State of California
Department of Transportation

TRAFFIC SIGNAL OPERATIONS BUSINESS PLAN

Prepared by the Division of Traffic Operations
Office of Traffic Management

August 6, 2015

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MESSAGE FROM THE TRAFFIC OPERATIONS DIVISION CHIEF

Traffic signal operations are an integral component of Intelligent Transportation Systems (ITS). The Division of Traffic Operations is excited to maximize the benefits from an improved Traffic Signal Operations Program. We value the expertise of district subject matter experts in traffic operations. We have incorporated this expertise into this document that identifies the steps to achieve the Traffic Signal Operations program's objectives for arterial management.

The goal of an effective Traffic Signal Operations Program is "to advance management practices and operations strategies that promote the safe and efficient use of arterial roadway capacity to reduce congestion." This is consistent with Caltrans' mission which includes providing an efficient transportation system and the goals of safety and health (provide a safe transportation system for workers and users, and promote health through active transportation and reduced pollution), stewardship and efficiency (responsibly manage assets), and system performance (collaboration and strategic partnerships to develop an integrated transportation system).

The Federal Highway Administration (FHWA) encourages states to increase their focus on signalized arterials due to many benefits, including travel time savings, reduced fuel costs, and environmental benefits from reduced greenhouse emissions. These benefits increase when integrating the freeway and the arterial system of transportation - an example of Transportation System Management and Operations. This is also demonstrated in the Integrated Corridor Management (ICM) projects, which control the timing of all signalized intersections within a corridor during emergencies or certain events. Recently, through a pilot project conducted with the University of Nevada, Reno, Caltrans has shown that the benefit-cost ratio of improving traffic signal timing is approximately 130:1.* Through the use of the "Trans-Sync" tool, we look forward to further improvements in the near future. Please review the objectives outlined in this business plan, as well as the planned strategies.

T. P. Hallenbeck

THOMAS P. HALLENBECK, Chief
Division of Traffic Operations

8/11/15

Date

* "Signal timing using SMRT Case Study at CA 49 in Caltrans District 3" by Zong, Tian, PhD., P.E, Center for Advanced Transportation Education and Research, University of Nevada, Reno, November 2014.

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EXECUTIVE SUMMARY

This Traffic Signal Operations Business Plan identifies the steps to achieve the Traffic Signal Operation Program's objectives and goals of the arterial management system, which are "to advance management practices and operational strategies that promote the safe and efficient use of the arterial roadway capacity to reduce congestion." Caltrans will improve the Traffic Signal Operations Program to improve safety, reduce delays and improve efficiency.

The United States Department of Transportation (USDOT) Intelligent Transportation Systems (ITS) Joint Program Office maintains a database that documents traffic signal management and operations studies conducted by various agencies demonstrating benefit-cost ratios exceeding 40:1 for ITS. Recently, the University of Nevada, Reno showed a 130:1 ratio for improving traffic signal timing within one corridor located in District 3.

There are approximately 5,000 Caltrans operated traffic signals in California. At each signal, there are multiple factors that influence traffic flow and opportunities to improve traffic throughput. Properly designed, operated and maintained traffic signals can:

- Provide smooth flow of traffic along streets and highways at defined speeds, reducing congestion and enhancing safety.
- Effectively manage the traffic-handling capacity of intersections to improve mobility through the use of appropriate (geometric design) layouts, control measures, regular reviews and updates to operational parameters.
- Reduce vehicle stops and delays, reducing fuel consumption and improving air quality.
- Reduce the number and severity of traffic collisions and moving violations at traffic signals.

In 2014, Caltrans deployed the Traffic Signal Management and Surveillance System (TSMSS) across California. This system allows for remote communication with signalized intersections. There are currently 126 traffic signals connected to TSMSS. The system is designed to improve travel time reliability, and allows Caltrans to post reliable travel times to the PeMS system for the public and other interested parties.

This document lists the strategies for each of the Traffic Signal Operations areas:

- Signal Timing Reviews
- Yellow Timing
- Vehicle and System Detection
- Transit Signal Priority
- Battery Backup Systems
- Americans with Disabilities Act compliance and Pedestrian Needs
- Remote Communications
- Bicycle Detection
- Enhanced Intersection Safety
- Closed-Circuit Television (CCTV) Cameras
- Vehicle-to-Vehicle Communications

With the TRAC software tool, Districts will document work performed for traffic signals. This documentation will assist districts to align local plans with statewide goals and objectives of the Traffic Signal Operations Program.

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CALTRANS MISSION, VISION, GOALS AND VALUES

The Traffic Signal Operations Program aligns with Caltrans mission, vision, goals and values by focusing on an efficient transportation system, and promoting the safe and efficient use of the arterial roadway capacity to reduce congestion when traffic signals are properly operated to their maximum capability for optimal traffic throughput and signal coordination.

MISSION: Provide a safe, sustainable, integrated and efficient transportation system to enhance California's economy and livability.

VISION: A performance-driven, transparent and accountable organization that values its people, resources and partners, and meets new challenges through leadership, innovation and teamwork.

GOALS:

Safety and Health - Provide a safe transportation system for workers and users, and promote health through active transportation and reduced pollution in communities.

Strategic Objectives:

1. Reduce employee injury and illness rates – remote monitoring of traffic signal operations and remote diagnostics will reduce the need for field visits and thereby reduce risk to operations and maintenance staff.
2. Promote community health through active transportation and reduced pollution in communities:
   - Increase and improve opportunities for safe and accessible active transportation: responsive to transit signal priority (bus rapid transit) needs and to bicyclists' needs.
   - Percent reduction of transportation system-related air pollution for criteria pollutant emissions: efficient arterial traffic results in fewer vehicle stops and decreased emissions.

Stewardship and Efficiency – Money counts. Responsibly manage California's transportation-related assets.

Strategic Objectives:

1. Effectively manage transportation assets by implementing the asset management plan, embracing a fix-it-first philosophy.
2. Effectively manage operations of the transportation system:

   - Measure of ITS health, system operability, and equipment workability - remote monitoring of traffic signal operations and remote diagnostics will allow preventative maintenance and remote repairs.
   - Employ "best practices" to continuously improve Caltrans facilities, operations and services - Both a.m. and p.m. peak traffic signal reviews can lead to continuous improvement of traffic flows through arterials, as recommended by the National Transportation Operations Coalition. Real-time video of signalized intersections through Closed Circuit Television (CCTV) cameras can greatly assist staff in managing traffic.

Sustainability, Livability and Economy – Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl.

