM	Countermeasure
CMF	Crash Modification Factor
CRF	Crash Reduction Factor
"4 E's of Safety"	Engineering, Enforcement, Education, and Emergency Medical Services
EMS	Emergency Medical Services
FHWA	Federal Highway Administration
HCCL	High Crash Concentration Location
HR3	High Risk Rural Roads Program
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
RSA	Roadway Safety Audit
SafeTREC	Safe Transportation Research and Education Center (SafeTREC) at the University of California, Berkeley
SHSP	Strategic Highway Safety Plan
SRTS	Safe Routes to School (Program)
SWITRS	Statewide Integrated Traffic Records System
TIMS	Transportation Injury Mapping System (a product of SafeTREC)

Appendix H: References

1. FHWA, Office of Safety website: Local and Rural Road Safety Program
   - http://safety.fhwa.dot.gov/local_rural/

2. FHWA, Office of Safety website: Training, Tools, Guidance and Countermeasures for Locals Roadway includes the following links to three Local Rural Road Owners Manuals
   - http://safety.fhwa.dot.gov/local_rural/training/fhwasa1108/
   - http://safety.fhwa.dot.gov/local_rural/training/fhwasa1109/
   - http://safety.fhwa.dot.gov/local_rural/training/fhwasaxx1210/

3. Highway Safety Manual (HSM), First Edition, 2010. Product of the American Association of State Highway and Transportation Officials.
   - www.highwaysafetymanual.org

4. FHWA, Office of Safety website: Transportation Safety Planning (TSP) State Fact Sheets
   Fatality Analysis Reporting System (FARS) 2000-2008 Final & 2009 Annual Report File (ARF)
   - http://safety.fhwa.dot.gov/hsip/tsp/factsheets/ca.pdf

5. FHWA, Office of Safety website: Local and Rural Road Safety Program
   2009 Traffic Safety Facts “Rural/Urban Comparison” (DOT-HS-811-395)
   - http://www-nrd.nhtsa.dot.gov/Pubs/811395.pdf

6. California - Manual on Uniform Traffic Control Devices (CA-MUTCD)
   - http://www.dot.ca.gov/hq/traffops/signtech/mutcdsupp/ca_mutcd2012.htm

7. Caltrans’ website on the Highway Design Manual
   - http://www.caltrans.ca.gov/hq/oppd/hdm/hdmtoc.htm

8. AASHTO’s bookstore page for the FHWA “Green Book”
   - https://bookstore.transportation.org/Item_details.aspx?id=110

9. FHWA, Research and Development website for PEDSAFE
   - http://www.fhwa.dot.gov/research/deployment/pedsafe.cfm

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    - https://bookstore.transportation.org/collection_detail.aspx?ID=105

11. FHWA – Public Roads Magazine: Finding the Right Tool For the Job
    By Frank Gross and Karen Yunk
    - http://www.fhwa.dot.gov/publications/publicroads/11novdec/04.cfm