Strategic Objectives:

1. Improve the quality of life for all Californians by providing mobility choice, increasing accessibility to all modes of transportation and creating transportation corridors not only for conveyance of people, goods, and services, but also as livable public spaces – establish standards for vehicle detection that can identify bicycles to provide the required additional signal timing, thereby supporting bicyclists.
2. Reduce environmental impacts from the transportation system with emphasis on supporting a statewide reduction of greenhouse gas emissions to achieve 80 percent below 1990 levels by 2050 – improve traffic signal operations by increasing traffic flow through fewer stops or delays.

System Performance – Utilize leadership, collaboration and strategic partnerships to develop an integrated transportation system that provides reliable and accessible mobility for travelers.

Strategic Objectives:

1. Improve travel time reliability for all modes – including arterial travel times and sharing with partners as well through the capabilities of the Traffic Signal Management and Surveillance System (TSMSS) software tool that communicates remotely with the traffic signals.
2. Reduce peak period travel times and delay for all modes through Intelligent Transportation Systems (ITS), operational strategies, demand management and land use/transportation integration - through TSMSS.
3. Improve integration and operation of the transportation system – through the benefits of TSMSS and Integrated Corridor Management (ICM) projects.
4. Develop integrated corridor management strategies for those of highest statewide significance – through supporting ICM projects.

Organizational Excellence – Be a national leader in delivering quality service through excellent employee performance, public communication, and accountability.

Strategic Objectives:

1. Improve documentation for traffic signal operations engineers: Publish "Best Practices and Signal Operations Guidelines" and update the Signal, Lighting Electrical Systems Design Guide and the User's Guide for TRAC.
2. Update statewide policy and standards for Battery Backup Systems and alternative vehicle detection systems.

Our VALUES of Integrity, Commitment, Teamwork and Innovation are integrated in all aspects of traffic signal operations.

TRAFFIC SIGNAL OPERATIONS PROGRAM

Purpose and Goal

An arterial management system is a system that manages traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travelers. These systems make use of information collected by traffic surveillance devices for smooth traffic flow along travel corridors. As a component of the arterial management system, the Traffic Signal Operation Program is designed "to advance management practices and operations strategies that promote the safe and efficient use of the arterial roadway capacity to reduce congestion."

Efficient, optimal traffic signal timing reduces delays to the traveling public, including bicyclists and pedestrians. This program uses realistic, well-defined operational objectives, documented with measureable supporting strategies to manage traffic signals and operations. All districts share best practices through clear documentation and regular meetings between the Traffic Signal Functional Managers Team and the Traffic Signal Committee. Strategies determine the most appropriate tactics for a well-planned traffic signal management system, and include guidelines provided by the FHWA.

Objectives

The goals of the Traffic Signal Operations program are consistent with the Caltrans goals of safety and health, stewardship and efficiency, sustainability, livability and economy, system performance and organizational excellence. These are achieved by accomplishing the objectives listed below:

- Field infrastructure reliability: ruggedized hardware and software with remote diagnostic capability to aid with maintenance and troubleshooting.
- Signal timing that addresses congestion, to optimize mobility and reliability.
- Predictable and consistent signal operation best practices.
- Flexible signal timing plans to respond to changing traffic conditions.
- Clear and reliable communications (both to and from the field elements and between agencies, staff and the public).
- Performance-based resource allocations.

TMS Business Plan

The Transportation Management Systems (TMS) Business Plan Update (April 2013) discusses the plan for arterial signal coordination. The plan states that Caltrans will be proactive in implementing real-time traffic management. In order to provide real-time traffic data, Caltrans needs to improve remote communication with the traffic signals.

Real-time traffic management or "active traffic management," is a part of system management. Another aspect of system management is the Performance Measurement System (PeMS). Currently, PeMS collects data from over 39,000 detectors and maps traffic data in real-time. PeMS detectors are deployed on the freeway system across all major metropolitan areas of California but not, at present, on signalized intersections. Caltrans

plans to deploy the Arterial Performance Measurement System (APeMS) on Caltrans controlled intersections to eliminate this critical data gap. Enhanced management of the transportation system requires both freeway data and arterial data in PeMS.

One of the goals in the business plan is to *"establish a well-maintained and high-performing TMS Infrastructure that supports real-time traffic management."* Along with freeway data, real-time arterial data can then be immediately useful for decision-making and allow variable arterial signalization plans. This is a key component of connected corridors. This goal includes various action items. Action items include:

- Provide remote access to system elements
- Communicate to signalized intersections for monitoring traffic and performance measurement (travel times, origin/destination, level of service, etc.)

Traffic Signal Operations Areas

There are multiple areas involved with traffic signal operations; these include:

- Signal Timing Reviews
- Remote Communications
- Signal Interconnectivity
- Yellow Timing
- Bicycle Detection
- Vehicle and System Detection
- Closed-Circuit Television (CCTV) Cameras
- Transit Signal Priority
- Enhanced Intersection Safety
- Battery Backup Systems
- Americans with Disabilities Act compliance and Pedestrian Needs
- Vehicle-to-Vehicle Communications

Signal Timing Reviews

In order to optimize vehicle throughput, it is important to identify the right frequency for traffic signal timing updates as a part of a proactive monitoring program. Monitoring should include external sources, including planning or development review staff or other agency staff that are in the field. It may also include citizen complaints collected from phone calls or email. Monitoring also includes data such as vehicle presence, volume and occupancy, from vehicle detectors (whether in-pavement or off-pavement), as well as video from CCTV. Detection technology continues to progress, allowing traffic signal operators to obtain traffic volumes, including turning movements.

Traffic signal timing should be reviewed during both a.m. and p.m. peak times as appropriate, and more often when there are significant changes in traffic volumes or roadway conditions. At a minimum, a review of traffic signal timing should occur every three years, according to the 2012 National Traffic Signal Report Card Technical Report. Both proactive and reactive traffic signal timing plan reviews should be performed:

- **Proactive** signal reviews are to be done during both a.m. and p.m. peak times so that retiming of one third (⅓) of the traffic signal system is completed annually. Where significant and appropriate, peak time traffic signal reviews may be done during midday or weekends.
- **Reactive** signal reviews will be reported annually. Selecting areas for retiming is based on the observation of degraded performance or areas undergoing development or redevelopment. The latter is due to increased intersection delays or symptoms such as cycle failure (queues do not completely discharge during each signal cycle), spillback from left turn bays or between intersections, and unused green time on side streets.

An engineering analysis is required for both proactive and reactive reviews, where traffic signal timing adjustments may be required. Engineering analysis may use simulations or signal timing software that compares the performance of the existing timing system against its optimized timing. A tool such as the Signal Management Retiming Tool (SMRT) may also be used to quantify improvements, such as number of stops and travel time, for coordinated arterial corridors.

Remote Communications

Caltrans must be able to communicate to all traffic signals on a real-time basis. Engineers require the ability to view and download all traffic signal timing parameters (offset, cycle split, cycle length, etc.) as well as the capability to upload traffic volumes. This will improve response time and reduce travel time and expense.

The Traffic Signal Management and Surveillance System (TSMSS) will be deployed in all districts and includes remote communications to each traffic signal, where feasible. Currently, there are 126 intersections that are connected through the TSMSS throughout the state, out of approximately 5,000 Caltrans traffic signals. Districts will continue to bring more intersections online. Caltrans expects 75 percent of all intersections to be online by the year 2020, and 100 percent of all intersections by the year 2025, where practicable.

In order to remotely communicate with a traffic signal, the communications infrastructure must be in place. With an adequate communications capacity, Caltrans will be able to monitor the intersection traffic in real-time. It is important to note that there are communication costs required for remote management and surveillance. See Figure 1.

At the core of ITS elements is a centralized Advanced Transportation Management System (ATMS), which provides centralized traffic signal control over a wide geographical area. In order to optimize traffic flow, the ATMS may also control other ITS field elements, such as changeable message signs, ramp meters, CCTV cameras, etc. The system will allow management of multiple traffic signals utilizing advance coordination methodologies that will improve incident response time, reduce traffic congestion and carbon emissions by improving traffic flows. Transportation Management Center (TMC) operators will work with traffic signal operations engineers and coordinate efforts of traffic management of the entire highway system, including signalized arterials.

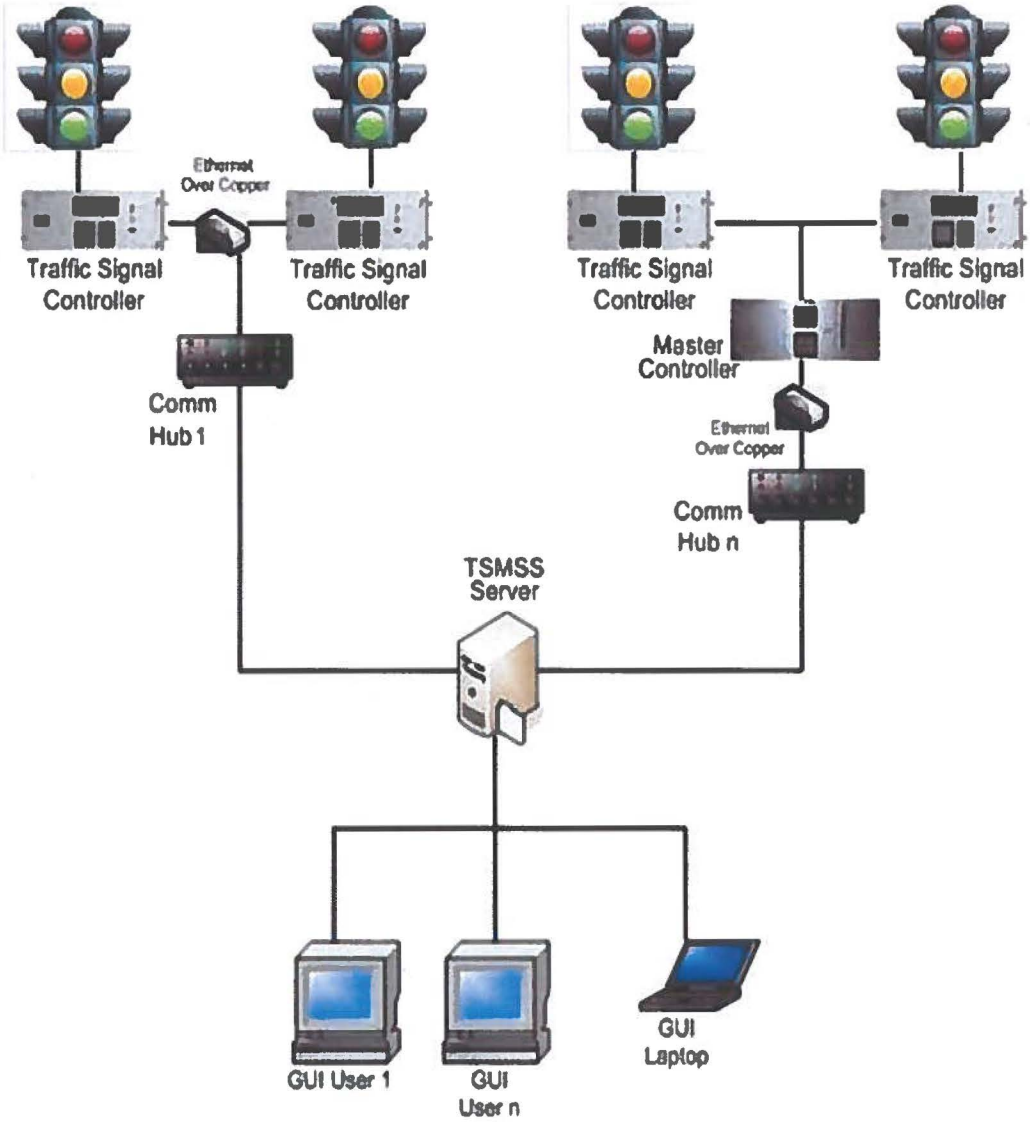

Figure 1 - Representation of current Traffic Signal Network Communicating to the TSMSS Server

Yellow Timing

The yellow change interval (yellow signal timing) and the flashing yellow arrow are two areas of concern with respect to the traffic signal head display.

Yellow Signal Timing – The Manual on Uniform Traffic Control Devices (MUTCD) allows modifications to the yellow signal timing at all Caltrans' signalized intersections. The MUTCD specifies that yellow signal timing be determined by the prevailing traffic speeds (documented from speed studies) or by using the posted speed limit. Districts will review the yellow signal timing for all of their signalized intersections.

Flashing Yellow Arrow – The use of the three-section Flashing Yellow Arrow (FYA) signal faces that use the middle section to show both the FYA and the steady yellow arrow has received interim approval from the Federal Highway Administration. The MUTCD allows this type of operation. Currently this is an option for use on state right-of way, but may become a requirement. If this becomes a requirement, Caltrans would need to adapt the necessary software changes to the traffic signal controller program (TSCP), update the software in all the controllers, and provide training to all the districts.

Bicycle Detection

California Vehicle Code section 21450.5 requires bicycle detection at new or modified traffic-actuated signals. The Traffic Operations Policy Directive 09-06 and subsequent implementation memo describe that a bicycle must be detected or a traffic signal must be on "vehicle recall" for all phases without bicycle detection, using extended bike green times (minimum bicycle timing) as defined by the distance from the limit line to the far-side of the last conflicting lane. This means that the green time must be long enough for a bike to cross the intersection, whether or not a bicycle is present.

However, unnecessary green cycle time increases vehicle delays. Wherever feasible, newer technologies should be used that can detect and distinguish (discriminate) between a bicycle and other vehicles (trucks, cars, etc.). With technology such as radar detectors, the longer bicycle green time would be active only when a bicycle is detected.

During 2012 and 2013, Caltrans tested a radar detector in the City of Chico to verify the capability of this detector to differentiate between bicycles and other vehicles (trucks, cars, etc.) as well as to quantify the accuracy. During 2014 and 2015, Caltrans started a pilot project in the City of West Sacramento. The Model 2070 local controller software, Traffic Signal Control Program (TSCP), can serve two different minimum green times, providing a longer cycle time when a bicycle is detected.

Vehicle and System Detection

Caltrans plans to maximize the advantages of proven vehicle detection technologies, in addition to traditional inductive loop detectors. Examples include off-pavement detection systems such as radar detectors, Forward-Looking Infrared (FLIR) detectors, and omni-directional fish-eye lens cameras for video detection. Caltrans is testing the Model 2070 controller software which has the capability to accept additional inputs and make signal timing determination, which allows specific bicycle programming. Bicycle timing would be required only when a bicycle is detected. Besides ensuring adequate time for a bicyclist to cross an intersection, off-pavement detection increases safety for personnel (both Maintenance and Operations) by decreasing exposure to traffic and minimizes the need for lane closures.

A long-term goal is for Caltrans to upgrade controller systems to Simple Network Management Protocol (SNMP), an Internet-standard protocol for managing devices on IP networks, to remotely monitor the functionality of vehicle detectors, the controller, and the

communications hardware. Caltrans will study the potential for better proactive maintenance and improved response time for infrastructure repair.

Closed-Circuit Television (CCTV) Cameras
Caltrans has installed hundreds of CCTVs that monitor freeway traffic and has recently begun to install CCTVs at selected signalized intersections. Caltrans currently has video from multiple cameras posted online:

- To provide motorists visual verification of weather and traffic conditions to make informed travel decisions.
- To provide Caltrans visual information to improve response to traffic and/or weather-related incidences on the highways.

These video feeds, however, are not typically of signalized intersections. Most districts continue to deploy or plan for CCTVs at signalized intersections where video surveillance will be helpful and is feasible. Considerations for CCTV locations include:

- Locations with high traffic volumes.
- Locations with a history of traffic incidents (crashes, etc.) during peak times and/or during off-peak times.
- Locations with higher than average number of field visits (per TRAC reports).
- Locations where signal timing is changed/modified remotely due to incidents, and verification would be critical.
- Locations where remote incident verification would be critical because of its distance from maintenance stations.
- Diversion routes: when traffic is diverted from freeways to arterials, as part of a System Corridor Incident Management Plan.
- Locations requested by Traffic Investigations.
- Special strategic locations (example: stadium, amusement park, large hotel areas, near special events).

The CCTV video is not recorded since it is generally not practical to store such large data files. Data such as traffic volumes, including turn volumes, may be generated from video detection systems without the need to store the video.

Caltrans will further explore the advantages of combining the functionality of CCTV (pan-tilt-zoom capability) and vehicle detection. For example, an omnidirectional fisheye (ultra wide angle) lens camera with a ruggedized processor can manage an intersection with a virtually maintenance-free system, reducing the cost of maintaining the traffic signal system. Off-pavement vehicle detection would result in decreased risk for maintenance staff, as well as cost savings at installation since it could eliminate the need for lane closures. A Video Imaging Vehicle Detection System (VIVDS), which can be used in limit line detection applications, would also be a useful vehicle video detection system for traffic signal control and data collection.

Transit Signal Priority (Bus Rapid Transit Signal Priority)
Transit Signal Priority (TSP) is a general term for operational improvements and/or adjustments that reduces or eliminates waiting time at traffic signals for transit vehicles (such as a bus) by holding green traffic signal lights longer or shortening the green traffic signal lights (providing early green or extended green), to keep the bus on schedule. TSP may be implemented at individual intersections, across corridors or the entire street system.

As the Federal Transit Administration's TSP Planning and Implementation Handbook states, the distinction between TSP and signal pre-emption is an important one because "signal priority modifies the normal signal operation process to better accommodate transit vehicles, while pre-emption interrupts the normal process for special events such as an approaching train or responding fire engine..." [U.S. DOT, Federal Transit Administration, "Transit Signal Priority: A Planning and Implementation Handbook" 2005].

TSP systems typically require four components: a detection system aboard transit vehicles, a priority request generator which can be aboard the vehicle or at a centralized management location, a strategy for prioritizing requests, and an overall TSP management system. Caltrans and the City of Los Angeles have developed unique software to suit these requirements. Caltrans will continue to support transit signal priority, where feasible.

Enhanced Intersection Safety

At-Grade Railroad Crossings: Caltrans will continue to work with the California Public Utilities Commission and other local agencies to update protocols and processes to improve traveler safety regarding railroad preemptive timing circuits, gate-down monitoring circuits, etc. when deemed appropriate.

Intersection Detection: As systems become available and are proven to be effective, Caltrans will study technology opportunities for intelligent systems to reduce most broadside accidents through center-of-intersection detection for 1) yellow-flow reduction (minimize number of vehicles arriving during the yellow phase) and 2) dynamic all-red extension. Collision avoidance may include usage of vehicle, bike, and pedestrian detection through various technology detectors (radar, enhanced video, etc.) and/or vehicle-to-roadway and vehicle-to-vehicle communications.

Battery Backup System (BBS)
Due to rolling blackouts that were commonly experienced in California and the retrofitting of all intersections from incandescent traffic signals to LED traffic signals, it is now feasible to provide backup power for an entire signalized intersection for "normal operations" for a period in excess of 2 hours. Each BBS enables the intersection to continue operating normally for periods in excess of 2 hours by converting DC battery voltages into AC line voltages.

Where feasible, a BBS system may fit into an existing 332L cabinet with no modifications, reducing retrofit costs. Otherwise, an external cabinet is used. The system may backup an intersection for a minimum of 2 hours, and then be fully recharged and prepared for

another 2 hours of operation in less than 24 hours. Caltrans will keep up with advancements in BBS technology when it is beneficial and cost-effective. Caltrans will update the statewide policy for BBS installations by December 2017.

Americans with Disabilities Act (ADA) and Pedestrian Needs
Traffic signal timing needs to comply with recent policy changes (TOPD 12-01, dated March 30, 2012, "Change the Pedestrian Clearance Time to a Maximum Walking Speed of 3.5 feet per second, and Install Accessible Pedestrian Signal (APS) Systems and Pedestrian Countdown Timers at Signalized Intersections and Signalized Pedestrian Crossings on the State Highway System"). District signal operations engineers continue to update the traffic signal timing to increase the walk signal timing required. In addition to walk signal timing, the districts continue to update the pedestrian equipment to comply with ADA requirements.

Vehicle-to-Vehicle Communications
Vehicle-to-Vehicle (V2V) Communications is a dynamic wireless exchange of data between nearby vehicles that offers the opportunity for safety improvements. By exchanging anonymous, vehicle-based data regarding position, speed, and location, V2V communications enables a vehicle to: sense threats and hazards with a 360 degree coverage for awareness of the position of other vehicles and the threat or hazard they may present; calculate risk; issue driver advisories or warnings; take pre-emptive actions to avoid and mitigate crashes. A data message can be derived using non-vehicle-based technologies such as GPS to identify location and speed of a vehicle, or vehicle-based sensor data wherein the location and speed data is derived from the vehicle's computer and is combined with other data such as latitude, longitude, or angle to produce a richer, more detailed situational awareness of the position of other vehicles. In the United States, V2V is an important part of the intelligent transportation system, a concept that is being sponsored by the United States Department of Transportation and the National Highway Traffic Safety Administration (NHTSA). An intelligent transportation system will use the data from vehicle-to-vehicle communication to improve traffic management by allowing vehicles to also communicate with roadside infrastructure such as traffic signals and signs. Research is ongoing in this area.

National Transportation Operations Coalition Report Card

Caltrans will continue to participate in the national report card, or self-evaluation of traffic signals operations. The Traffic Signal Operations Management program is divided into five areas:

1. Management - Planning and oversight, including programmatic actions; updating inventory database; managing all signal system networks, dividing resources for tasks and targets; analysis of performance measures and production reporting.

2. Traffic Signal Operations – Develops strategies to support efficiency while maintaining safety, such as providing signal timing that minimizes and balances congestion while providing constant and predictable traffic flow. Reviewing and updating timing and operational aspects of signalized intersections on a regular basis is extremely important, especially where changes in traffic volumes and/or adjacent land uses have occurred.

3. Signal Timing Practices – Determining overall effectiveness of signal operations that result from signal reviews and strategies. Evaluating the effectiveness of signal operations through consideration of the degree of signal timing practices that produce efficient operations. The TSMSS will be used for setting timing plans remotely, when feasible, and when new timing plans are implemented from the field.

4. Traffic Monitoring and Data Collection – A robust program and supporting system needed to determine the condition of the traffic flow on roadway networks, following a set of metrics. The TSMSS will collect data to: provide input to traffic signal control operations; monitor systems in real-time; formulate strategies to effectively manage and control the flow of traffic; monitor flows over long periods of time via data archiving; distribute to others, such as local agencies; and assist in incident response and management.

5. Maintenance – Support key strategy of field infrastructure reliability that leads to effective signal operations. A well-timed system is accompanied by effective maintenance to provide high-quality service to the traveling public.

TRAFFIC SIGNAL MANAGEMENT INDICATORS

Currently, there are two performance measures being reported quarterly:

- Number of inquiries/complaints
- Percentage of traffic signals that are remotely accessible

We are in the process of implementing a new performance measure which will report the progress for each district's goal for full proactive signal reviews (both a.m. and p.m. peak reviews). Using the TRAC system, the functional manager will determine whether a unique one-third of the districts' inventory has had the complete review each year, and report on a quarterly basis whether they are on track to meet the 3-year target of complete field reviews for all of the designated signalized intersections. Designated traffic signals include those in Categories 1, 3 and 4:

Category 1 Signals – Signals Owned, Operated and Maintained by the State
Category 3 Signals – Signals Owned by the Local Transportation Agency; Operation and Maintenance delegated to the State
Category 4 Signals – Signals Owned and Operated by the State; maintenance delegated to Local Transportation Agency

The proposed dashboard is shown in Figure 2. This dashboard will be displayed for the total statewide progress, as well as separately for each district. The districts will also be able to monitor their progress monthly, since it will be straightforward to use TRAC to determine the progress during the three-year cycle. A separate dashboard may be used for each of the three years to display the progress.

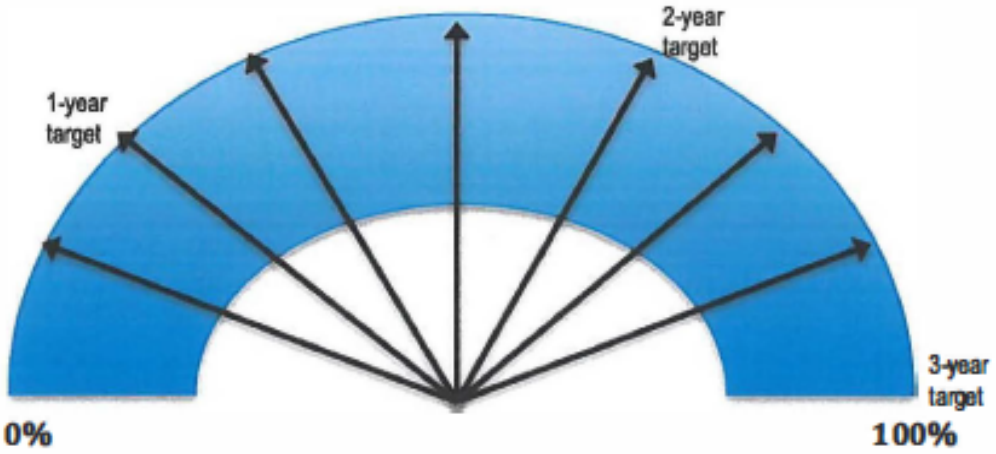

Figure 2 – Dashboard: Displays Percentage of Completed Traffic Signal Proactive Field Reviews over 3-year timeframe

TRAFFIC SIGNAL RESOURCE MONITORING

TRAC - The TRAC system is a tool that is used by traffic signal operations staff for documenting all tasks related to traffic signals. TRAC is an open-source project management tool that is implemented as a web-based application that features the ability for users to submit "tickets." This TRAC software is a management tool for districts, as well as for Headquarters (HQ), and provides various detailed reports ranging from "daily diaries" to all work done within a district, sorted by staff member. The total time spent on the various tasks is also recorded and documented.

Not only do the TRAC reports reflect work done by specific location, but reports also may be obtained to reflect those locations that lack field reviews. In this way, districts will be able to report on all locations that have been reviewed annually, as well as over a span of several years. In addition, TRAC can provide reports on specific locations that have not yet been reviewed over a user-selected number of years.

Traffic Signal Management and Surveillance System (TSMSS) - With reliable real-time data communications to the traffic signals, staff may quickly respond to incidents or changing traffic conditions. The TSMSS will be further deployed to more traffic signals statewide to assist Traffic Operations staff to remotely monitor and control traffic signals. The number of traffic signals that have connectivity to TSMSS will be reported quarterly, as well as the projected annual goal. Real-time traffic data collected of traffic volumes and speeds will be posted onto PeMS, as well as travel times.

Traffic Monitoring Through Closed Circuit Television - Several districts have installed Closed Circuit Television (CCTV) cameras for traffic surveillance. These locations, however, do not have pan, tilt and zoom (PTZ) capability. Other districts are in the planning stages of installing CCTVs. Advantages include being able to see traffic remotely for "virtual site visits." In particular, viewing locations of recurring congestion is very important. Table 1 summarizes the status of CCTVs in all districts for video surveillance at signalized intersections. Districts will update their annual goals and progress for quarterly reports.

District	CCTVs	PTZ	Comments
1	4	Yes	IP-addressable; an additional CCTV has been requested by Safety Investigations for a 5-legged intersection.
2	4	Yes	Viewable from TMC; not being used by Signal Operations.
3	11	Yes	Viewable from TMC; not being used by Signal Operations (4 more in construction); Plan to install at new intersections.
4	25	Yes	But NOT using PTZ – prefer fixed; IP-addressable; planning for 120 additional signalized intersections.
5	None	-	Interested in viewing locations with "busy" intersections.
6	6	Yes	Located at signalized intersections (not at interchanges), viewable from TMC. Approximately 40 more are being planned.
7	28	Yes	Not IP-addressable. Planning to install 40 more (IP-addressable).
8	2	No	Iteris system – also used for vehicle detection; interested in viewing freeway interchanges
9	None	-	Interested in viewing locations with recurrent congestion.
10	None	-	Plan to install at all new intersections.
11	90	No	Optical /Infrared Systems – used for video detection and viewable from TMC (Iteris, Traficon & FLIR); interested in PTZ video for surveillance to view ALL legs of all signalized intersections.
12	None	-	Has 92 IP-addressable CCTVs for 46 signalized intersections as part of the ICM project.
TOTAL:	**159**		

Table 1 – District Inventory of CCTV Cameras for Traffic Signal

TMS Inventory Database

Along with Transportation Management System (TMS) elements such as Changeable Message Signs (CMS), Ramp Meters, and Closed Circuit Television cameras (CCTV), traffic signals are included in the statewide TMS inventory database and are updated on a weekly basis. Traffic signal performance and operations will benefit from a well-managed database. This database includes specific details for each traffic signal. Districts will continue to submit any updates or changes in their district so that the inventory database is up-to-date. The TRAC system uses this database. A comprehensive database will be accessible regarding the design and all work done to or for a particular traffic signal, for both preventative and reactive work, through the TRAC ticketing system. Time spent working on the traffic signal will also be recorded and accessible. The Traffic Signal Operations Production Reporting User's Guide will be updated as features are updated or modified.

Responsiveness - Districts are responsive to citizens, media, policy makers and elected officials; complaints and inquiries are responded to in a timely manner. Typically, the required response to inquiries and complaints range from within the week to one month. This usually requires an immediate response letter explaining that the issue is being addressed, and another letter is sent when the investigation has been completed. The objective is clear and reliable communication. The total number of inquiries/complaints is recorded each month, per specific location.

TRAFFIC SIGNAL OPERATIONS CONTACTS

Table 2 lists the District's Traffic Signal Operations Functional Managers:

District	3SIGL Functional Managers	email
1	John Carson	jpcarson@dot.ca.gov
2	Rob Stinger	rob.stinger@dot.ca.gov
3	Steven Block	steve.block@dot.ca.gov
4	Einar Acuna	einar.acuna@dot.ca.gov
5	Julie Gonzales	julie.m.gonzalez@dot.ca.gov
6	Anthony Lopez	anthony.r.lopez@dot.ca.gov
7	Ajaykumar Shah	ajaykumar.shah@dot.ca.gov
8	Tony Sarmiento	tony.sarmiento@dot.ca.gov
9	Philip Graham	philip.graham@dot.ca.gov
10	John Castro	john.castro@dot.ca.gov
11	Brian Pecus	brian.t.pecus@dot.ca.gov
12	Fedrico Hormozi	fedrico.hormozi@dot.ca.gov

Table 2 – Traffic Signal Operations Contact List: District Functional Managers for Traffic Signal Operations

Table 3 lists the HQ Traffic Signal Operations support staff:

3SIGL: HQ Traffic Signal Operations Support	email
Martha Styer – 3SIGL Functional Manager	martha.styer@dot.ca.gov
Hamid Zolfaghari – TSMSS Project Manager	hamid.zolfaghari@dot.ca.gov
Ted Lombardi – TSCP Project Manager	ted.lombardi@dot.ca.gov
James Lau – TSCP Technical Support	james.lau@dot.ca.gov

Table 3 – HQ Traffic Signal Operations Support Staff

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APPENDIX

Traffic Signal Areas Fact Summaries

I. Signal Timing Reviews

Purpose – To advance management practices and operational strategies that promote the safe and efficient use of arterial roadway capacity to reduce congestion.

Goals and Plans –

- Regularly scheduled peak-time full field reviews to assess situation and optimize traffic flow.
- Continue documenting work/production through TRAC and report progress through dashboards and other appropriate mediums.
- Remote system monitoring through TSMSS. 40 percent of signals to be connected by year 2017 and 75 percent by year 2020. Ensure adequate communications infrastructure, such as fiber optics, for signal interconnection system.
- Support integrated corridor management (ICM) systems. Provide guidelines and assistance for optimal traffic signal timing for signalized corridors.

Accomplishments –

- Deployed TRAC system (February 2014) to document all work being done at traffic signals, by location. TRAC system also captures travel time and time expended for each task.
- Deployed TSMSS in all districts (2013/2014). Currently communicating remotely with 126 traffic signals. More traffic signals will be "online" as Model 2070 controllers become available for remote monitoring.
- Began testing of SMRT (Signal Management Retiming Tool) and planning pilot projects (November 2014).

II. TSMSS & Remote Communications

Purpose – To use the statewide Traffic Signal Management and Surveillance System, (TSMSS) as a tool to more effectively manage traffic signals remotely, reducing field visits, improve incident response time, reduce traffic congestion and carbon emissions by improving traffic flows.

Goals and Plans –

- Continue to connect more traffic signals to TSMSS as Model 2070 controllers become available and as communications infrastructure is installed.
- Continue to support districts with training and assistance.
- Revise the TSMSS to include additional features to support upload of detector volume data for all 40 detectors and 4 pedestrian inputs.
- Store controller data to generate reports for the Traffic Census Program.

- Deploy APeMS to capture and share arterial traffic volumes, speeds, and travel times.

Accomplishments - As of February 2014, Caltrans has deployed TSMSS in all districts and a total of 126 traffic signals are online and connected to TSMSS.

III. Bicycle Detection

Purpose – Provide off-pavement vehicle detection that can distinguish between cars/trucks from bicycles, so that extended green bike time is needed only when a bicycle is detected.

Goals and Plans –

- Continue testing of radar detector to validate/verify the accuracy and complete pilot test project in West Sacramento to run a signalized intersection exclusively using the radar detectors.
- Install system at a Caltrans-controlled intersection (possibly District 12).
- Upon success of project, develop standard specifications for optional use statewide.

Accomplishments – Completed test project in Chico (District 3) to document accuracy of radar detectors. Conclusions presented at the "Western States Rural Transportation Technology Implementers Forum" in 2013.

IV. Vehicle and System Detection

Purpose – To maximize the advantages of proven vehicle detection technologies, including traditional in-pavement loop detectors. To pursue the Simple Network Management Protocol (SNMP) to better monitor the health of the vehicle detectors, the traffic controller, and communications hardware.

Goals and Plans –

- Continue testing radar detectors for detecting bike and other vehicles.
- Complete the analysis of the Forward Looking Infrared (FLIR) camera video detection system being used in District 11.
- Test the omni-directional video detection system for traffic signal operations in District 10.
- Explore Simple Network Management Protocol (SNMP), an Internet-standard protocol for managing devices on IP networks, for monitoring health of communications infrastructure, traffic controller and vehicle detection system.

Accomplishments – First phase of evaluation of radar detection in District 3 completed.

V. CCTV (Closed Circuit Television) Cameras

Purpose - To provide motorists visual verification of weather and traffic conditions of signalized intersections or corridors to make informed travel decisions and to provide

Caltrans visual information to improve response to traffic and/or weather related incidences on the highways.

Goals and Plans – Support the districts as they deploy more IP-addressable CCTV cameras at signalized intersections where video surveillance will be helpful and is feasible.
Accomplishments – Currently there are 159 cameras at signalized intersections statewide, of which 106 are IP-addressable.

VI. Transit Signal Priority (Bus Rapid Transit Signal Priority)
Purpose – To allow bus transit agencies to extend or truncate green cycle times at traffic signals for more accurate schedule adherence.

Action Item – Assist districts or local agencies when requested.

Accomplishments – Successfully assisted with traffic controller software modification for various agencies in the San Francisco Bay Area for their bus rapid transit projects.

VII. Enhanced Intersection Safety (At-Grade Railroad Crossings & Intersection Detection)
Purpose – To collaborate with the CPUC and other local agencies for traffic signal timing at or near at-grade railroad crossings. To pursue detection technologies that can detect and prevent broadside (T-bone) crashes.

Action Item – Assist districts or local agencies when requested.

Accomplishments - Completed updated worksheet for traffic signal timing for at-grade railroad crossings.

VIII. Battery Backup System (BBS)
Purpose – To provide backup power for signalized intersections in the event of loss of power in the vicinity.

Goals and Plans – Pursue updated BBS systems and update statewide policy and standards.

Accomplishments – Existing standards have kept signalized intersections running at full capacity while there was a power outage. For example, only the District 12 traffic signals continued to operate in southern Orange County during the 2011 Southwest blackout, which affected the southwestern part of the United States and northern Mexico. As designed, these intersections ran on full-operation mode for 2 hours then on flash-mode, until the power was restored.

IX. American with Disabilities Act (ADA)

Purpose – To comply with the Federal Americans with Disabilities Act.

Goals and Plans – To update traffic signal timing at all intersections to include the 3.5 feet per second requirement for the WALK signal. To update the accessible pedestrian signals as requested, including pedestrian countdown timers, by December 2017.

Accomplishments – An average of 30 percent of district traffic signals have been updated.

STRATEGIES

TRAFFIC SIGNAL OPERATIONS AREA	CALTRANS GOAL(S)	PRIORITY	ESTIMATED DATE TO COMPLETE
Signal Timing Reviews: 1. Districts will resume AM & PM peak traffic signal reviews (proactive) and plan their schedule so that ALL signals are thoroughly reviewed every 3 years. Progress will be reported for 3-year cycle dashboard and quarterly progress (dashboard).	Safety & Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	HIGH	Annually; complete cycle every 3 years
2. Districts will document all traffic signal related work in TRAC on a monthly basis.	Safety & Health; Stewardship/ Sustainability, System Performance	HIGH	Ongoing since Feb. 2014
3. Tools will be available for signal operations staff, including in-vehicle GPS based progression verification, to evaluate and fine-tune coordination timing. Evaluate UNR Signal Management & Retiming Tool (SMRT) through Pilot field tests (D3 and D4).	Stewardship/ Sustainability, System Performance	HIGH	Dec. 2016
4. Develop capacity for each signalized intersection to collect and distribute traffic count data, speed and occupancy. Signalized intersection data will be stored and made available for the Arterial Performance Monitoring System (APeMS).	Stewardship/ Sustainability, System Performance	MEDIUM	Dec. 2017
5. Real-time travel time will be available in arterial corridors, through the use of wireless communication technology, including Bluetooth readers. A pilot project is programmed for District 3 and real-time travel times will be made available on the Performance Measurement System (PeMS) website.	Stewardship/ Sustainability, System Performance	MEDIUM	Dec. 2017
6. Caltrans will publish the "Best Practices and Signal Operations Guidelines" and update the Signal, Lighting and Electrical Systems Design Guide by the year 2016. To be updated every 5 years.	Organizational Excellence	HIGH	Dec. 2016
7. HQ and Districts will assist with current and planned Integrated Corridor Management (ICM) programs: • *District 7:* continue to lead the ICM program: work with local partners using ITS technologies to coordinate the operations between different networks of the corridor to maximize transportation capacity. Subsequent documentation/procedures for congested conditions by reducing travel demand by providing enhanced choices, including mode, time of travel, location of travel and route to the traveling public. Specifically, Caltrans will actively promote signalized intersection and highway ramp coordination (on-ramps and off-ramps). • *District 4:* continue to support the San Mateo Smart Corridor and I-80 ICM projects (as well as other similar projects). • *District 11:* continue to actively support the San Diego Association of Governments (SANDAG) ICM.	Stewardship/ Sustainability, System Performance, Organizational Excellence	HIGH HIGH HIGH	Dec. 2017 Ongoing since 2011 Ongoing since 2011
TSMSS & Remote Communications: 1. Districts will have at least 40% of their traffic signal inventory connected in to TSMSS (traffic signal categories 1, 3 and 4).	Stewardship/ Sustainability, System Performance	HIGH	Dec. 2017

2. Further deployment of TSMSS connection with traffic signals shall continue. Districts will have at least 75% of their traffic signal inventory connected in to TSMSS (traffic signals categories 1, 3 and 4).	Stewardship/ Sustainability, System Performance	HIGH	Dec. 2020
3. Revise the TSMSS to include additional capability to upload detector volume data for all detectors and pedestrian inputs. Data from the controllers will be stored to generate reports for the Traffic Census Program.	Stewardship/ Sustainability, System Performance	MEDIUM	Dec. 2017
4. Continue to evaluate Adaptive Signal Control and traffic-response control with TSCP Field Master controller software or within TSMSS.	Stewardship/ Sustainability, System Performance	MEDIUM	Dec. 2017
5. Deploy Arterial Performance Measurement System (APeMS) for real-time data collection and sharing of traffic volumes, speeds, and travel times.	Stewardship/ Sustainability, System Performance	MEDIUM	Dec. 2017
Bicycle Detection: 1. Deploy off-pavement detection for districts to distinguish between bicycles and motorcycles, cars, or trucks.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	HIGH	Dec. 2015
2. The traffic signal controller program (TSCP) will have the capability to make signal timing determination accordingly (i.e. extended bike timing required only when bike is detected).	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	HIGH	Dec. 2016
3. Caltrans will explore and test off-pavement vehicle detectors so that there will be standard specifications available for vehicle detection, in addition to inductive loop detectors. A pilot test project to implement the radar technology that can distinguish bicycles from cars started in the summer of 2014 in the City of West Sacramento.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	HIGH	Began Fall 2014 – complete Spring 2015
4. A pilot project in District 12 deploying the radar technology to distinguish bicycles from cars and specifically operate with the additional bike times when appropriate.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	HIGH	Dec. 2015
Vehicle and System Detection: 1. Test the omni-directional video detection system for traffic signal operations, which can "see" each leg of a 4-legged intersection (using the fish eye lens). The first pilot project will be in District 10.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Dec. 2015
2. Document other cities and counties experiences with this technology (e.g. City of Sacramento). Specifically, the uses of 3D vehicle modeling and tracking algorithms to detect and classify vehicles for all approaches of an entire intersection including real-time and archived traffic data, such as vehicle counts and turning movements, pan-tilt-zoom (PTZ) functionality without moving parts, which provides visibility around the entire intersection without impacting vehicle detection or data collection capabilities.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Ongoing; document by Dec. 2016

3. Document success of the FLIR camera video detection system deployed in D11.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Dec. 2015
4. Provide improved remote detection diagnostics of the traffic signal controller. Diagnostic capability will include detection, communications, and controller health. Diagnostic tools will also be available to alert traffic signal operation engineers of burnt-out lamps or issues with the LEDs in a traffic signal indication head. Diagnostic capabilities will also identify potential issues in the field, including vehicle detection, whether inductive loops, radar or video detection, etc.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Dec. 2017
5. Pursue research opportunities for SNMP (Simple Network Management Protocol) for diagnostic capability of communications and vehicle detector hardware.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Dec. 2018
CCTV (Closed-Circuit Television) Cameras: Caltrans will continue deploying and planning for the installation of CCTV cameras with PTZ capability that are IP-addressable to view signalized intersections where deemed advantageous and most appropriate.	Safety and Health; Stewardship & Efficiency; System Performance	HIGH	ongoing
Transit Signal Priority (Bus Rapid Transit Signal Priority): Caltrans will continue to support Transit Signal Priority (Bus Signal Transit) as requested by local agencies (software support, testing, etc.), where feasible.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Dec. 2016
Enhanced Intersection Safety: At-Grade Railroad Crossings 1. Caltrans will continue to work with the California Public Utilities Commission and other local agencies to update protocols and processes to improve traveler safety regarding railroad preemption timing, use of blank-out signs and gate-down, monitoring, etc.	Safety and Health; Stewardship & Efficiency; System Performance; Organizational Excellence	MEDIUM	ongoing
Intersection Detection 2. Caltrans will pursue traffic detection to reduce most broadside accidents through center-of-intersection detection, regardless if there is a car, bicyclist or pedestrian. This could be through radar detection of the conflict zones within an intersection.	Safety and Health; Stewardship & Efficiency; System Performance; Organizational Excellence	MEDIUM	Dec. 2018
Battery Backup System (BBS): Caltrans will update statewide policy and standards for BBS installations.	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance	MEDIUM	Dec. 2017
Americans with Disabilities Act (ADA) and Pedestrian Needs: Districts will continue to work with their ADA coordinator to assist with: • Pedestrian walk time set to a maximum 3.5 feet/second • Accessible Pedestrian Signals and Countdown timers	Safety and Health; Stewardship & Efficiency; Sustainability, Livability and Economy; System Performance; Organizational Excellence	HIGH	Dec. 2017

GLOSSARY

3SIGL	Expenditure Authorization (EA) code for charging personnel service hours for work performed as per the TOMIS and WACI for Active Traffic Management of signalized intersections and arterials.
APeMS	Arterial Performance Measurement System
ATMS	Advanced Traffic Management System
BRT	Bus Rapid Transit (see TSP)
CCTV	Closed-Circuit Television (camera)
CMS	Changeable Message Sign
IP	Internet Protocol (as in the specific IP address in the network)
ITS	Intelligent Transportation System
MUTCD	Manual on Uniform Traffic Control Devices http://www.dot.ca.gov/hq/traffops/engineering/mutcd/
Non-3SIGL	Work performed that is similar to 3SIGL but is requested by others (i.e. Capital Support or Permits)
NTCIP	National Transportation Communications for ITS Protocol
PeMS	Performance Measurement System http://pems.dot.ca.gov
PTZ	Pan, Tilt and Zoom capabilities of a CCTV camera
TMC	Transportation Management Center
TMS	Transportation Management System
TOD	Time of Day
TOMIS	Traffic Operations Management Information System
TRAC	A tool that is used by traffic signal staff for tracking all work (tasks) performed on or for traffic signals (both 3SIGL and Non-3SIGL). TRAC is an open-source project management tool that is implemented as a web-based application. It has an enhanced issue tracking system for software development projects that features the ability for users to submit "tickets" and generate customized reports. http://trac
TSCP	Traffic Signal Control Program
TSP	Transit Signal Priority (see BRT)
TSMSS	Traffic Signal Management and Surveillance System
U.S. DOT	United States Department of Transportation
VIVDS	Video Imaging Vehicle Detection System
VMS	Variable Message Signs
WACI	Work Activities Charging Instructions